

WHY IS RAINY LAKE SO DIFFICULT TO CONTROL?

Rainy Lake Property Owners Association Open House
Thunderbird Lodge, Int'l Falls, MN
August 6, 2015

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Github: <http://jckantor.github.io/Rainy-Lake-Hydrology/>

SUMMER FLOODING 2014



Photo by Bob King (rking@duluthnews.com)



⁰Photo by WCCO, CBS Minnesota

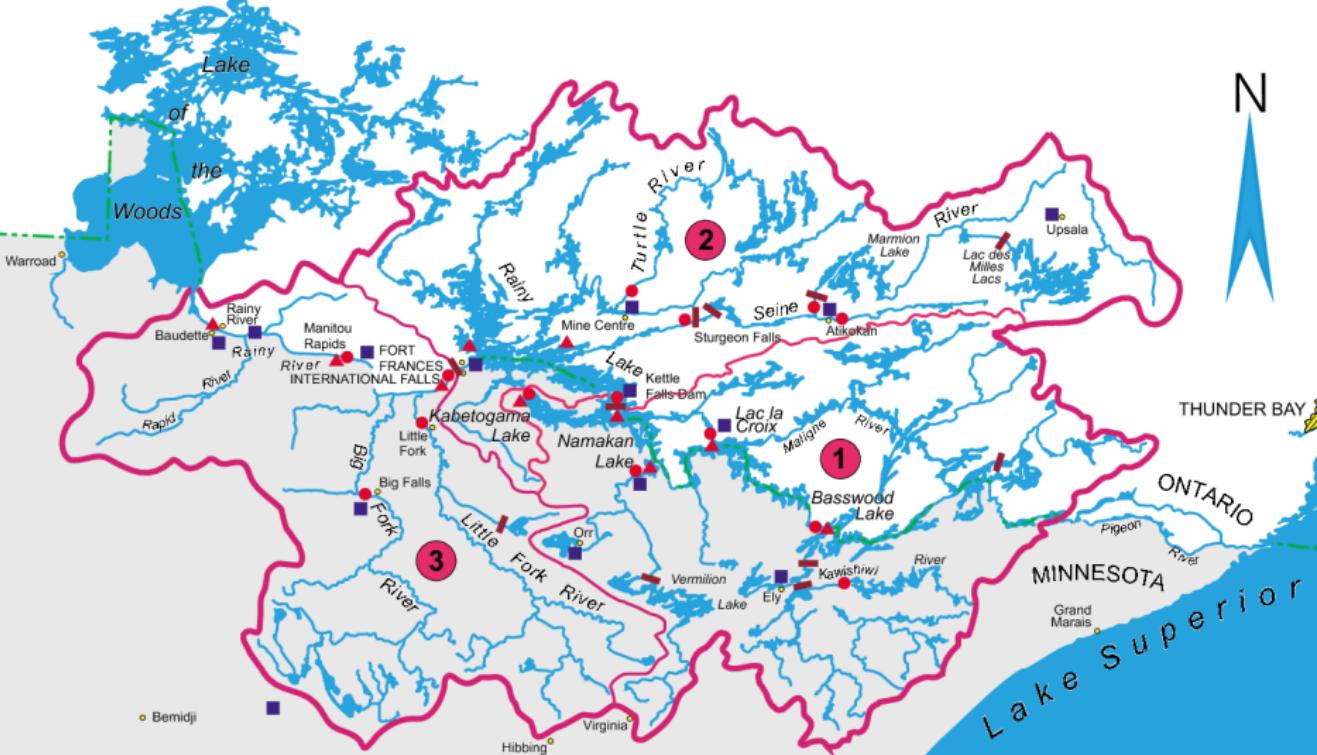


Photo by John Meyers, Duluth News Tribune

1987 LOW WATER YEAR



Photo by Larry Kec



LEGEND

- | | | | |
|------------------------|----------------|------------------------------|-------|
| International Boundary | ----- | Control Dams | ----- |
| Drainage Basin | ----- | Data Gauges (Near Real Time) | ----- |
| Sub-Basins | ----- | Stream Flow | ● |
| | ① Namakan Lake | Water Level | ▲ |
| | ② Rainy Lake | Precipitation | ■ |
| | ③ Rainy River | | |

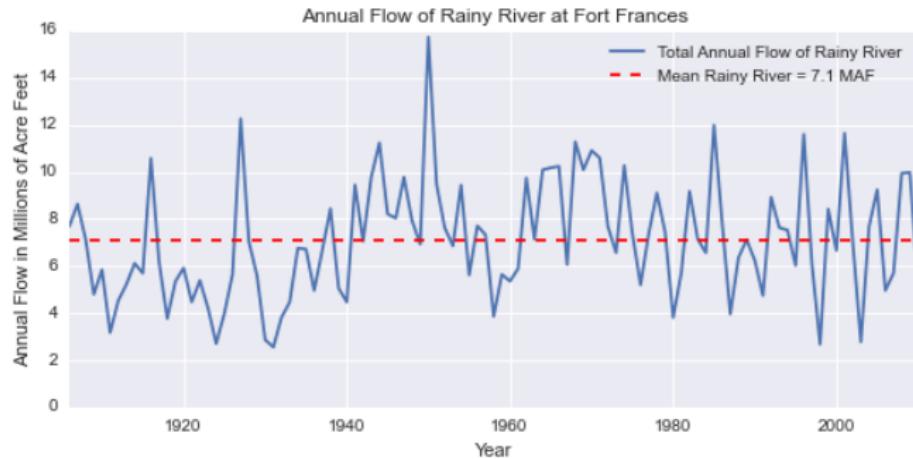
International Rainy Lake Board of Control
IRLBC

Rainy River Drainage Basin

0 10 20 30 40 50 60 km
0 10 20 30 40 mi



RAINY RIVER MEAN ANNUAL FLOW



Source: Github Repository for this paper.

	Million Acre-Feet/year
Rainy River at Fort Frances	7.1
Mississippi at St. Anthony Falls	8.7
Lake Mead Release at Hoover Dam	9.6
California, All managed Water	40



IMPACTS OF THE RULE CURVE CHANGE IN 2000

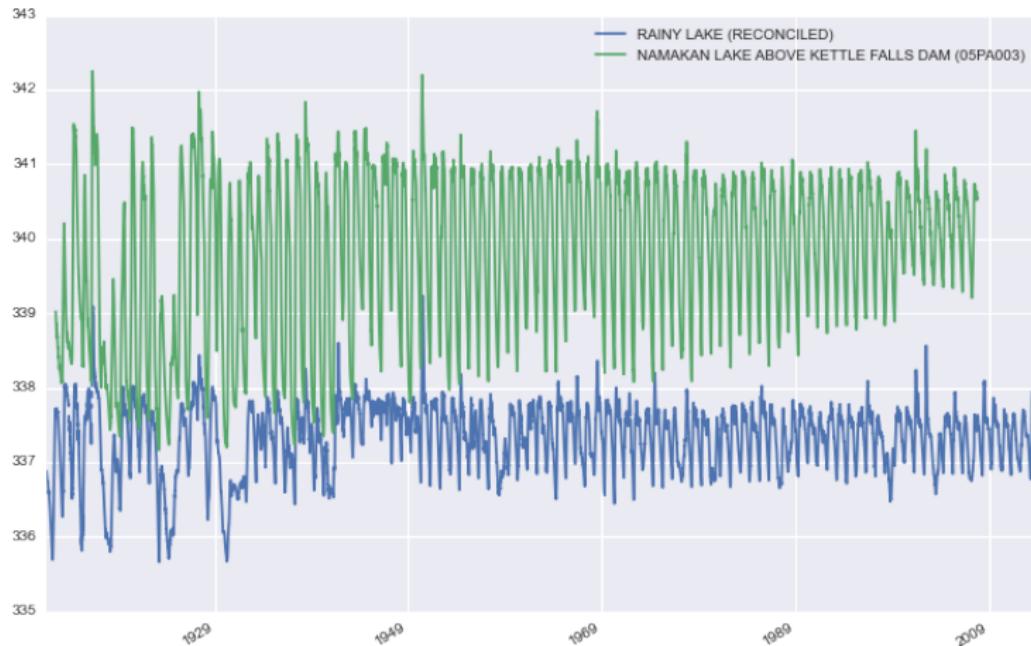
WATER FLOW NAMAKAN RESERVOIR THROUGH RAINY LAKE



Source: US National Park Service

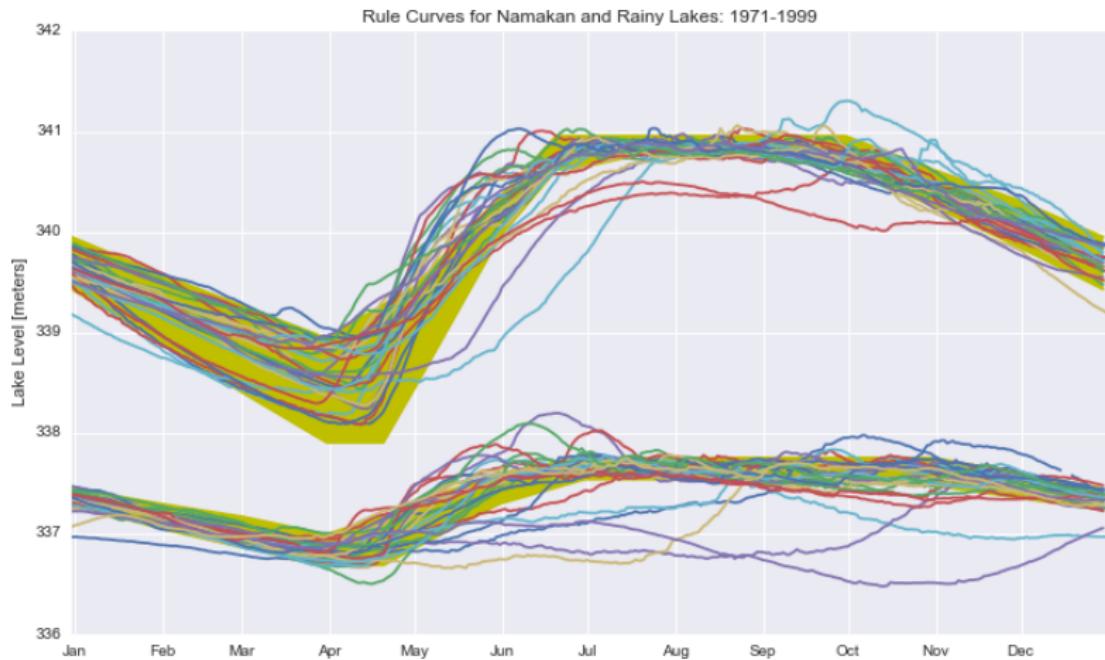
RAINY LAKE AND NAMAKAN LAKE LEVELS 1911–

Clearly see three rule curve regimes ...



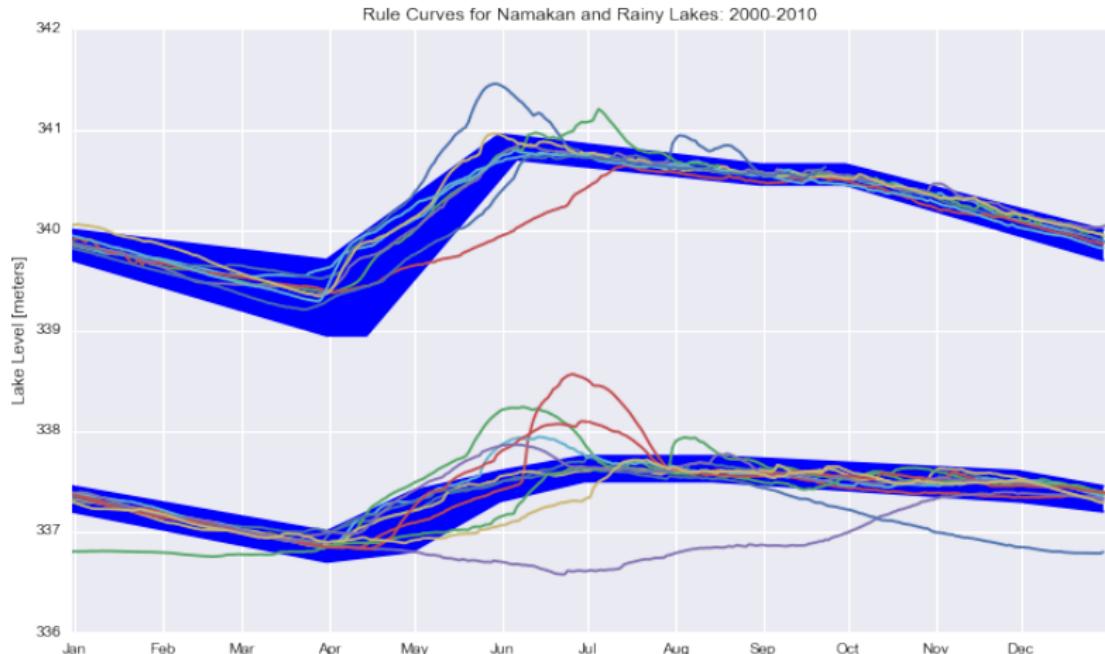
Source: Github Repository for this paper.

RULE CURVE PERFORMANCE 1970–1999



Source: [Github Repository for this paper.](#)

RULE CURVE PERFORMANCE 2000–2010

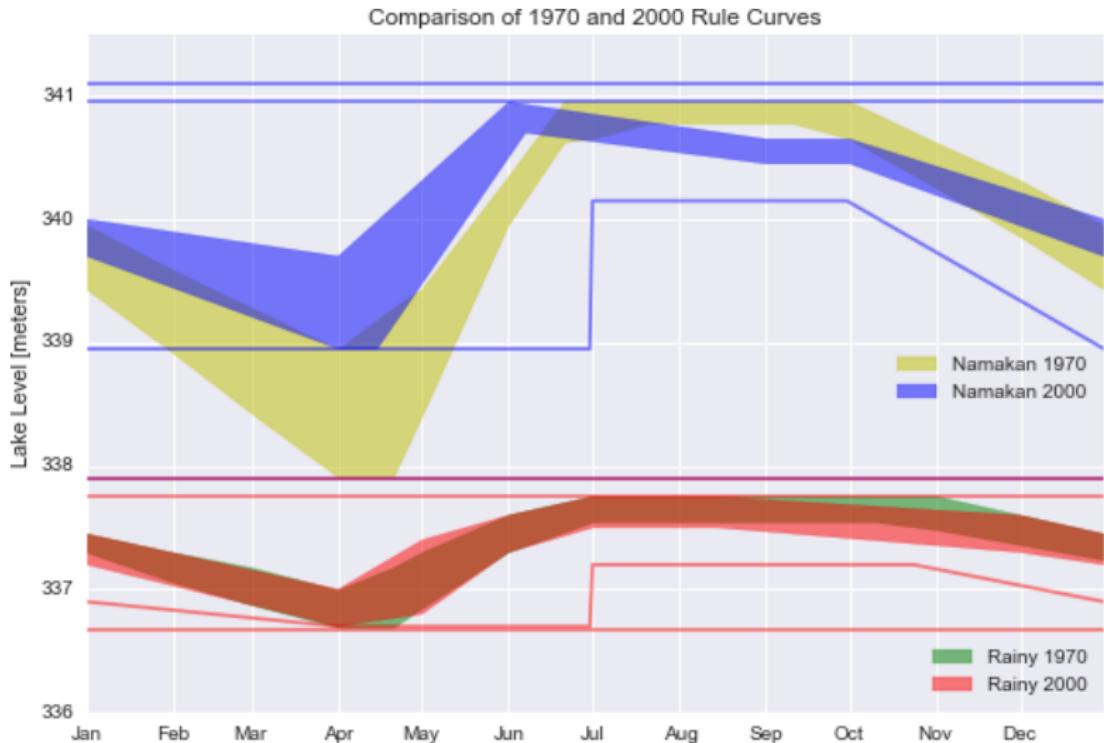


Source: [Github Repository for this paper.](#)

SUMMER HIGH WATER EVENTS (MAY–SEPTEMBER)

	1971–1999	2000–2010
	4437 days	1683 days
Rule Curve Exceeded		
Frequency	14.8%	17.8%
Median	0.07 m	0.23 m
95th Percentile	0.38 m	0.70 m
Emergency High Water		
Frequency	7.6%	13.7%
Median	0.05 m	0.19 m
95th Percentile	0.36 m	0.71 m
All Gates Open		
Frequency	1.9%	8.7%
Median	0.12 m	0.17 m
95th Percentile	0.29 m	0.62 m

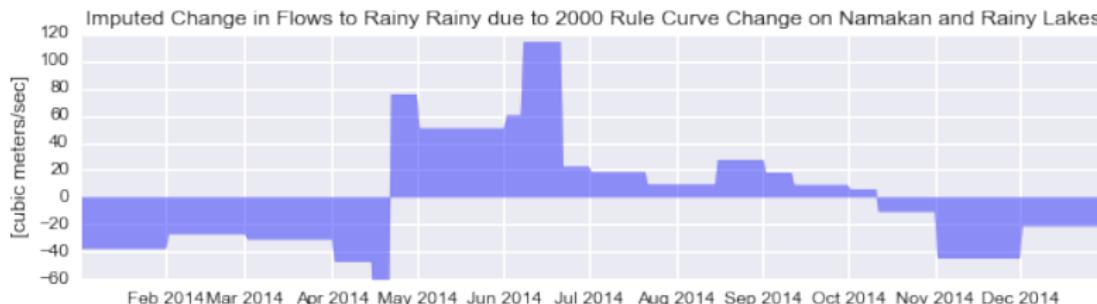
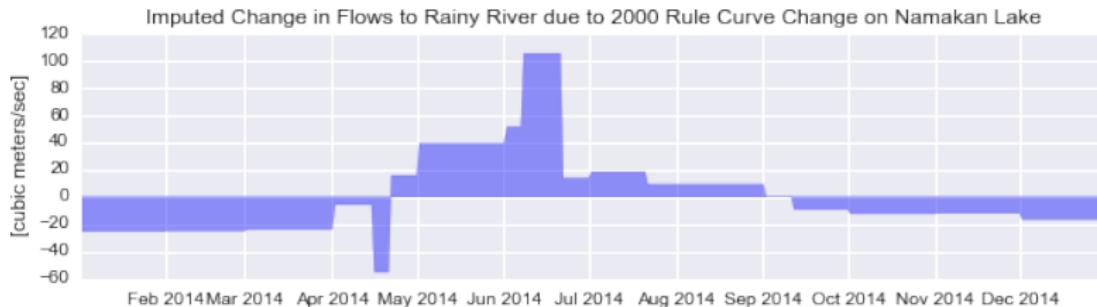
RULE CURVE CHANGES IN 2000



Source: Github Repository for this paper.

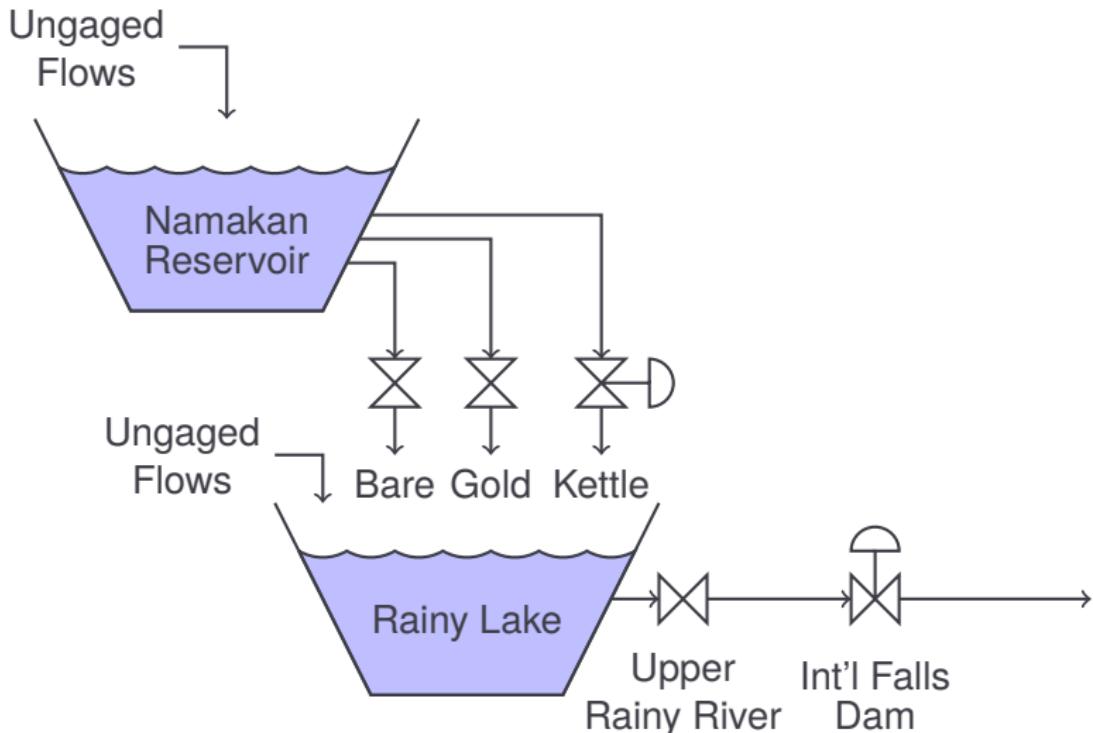
IMPUTED CHANGE IN FLOWS TO RAINY RIVER

The change in rule curves implies a change in flows to Rainy River.
Assuming midpoints of the rule curves ...

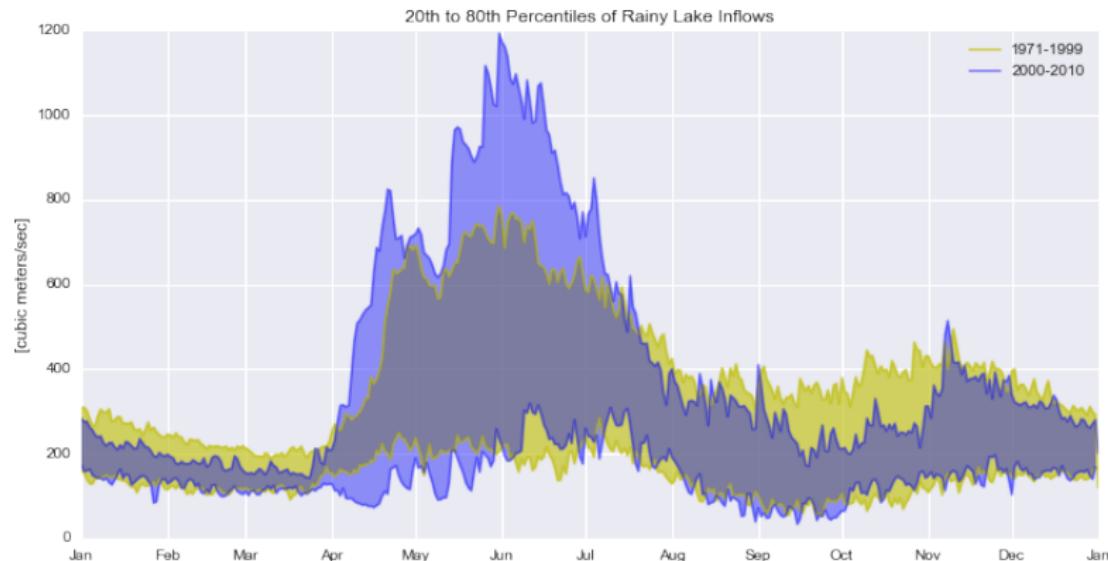


Source: [Github Repository for this paper.](#)

RAINY LAKE INFLOWS

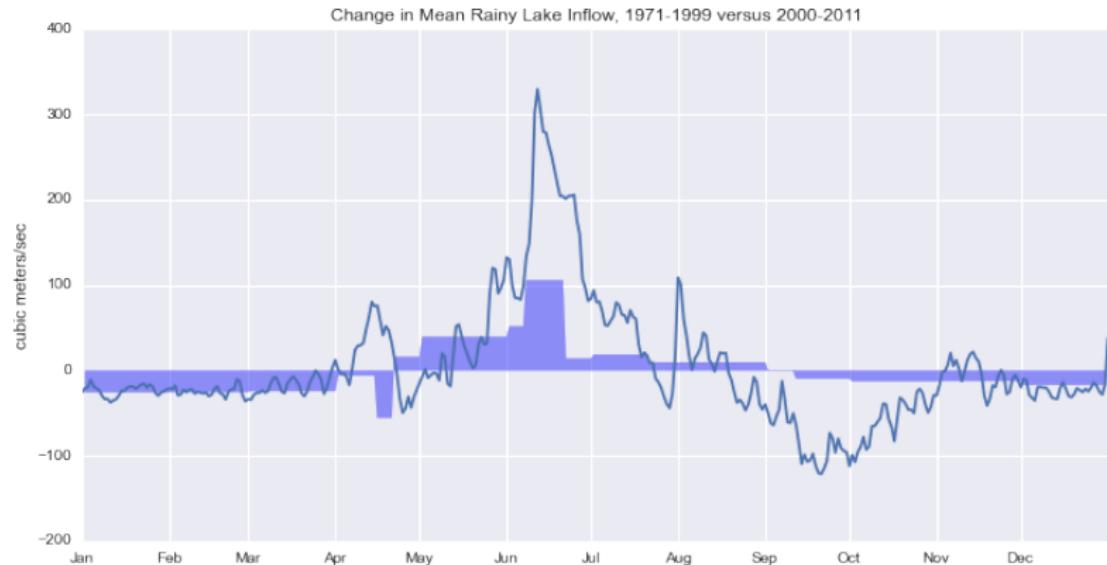


RAINY LAKE INFLOWS, 1970-1999 VS 2000-2010



Source: [Github Repository for this paper.](#)

CHANGE IN INFLOW TO RAINY LAKE, 1979-99 VS 2000-10



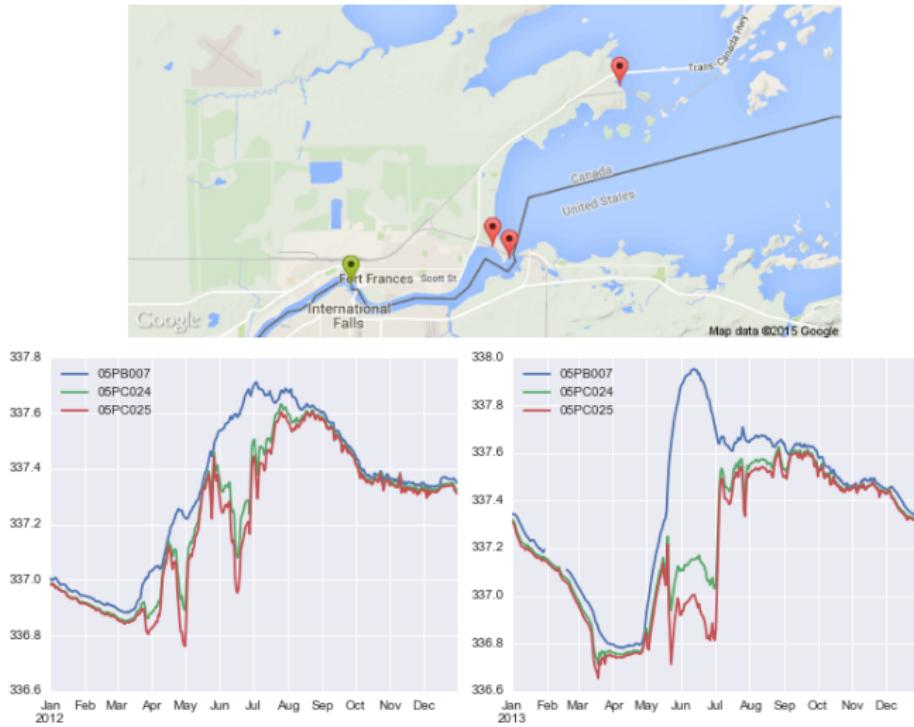
Source: [Github Repository for this paper.](#)

An aerial photograph of the Rainy River area. In the foreground, a large industrial complex with several buildings and storage tanks is situated along the riverbank. A dam structure is visible, with a long, low wall extending across the water and a small building on top. To the left, there's a circular concrete structure, possibly a water tank or a bridge pier. The river flows through the center of the image, curving to the right. On the far left, a city with a grid-like street pattern is visible, stretching towards the horizon. The surrounding land is a mix of green fields and some more industrial or residential buildings. The overall scene is a blend of natural waterways and human-made infrastructure.

BOTTLENECK AT RAINY RIVER

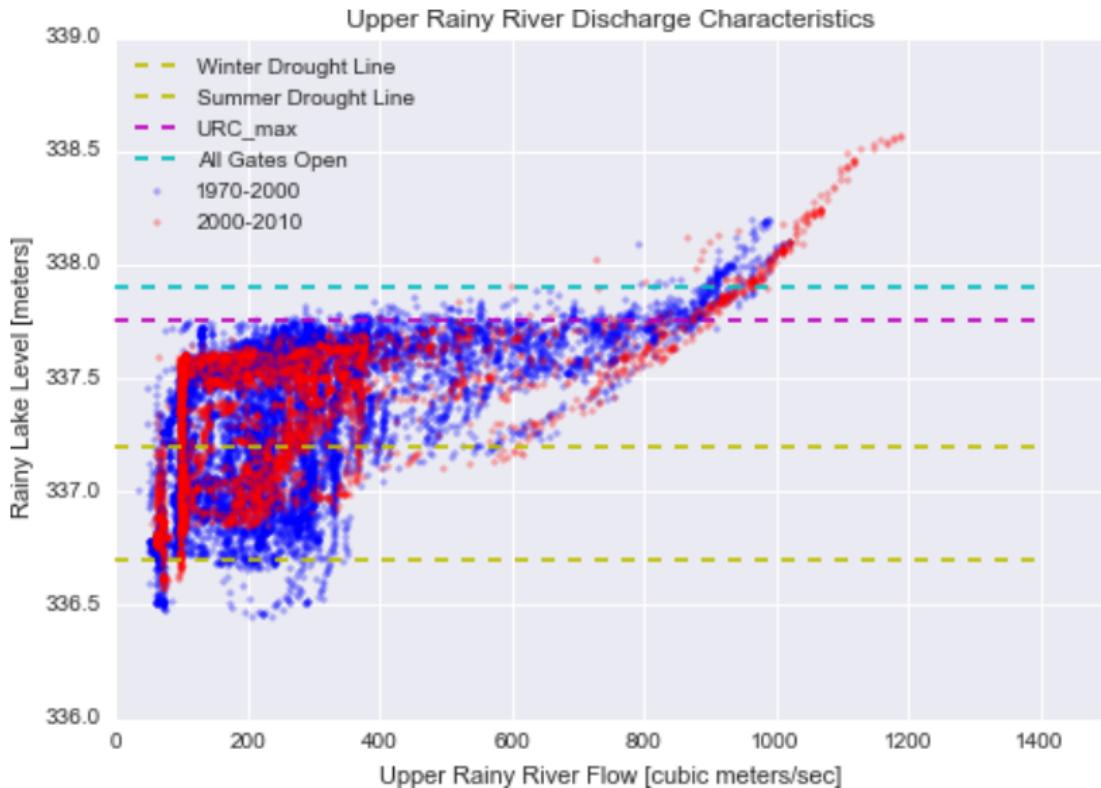
FLOW CONSTRICTIONS ON UPPER RAINY RIVER

Constrictions at Ranier limit the discharge rate from Rainy Lake



Source: [Github Repository for this paper.](#)

RAINY RIVER DISCHARGE 1970–2010



Source: Github Repository for this paper.

IMPACT OF THE RULE CURVE CHANGE, 1970 - 2000

1. Displaces winter inflow to Rainy Lake from winter to summer months.
2. Flow constrictions in Upper Rainy River lead to water level increases in May/June.

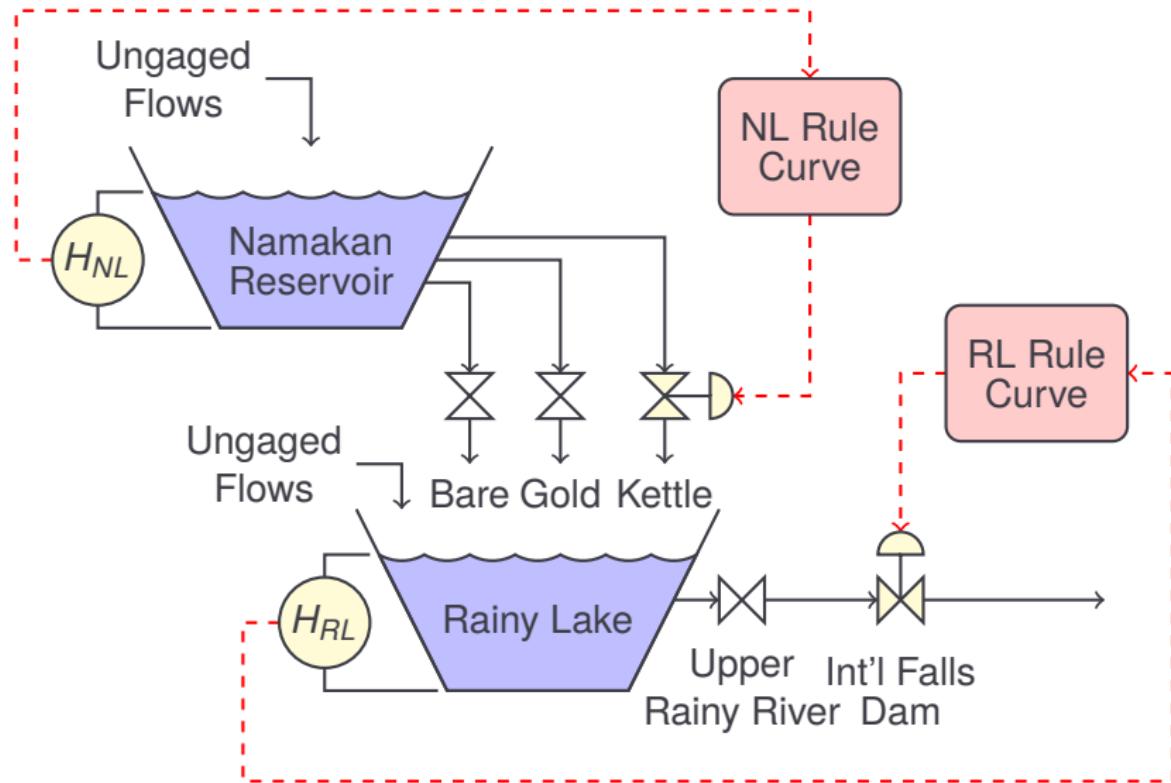
An aerial photograph showing a large dam structure spanning a wide river. On the left bank, there is a complex industrial facility with several buildings, pipes, and a bridge. A road or railway bridge crosses the river above the dam. The water is dark and reflects the surrounding environment. A white curved line is overlaid on the image, highlighting the dam's structure.

IMPROVING CONTROL OF LAKE LEVELS

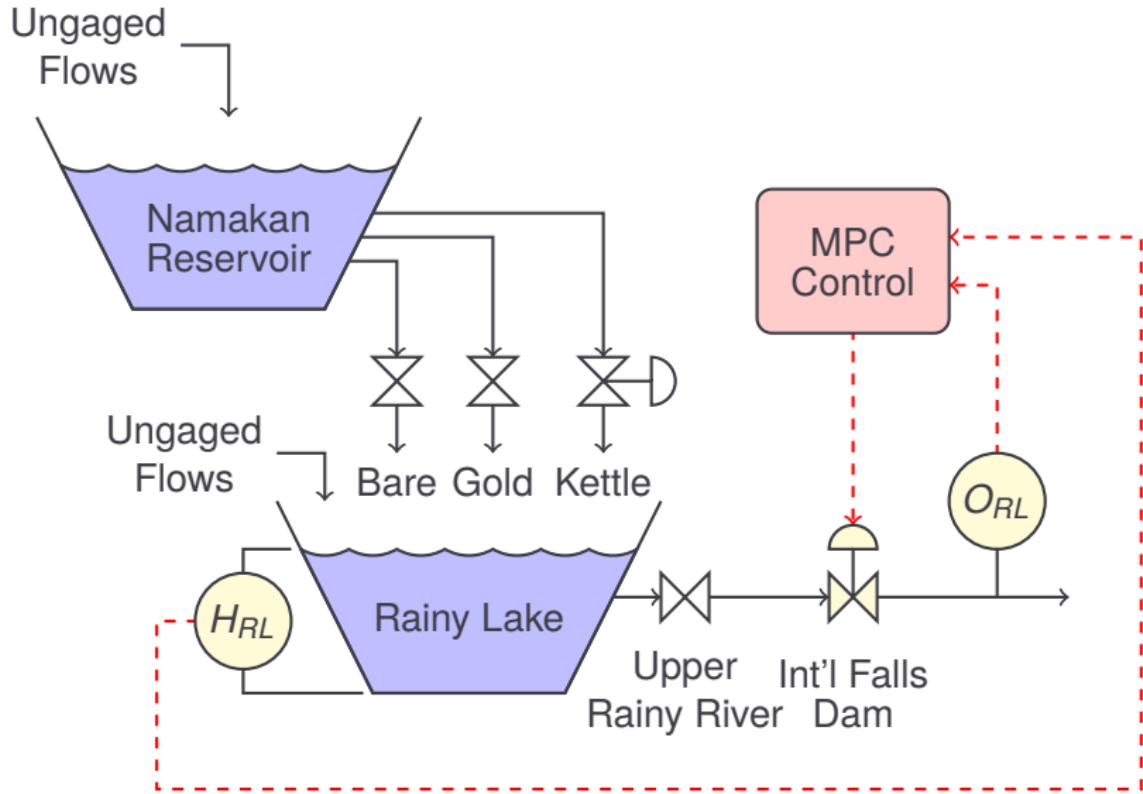
H2O Power LP

Boise Inc

CURRENT PRACTICE

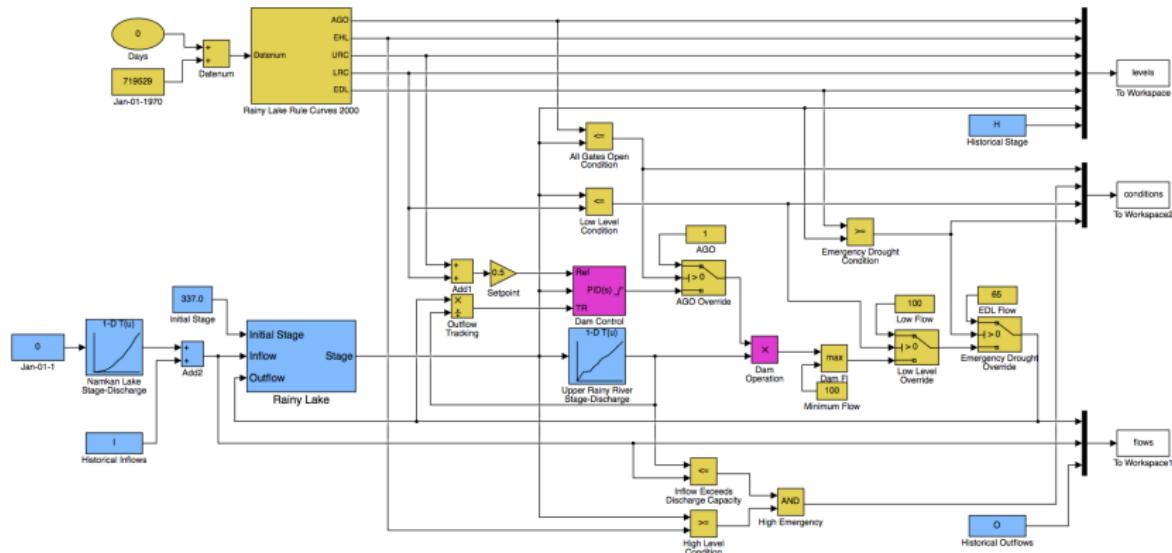


MODEL PREDICTIVE CONTROL FOR RAINY LAKE



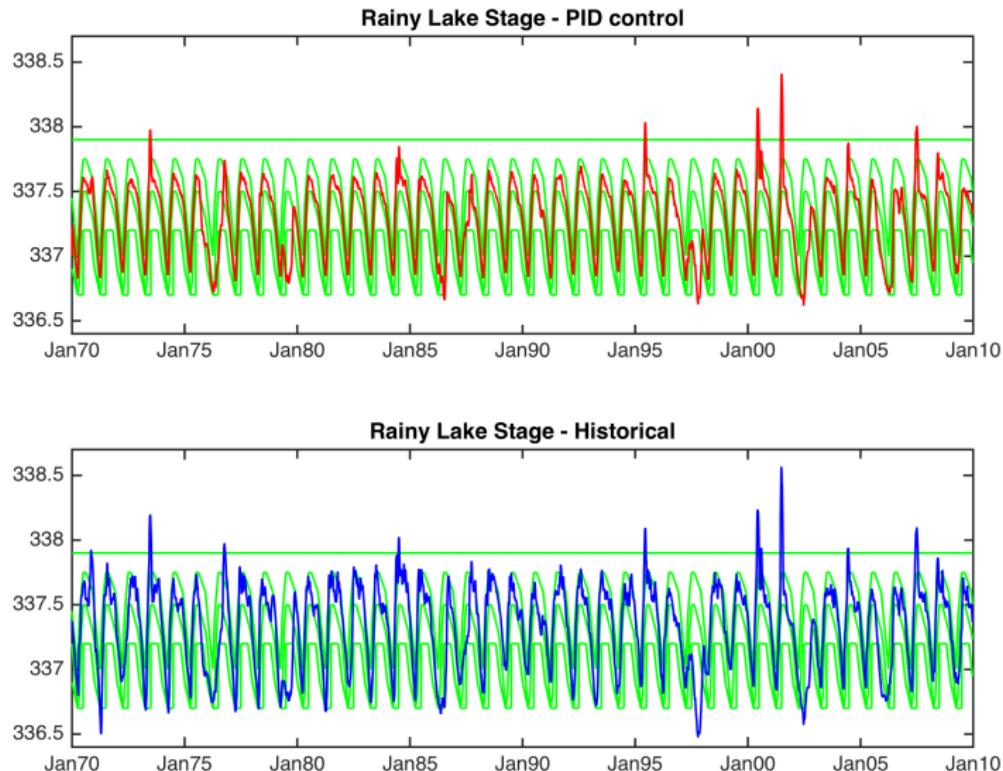
MATLAB/SIMULINK SIMULATION

A calibrated Matlab/Simulink model of single loop control and full implementation of the 2000 IJC Order for Rainy Lake.

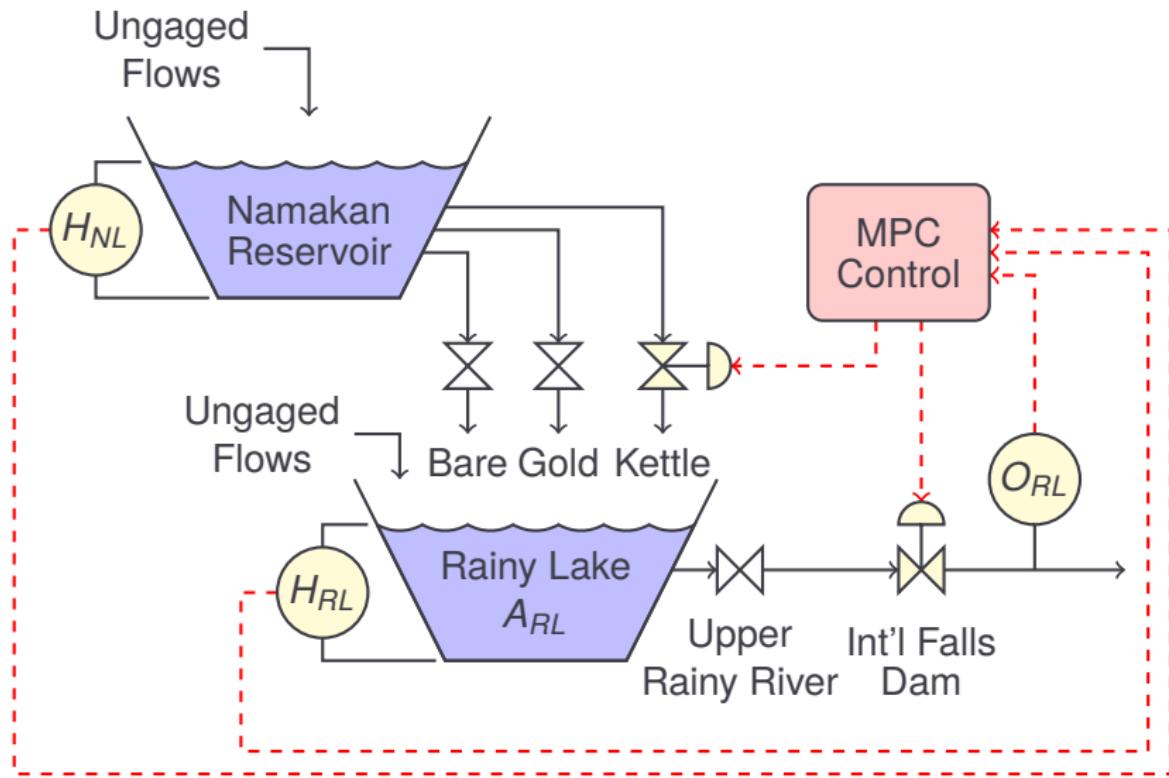


Source: Github Repository for this paper.

SIMULATION RESULTS FOR RAINY LAKE

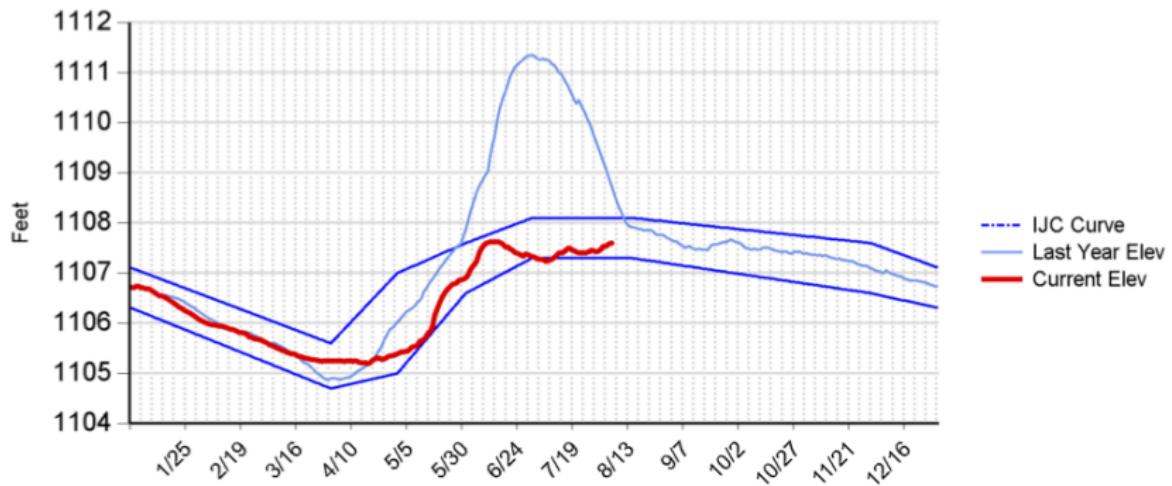


INTEGRATED CONTROL OF NAMAKAN AND RAINY LAKE



RAINY LAKE LEVELS 2015

RULE CURVES AND CURRENT ELEVATION FOR RAINY LAKE



IMPACT ON 2015 WILD RICE PRODUCTION





A scenic landscape featuring a river flowing through a dense forest. The river has several rapids, with white water crashing against dark rocks. Small, green, tree-covered islands are scattered across the water. The sky above is a vibrant blue, dotted with large, fluffy white clouds.

IMPLICATIONS FOR THE RULE CURVE REVIEW

1993 FINAL REPORT AND RECOMMENDATIONS

"To offset the potential for the proposed rule curve modifications to increase the frequency of spring flood events, the IJC should enforce the provision of its 1970 Supplemental Order requiring the dam operators to anticipate inflows and maximize the discharge capabilities of the dams to prevent emergency water levels.

"The Steering Committee believes that diligent use of the existing network of upstream lake level gauges and currently available hydrologic models can make this IJC mandate a reality and improve the accuracy and reliability of reservoir level control."

Source: Rainy Lake & Namakan Reservoir Water Level International Steering Committee, Final Report and Recommendations, November, 1993.

CONCLUSIONS

The rule curve review needs to include control implementation within the scope of its work.

1. Contrary to the 1993 Report, there is little evidence for "diligent use of existing network of upstream lake level gauges and currently available hydrological models can make this IJC mandate a reality and improve the accuracy and reliability of reservoir level control."
2. The 2000 rule curves are not a feasible mandate for level management on Rainy Lake.
3. Consideration should be given to an integrated control strategy for flow control points on the Rainy-Lake of the Woods watershed coupled with significant rule curve revisions.

A wide-angle photograph of a lake at sunset. The sky is filled with dramatic, colorful clouds in shades of orange, yellow, and blue. The lake's surface is very still, creating a perfect reflection of the sky and the dense evergreen forest lining both shores. The overall atmosphere is peaceful and reflective.

DISCUSSION

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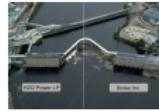
Lee Grim - IJC



Melody Hensel



Mike's Fly In



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