Trials and tribulations of hydrological and water management modelling in Raven: case studies, challenges, and lessons learned

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Introduction

- Considerable “demand” for including water management modelling in cumulative effects assessments of surface water quantity.
- Changes in land cover and climate can alter streamflow; sometimes the biggest alteration of flows is from water management
- Understand how water management may be altering flows/levels or how changing flows may alter operations.
- Raven’s water management module makes it possible to have a fully coupled model that considers both of these things at once.

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Types of Questions

- What are the cumulative effects of changes in climate, land cover, water management in our basin?
- Who is using water in our basin? Where are they using it? Where do we have water scarcity/shortages?
- How can we manage our water better? What management changes could improve outcomes? What are the tradeoffs if we change our operations?
- Can you build me a tool to replace this 20-year-old excel spreadsheet that no one knows how to fix since the person that built it retired?

All reasons to build a water management model!

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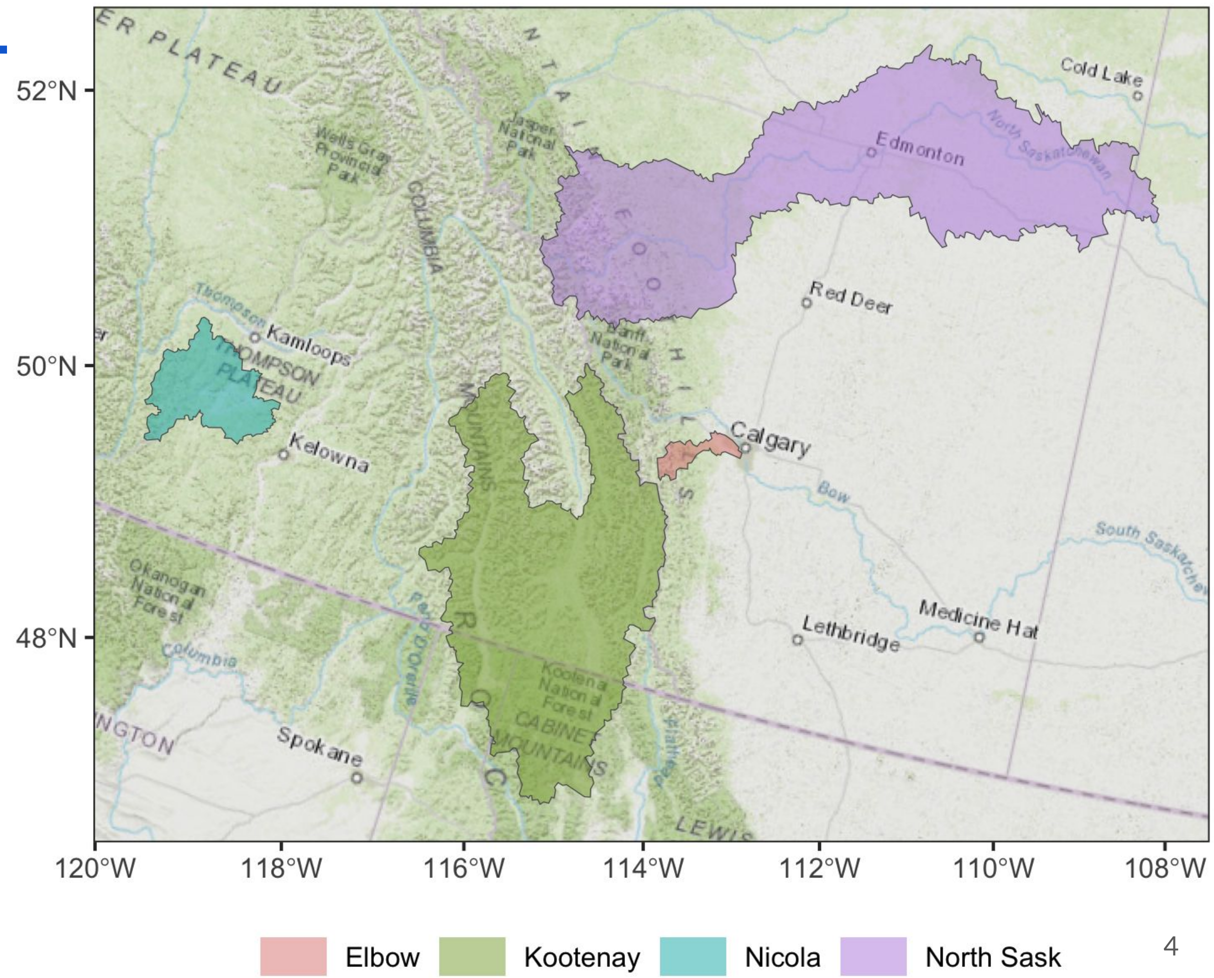
Case Studies

- MacHydro has broken/tested/applied Raven water management module in 4 regions
- Each model had different inputs, objectives
- Hopefully gives a bit of sense on the types of questions, problems, and solutions



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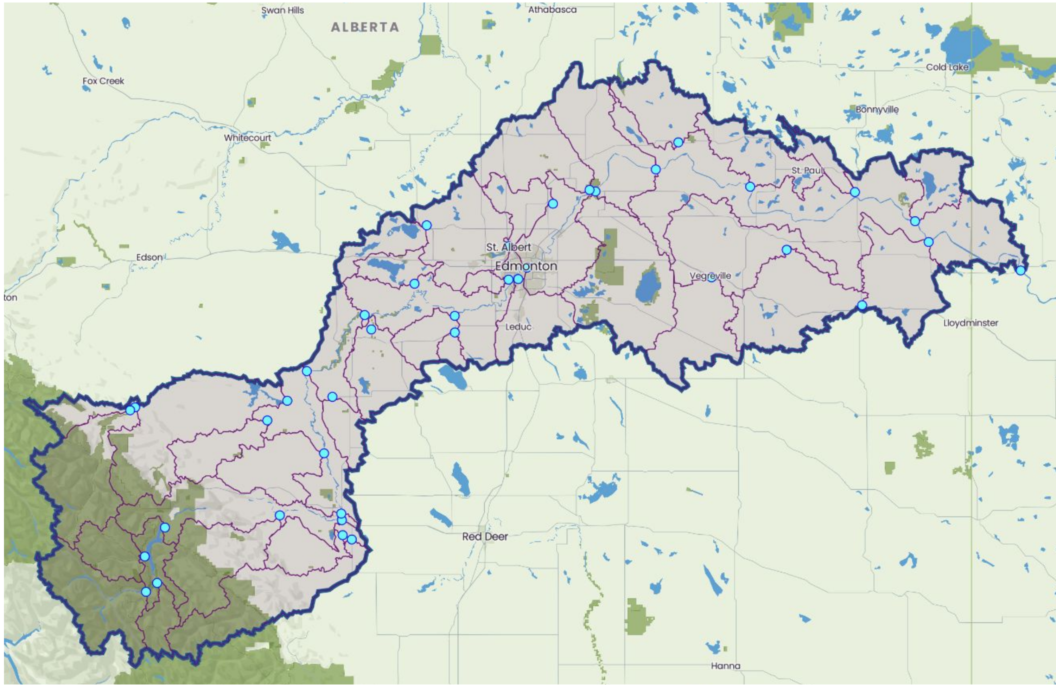
North Saskatchewan River Basin

- Capture the current and future state of water resources in the basin
  - Headwaters controlled by two large power-generating reservoirs
  - ~18,000 water licenses
- Built a large hydrological model for the region, integrated dam and water licensing operations
- Tool can evaluate management adaptations as well as identify future threats to water security.



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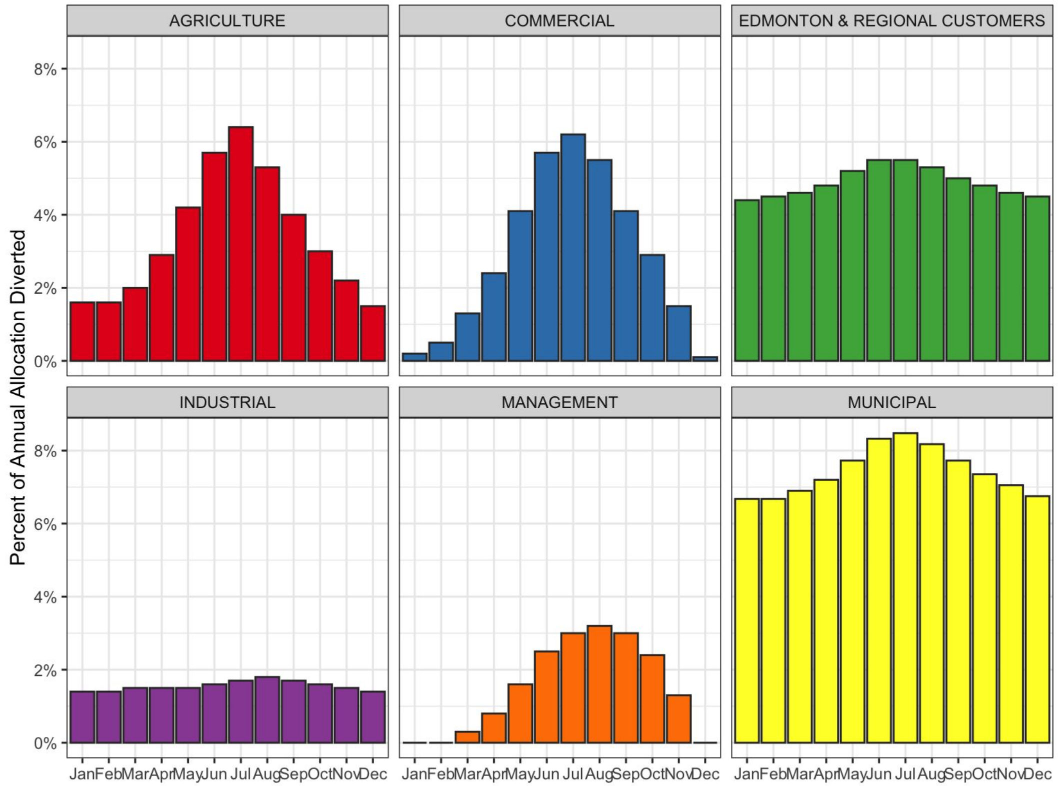
A Hazen Company watersmart! Water Management Solutions

NSWA NORTH SASKATCHEWAN WATERSHED ALLIANCE 20 YEARS

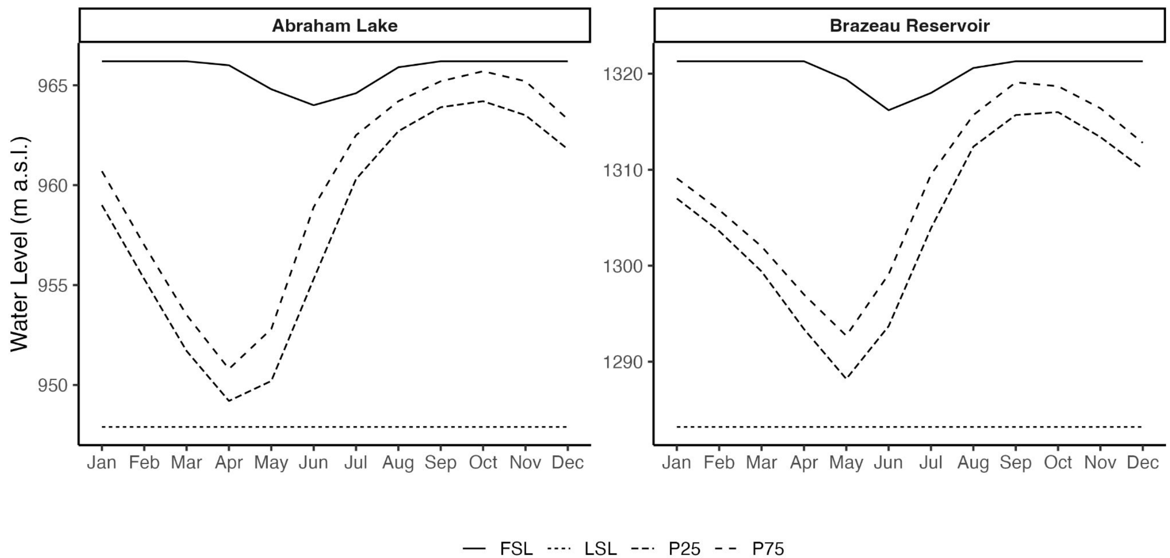
Water Licensing

- Allocated water != Water Use
- Diversion vs. Return Flow
- Reporting is often wrong! (misread water meter, data entry error)
- Used averages of reporting for all licenses



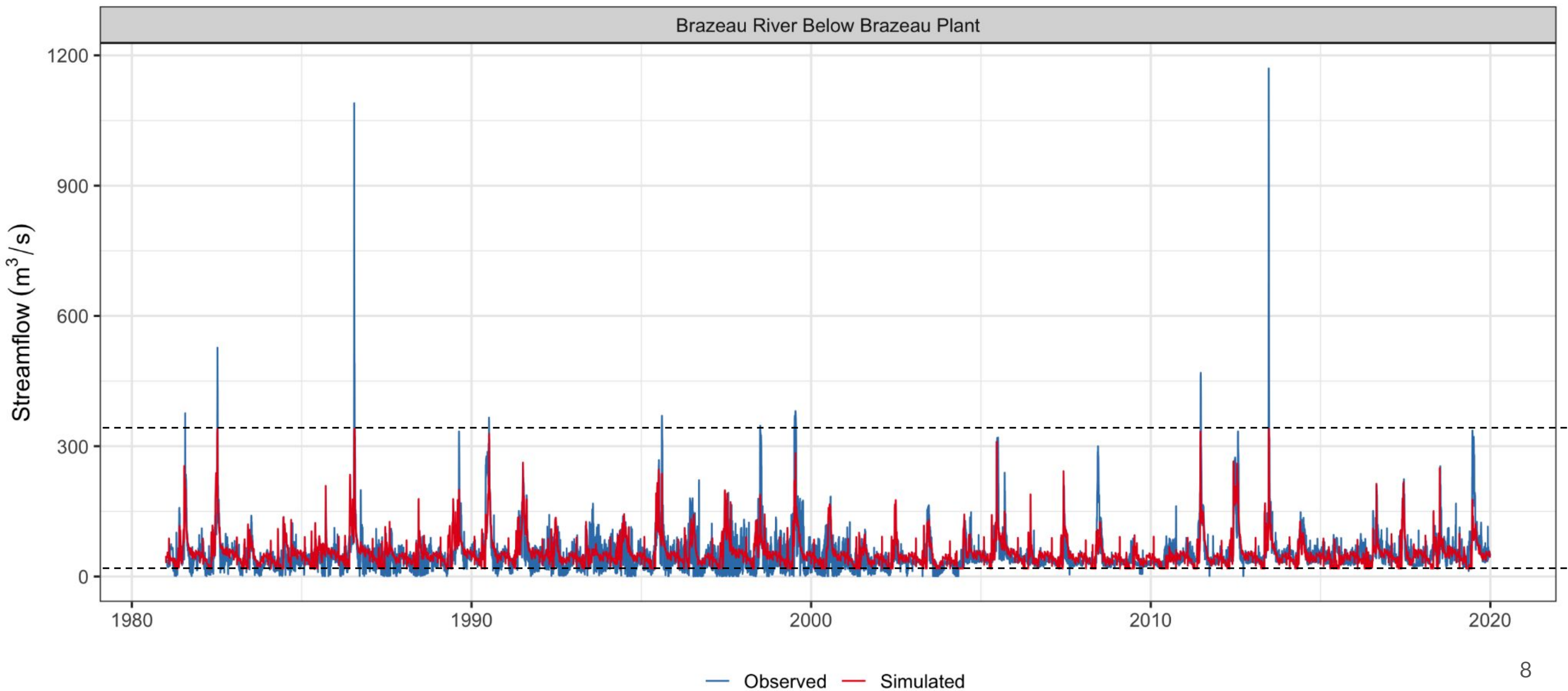
Dam Operations

- Provide "constraints" (FSL, LSL, Minimum/Maximum Flows)
- Set low penalty target for water levels based on historical quantiles
- Can't replicate all behaviour since some objectives are not shared (power demand)
- Model is more dogmatic at following goals than observed record



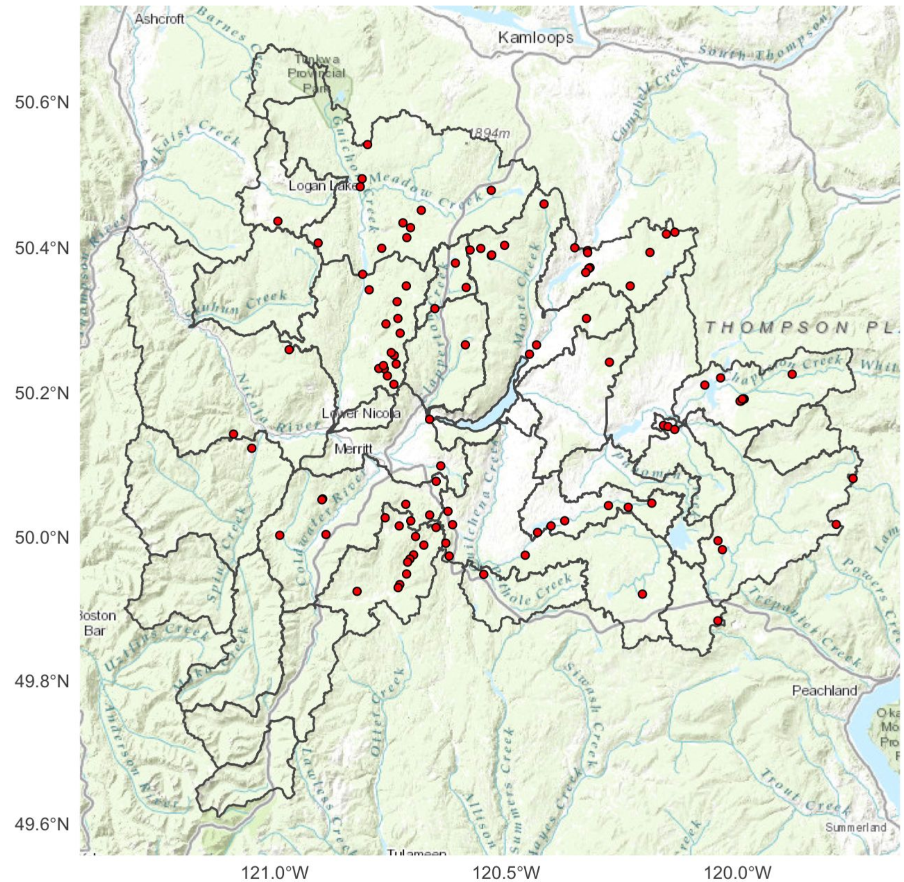
Changing Operations

1981 - 2020



Nicola Watershed

- Evaluate cumulative effects on surface water
  - Including changes to land cover, climate, water storage, and licensing
- Arid watershed, especially in the east and north
- Lots of water demand (irrigation)
- Lots of small dams, (some divert water out of basin)
  - Mostly operated by private landowners/ranchers (some located on FN lands)
  - Earthfill berms and culverts to full dams, in various conditions
  - Uncoordinated



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Chapperon Lake (Nicola Basin)

5.1 Current Reservoir Operations and Releases

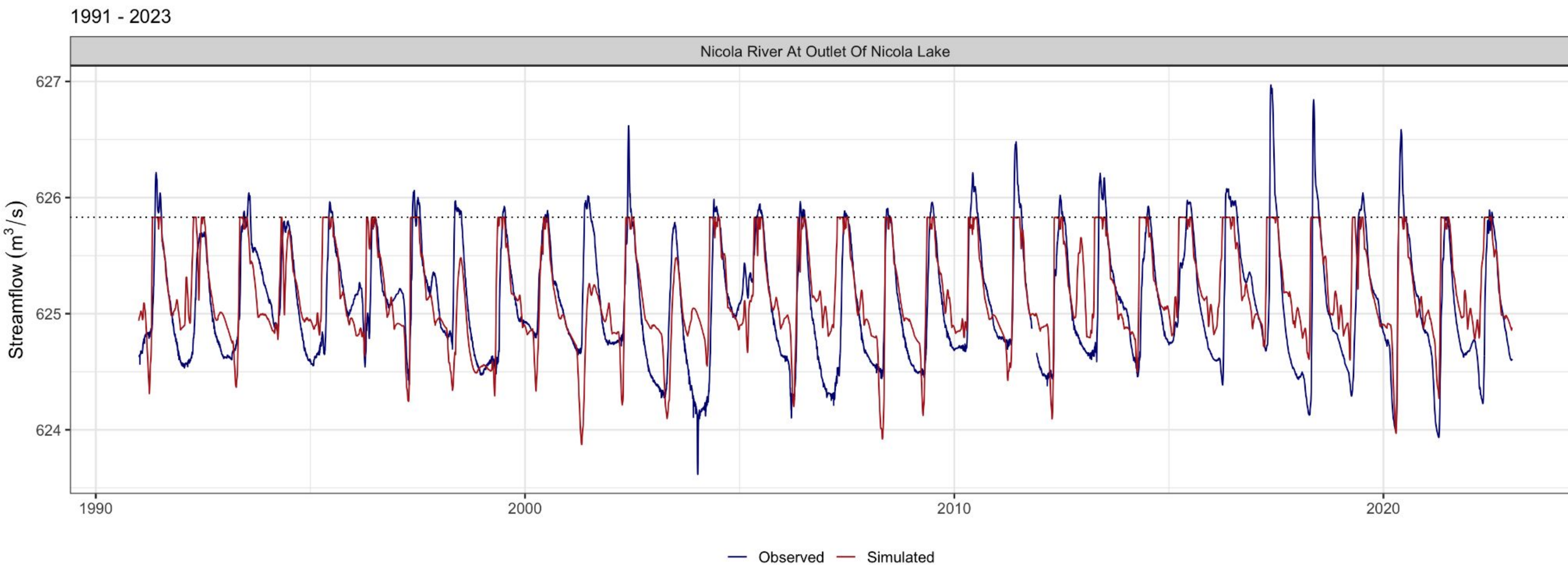
The objective of this project is to determine the amount of water to be released from storage over time. To understand the current operations of the reservoir, Kala conducted an interview with Mr. Phillip Braig and Mr. Stewart Murray of the DLCC on March 13, 2018. Mr. Murray has operated the Chapperon Lake dam for approximately 40 years. He reported that the fish channel is open all year long and the sluiceway pipes have been closed or near closed with the exception of 2015. Kala understands the sluiceway pipes were opened in 2015 and Christian St-Pierre, MRM, P.Ag. of FLNRO, Kamloops Office conducted a rating curve study at the Chapperon Lake outlet in 2015.

The current DLCC operation strategy is to retain as much water as possible in the Lake during spring freshet and release water to the downstream at a consistent minimum flow for aquatic life and wildlife. Mr. Murray said that typically, the high water period starts in mid-April and ends no later than early July each year. Mr. Murray reported that he checks the dam every 3 or 4 days (on average) starting from the 3rd week of May to determine if the sluiceway gates need to be adjusted to discharge more water to the downstream for safety and operation reasons, and every 3 or 4 days in August to determine if the gates need to be adjusted down. Mr. Murray said that if there is generally around 25 cm (10") of water (above the top of chute) in Chapperon Lake, the reservoir will be able to maintain a flow having a depth of 10 to 12 cm (4 to 5") and a width of 2.4 m (8') in the downstream channel during the low flow season, from August to March. 25 cm or 0.25 m (10") of water in the Chapperon Lake above the spillway chute is equivalent to a volume of 0.25 m × 4,049,250 m^2 = 1,012,312 m^3 [821 acre-foot] of water. If this amount of water is to be released over a period of 243 days, from August to March, the average release rate is 1,012,312 m^3 / 243 days = 4,166 m^3/d or 0.048 m^3/s [10.6 imperial gallon per second].

Mr. Murray also pointed out that, generally speaking, the surface water levels of Chapperon Lake have remained fairly consistent over the years in his view; however, he indicated that downstream flows in the Nicola River have decreased substantially over the years and he attributes this to both climate change and upstream logging activities.

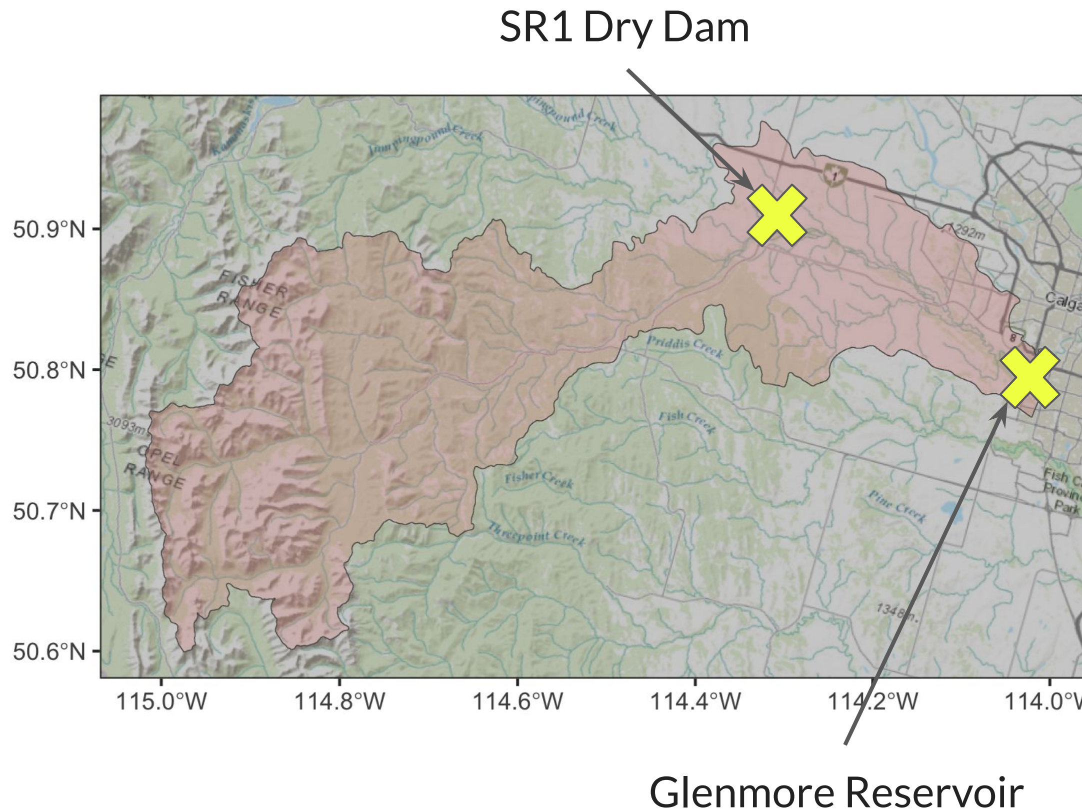
Nicola Lake

- Relatively undocumented operations
  - Operated by the same person until ~2020 when they retired
- Often relied on intuition to manage lake levels



Elbow River Flood Mitigation Operations

- The Springbank Reservoir (SR1) is a dry dam reservoir in the lower Elbow River
  - Designed to divert water during high flow events, store it, and release water following the event.
- Works in conjunction with Glenmore Reservoir to protect Calgary
- Upgraded Raven model to include water management
- Model also integrates with data assimilation and operational tools



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SWFT RESPONSE SNOW WATER FORECAST TECHNOLOGY

heron hydrologic

Flood Mitigation Operations

```
# Inflow Params -----
# Diversion Initiation Flow (m3/s); default is
250
:NamedConstant SR1_DivInitQ 250
# Diversion location (7 is Elbow @ Bragg Creek, 8
is Elbow above SR1)
:NamedConstant SR1_DivLocation 7
# Max Diversion (m3/s); default is 520
:NamedConstant SR1_MaxQ 520
# Target Bypass Flow (m3/s); default is 100
:NamedConstant SR1_BypassQ 100

# Outflow Params -----
# Drawdown Initiation Flow (m3/s); default 100
:NamedConstant SR1_OutflowInitQ 100
# Outflow initiation location (8 is Elbow above
SR1, 11 is Elbow @ Sarcee)
:NamedConstant SR1_OutflowLocation 11
# binary (0 is off, anything bigger is on)
:NamedConstant SR1_TargetOutflow 1
```

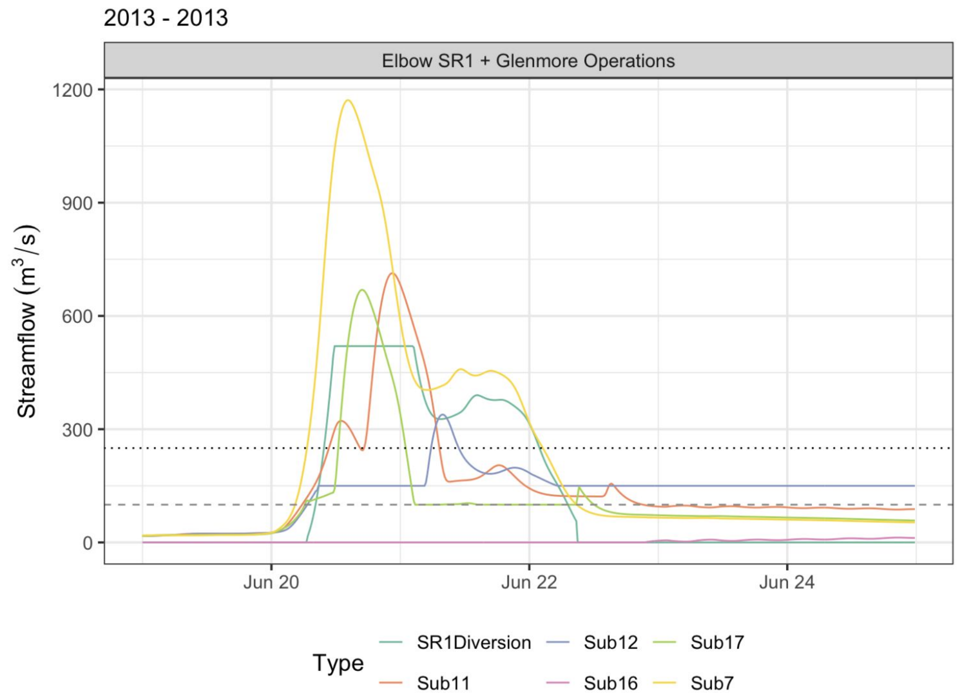

Figure 6: Hydrographs for the 2013 flood even on the Elbow River, demonstrating SR1 diversions on June 20 to 23 and returns (Sub16) following the event. Dotted line on is the Diversion Initiation Flow (at Elbow River at Bragg Creek; Sub7) and the dashed line is the Drawdown Initiation Flow (at Elbow River at Sarcee Bridge; Sub11).

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Aside: Non-Linearity

Stage-Discharge curves:

- Problem: uses last time-steps stage to calculate this timesteps outflow
- Issue: kind of a big deal during flood operations, especially if you have a longer timestep
- A solution: a simple example: Glenmore Lake outflow has to below the fully-open outflow curve:

Before:

```
:ManagementConstraint GlenmoreOutflow
        :Expression !Q16 < @lookup(GlenmoreQH,h16[-1])
:EndManagementConstraint
```

After

```
:NonlinearVariable ?h16 !h16
:ManagementConstraint GlenmoreOutflow
        :Expression !Q16 < @lookup(GlenmoreQH,?h16)
:EndManagementConstraint
```

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Flood Mitigation Operations

Important to note that tool is interactive (i.e. user turns on/off management options)

In a non-live setting, would be difficult to emulate flood ops

- Operator would see forecast, make a judgement call on when/how much to proactively lower reservoir level to increase storage
- Make judgement call on when to start filling the dry dam
- Make another judgement call on when to start releasing dry dam
- All while weighing the consequences of being “wrong”
    - Empty too much reservoir; may have to be extra careful about water supply in late summer/winter
    - Empty too little and limit ability to store flood pulse

Disembodied head of Flames mascot Harvey the Hound found floating in Saddledome

David Staples • Edmonton Journal

Published Jun 24, 2013 • 2 minute read

Join the conversation

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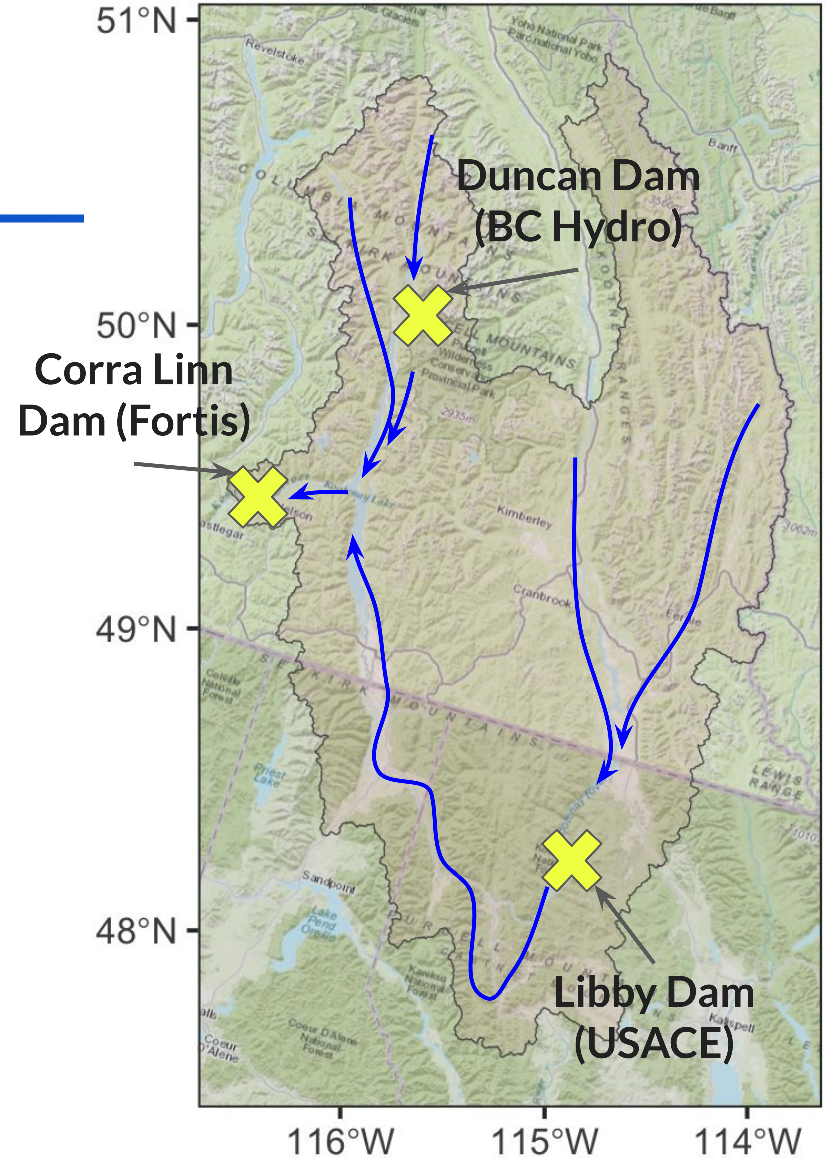
Kootenay Lake

- Understand how climate change will alter inflows to Kootenay Lake
- Managed system with many stakeholders
  - US Army Corps (USACE) operates Libby Dam
  - BC Hydro operates Duncan Dam
  - Fortis operates Corra Linn
  - Outflow from Kootenay Lake also affected by Kootenay Canal, which bypasses Corra Linn
  - Some of these dams are also part of CRT
- Depending on Lake levels, outflow limited by hydraulic constriction (Grohman Narrows)



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Byzantine Operations

- Lots of operations rely in seasonal forecasts
  - Presents issue of whether model should/can simulate forecast or assume “perfect foresight”.
- Some protocols are complicated, but highly prescriptive.
- Not always the case!

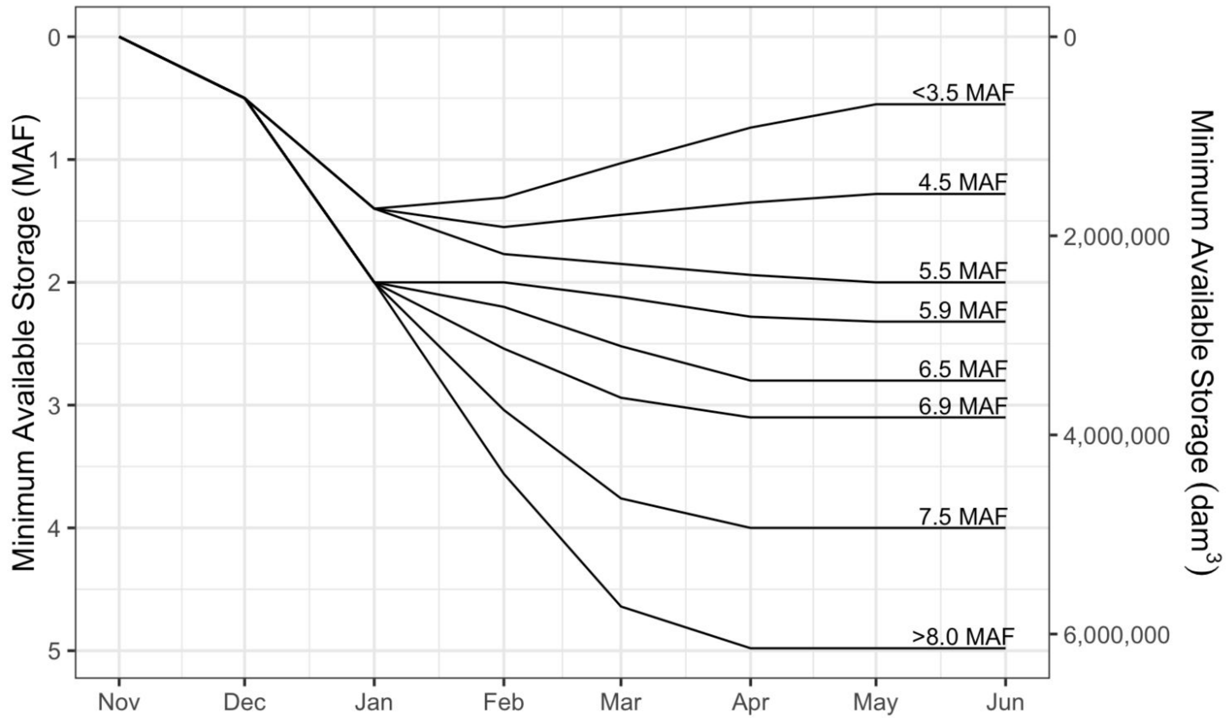

Figure 4: Minimum available storage on Lake Koocanusa depending on the April-August Libby Water Supply Forecast (WSF) in millions of acre-feet (MAF). Note that the value of Minimum Available Storage is determined by interpolating between the plotted lines.

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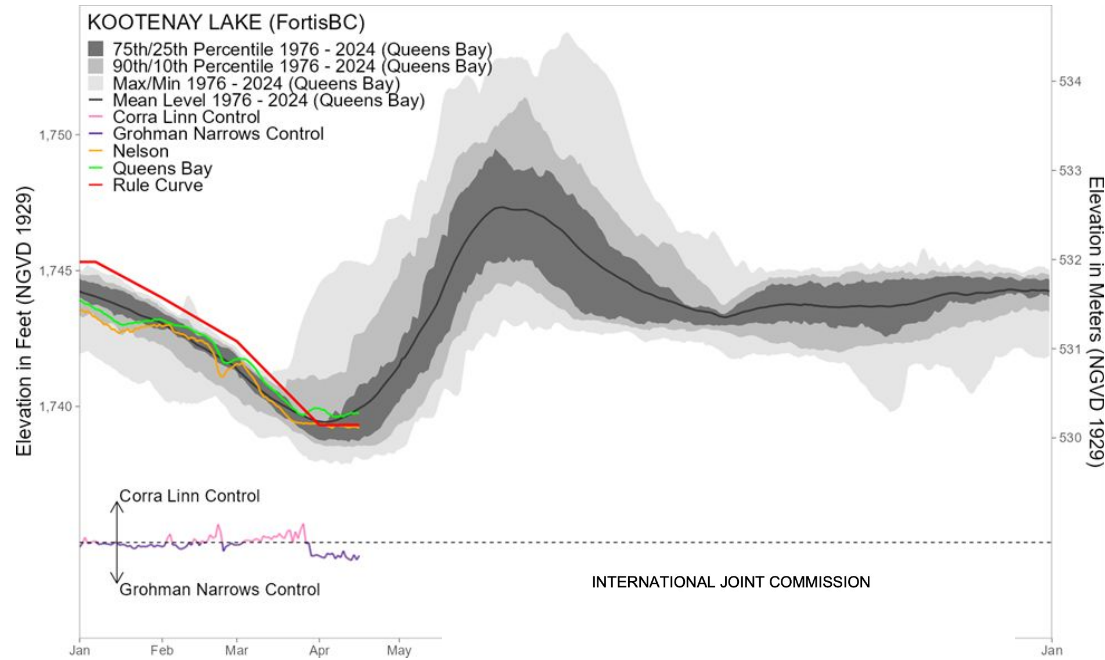
Kootenay Lake Rise

Kootenay Lake water level management determined by ICJ 1938 Order.

- Static maximum/minimum elevations between September and March
- Specific lowering formula for the rest of the year
- Exact date of switch is based on Spring Rise Declaration



INTERNATIONAL JOINT COMMISSION

IN THE MATTER OF THE APPLICATION OF THE WEST KOOTENAY POWER AND LIGHT COMPANY, LIMITED, FOR PERMISSION TO CONSTRUCT AND OPERATE CERTAIN WORKS IN AND ADJACENT TO THE CHANNEL OF THE KOOTENAY RIVER IN THE PROVINCE OF BRITISH COLUMBIA, AND FOR THE RIGHT TO STORE WATER IN KOOTENAY LAKE IN THE SAID PROVINCE OF BRITISH COLUMBIA.

ORDER OF APPROVAL

November 11, 1938

2025 Kootenay Lake Spring Rise Declaration

April 18, 2025

The International Kootenay Lake Board of Control, after consultation with FortisBC, the operator of the Corra Linn Dam, has determined that "the commencement of the spring rise," for purposes defined in the 1938 International Joint Commission Order that sets the maximum level of Kootenay Lake, occured at 00:00 PDT on April 18, 2025.

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Common Problems

- Data Availability
  - no data, wrong data, proprietary data, or very imprecise data
- Defining Operations
  - Changing operations
  - Complicated, byzantine operations
  - Nebulous operations
  - Forecasting activities (i.e. pre-flood emptying) and foresight
  - Objectives that are difficult to model (i.e. power demand, temporary diversion licenses)
- Competition versus Coordination/Cooperation
  - Infrastructure/stakeholders may operate independently, may be undocumented!
  - May be unwilling to alter operations to accommodate another goal
- Human Judgement vs. Model Dogma
- Model Performance

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All reasons not to build a water management model! (just kidding)

Conclusions

- Hopefully this gives some sense on some of the challenges and potential pitfalls in water management modelling, a sense of what kinds of uncertainty to expect.
- Technical problems are relatively easy to fix
- The harder problems are trying to make a computer replicate human decision making
- Raven provides a useful tool incorporate water management into modelling studies to investigate a range questions.
- Important to temper expectations and understand the limitations and sources of uncertainty.

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