Associated Environmental

Management of Okanagan mainstem lakes in spring 2017

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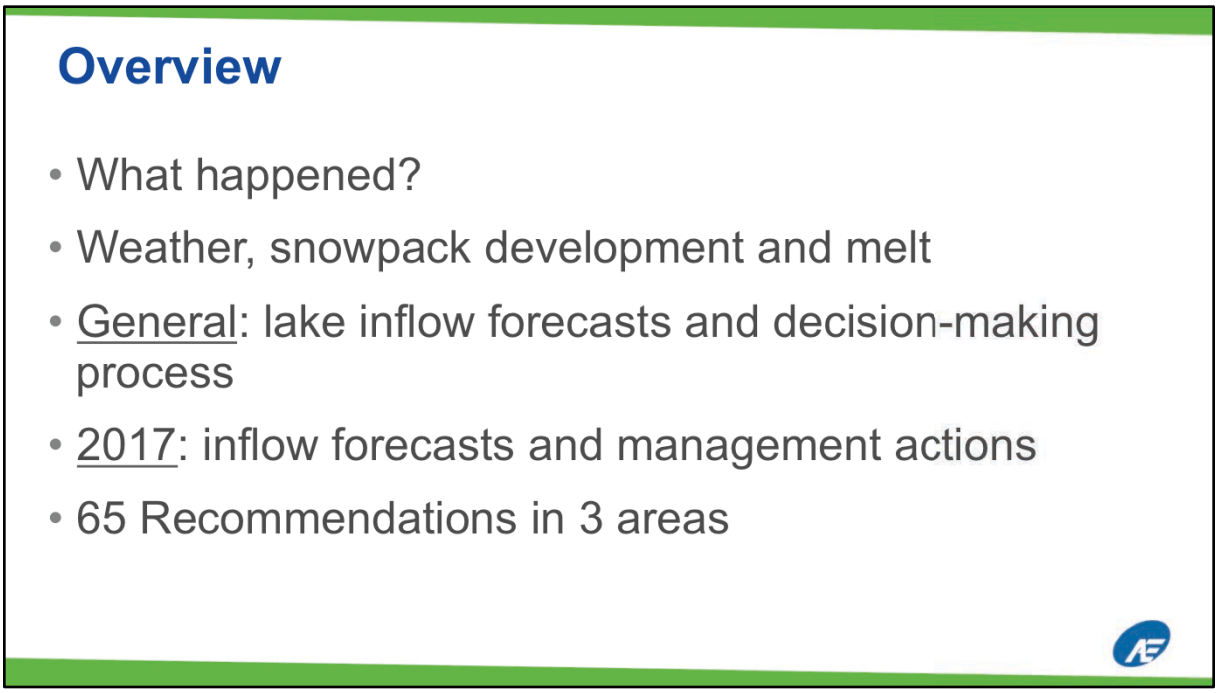
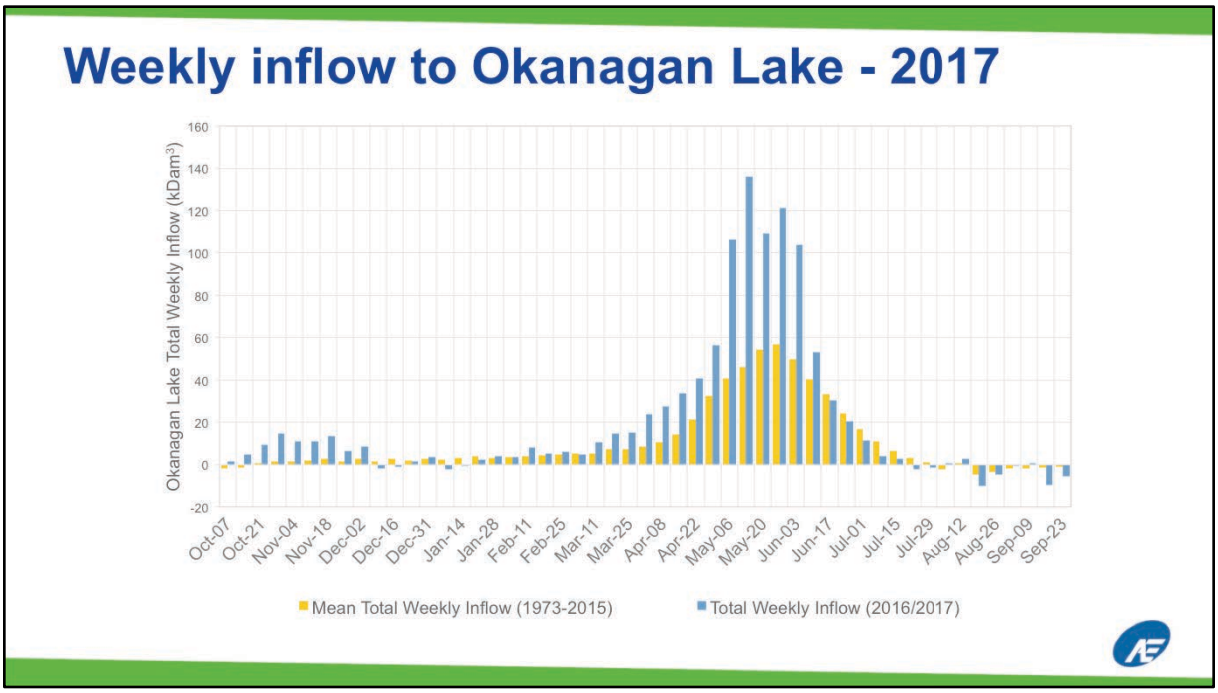
- After experiencing a wet spring with very high inflows to the mainstem lakes in the Okanagan, many people started questioning whether the Province, which manages the Okanagan Lake Regulation System (or OLRS) did their job properly. People wondered whether the Province was asleep at the switch – whether they could have or should have anticipated the high inflows and let more water out of the lakes earlier to prevent the flooding that occurred.
- So FLNRORD headquarters in Victoria hired us at AE **to answer that question and provide them with some recommendations** to help them improve their handling of the system in future.
- The work included the Nicola system as well, but I'll just talk about the Okanagan here, although the story was remarkably similar in the Nicola.
- We work was focused on all the main valley-bottom lakes from Kalamalka down to Osoyoos, but for today I'll mostly focus on Okanagan Lake since decisions made there totally dominate the story.
- The scope of our work was limited to the province's management of the mainstem lakes, not to their involvement with EMBC activities –e.g. flood response and recovery.



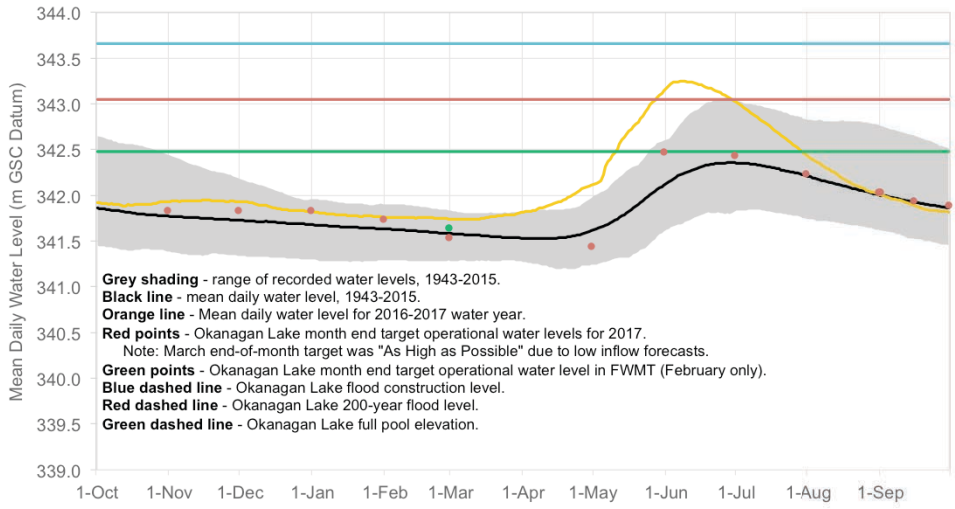
- Here's what we'll cover:
- First of all a reminder of what happened
- Then we'll start **looking as WHY** –
- We'll start by looking at the **unusual weather patterns** last year
- Then I'll show you how the **snowpack developed and melted**
- Then we'll look at **how the Province predicts** how much inflow will come into the lakes in spring and the process they go through to use that information to make decisions on setting the gates that establish the outflow on the mainstem lakes.
- Then we'll look at the **2017 situation** – the 2017 forecasts, and what actions were taken in Penticton
- **Bottom line is the province did a good job WITH THE INFORMATION THEY HAD AVAILABLE.**
- You can probably see what's coming – we still made 65 recommendations – basically to improve the information available –
- and I'll boil those down into about 15

- First of all, here's a few photos to remind you of what the Okanagan looked like in May last year.
- Clockwise from upper left:
  - Sun Oka Beach in Summerland
  - North end of Osoyoos Lake
  - Glenfir Road
  - Okanagan Lake on a windy day flowing across the highway near Peachland
  - And Okanagan River below Skaha Lake in the middle



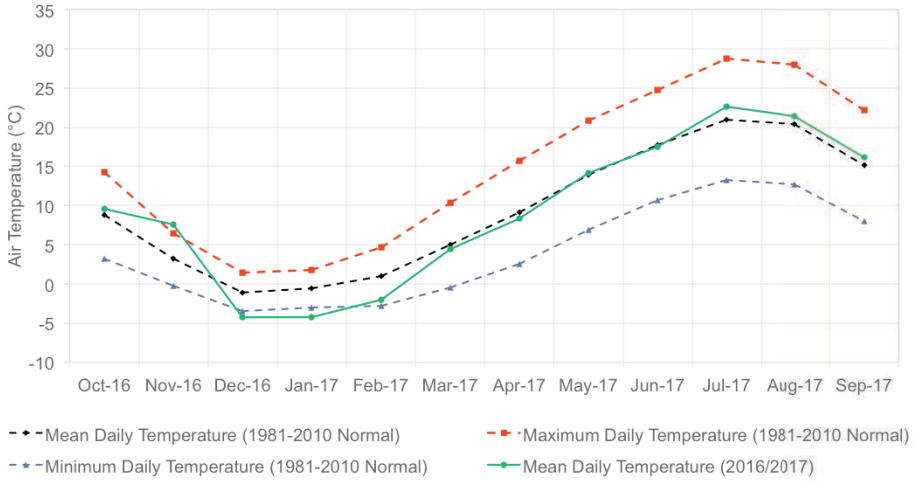
- Here's a **short summary** of the 2017 story: (I'll go into this a bit more slowly in a minute – but here's the big picture of what happened)
- The Water Manager in Penticton acts in **response to monthly inflow forecasts** supplied by the River Forecast Centre to store and release water to meet **multiple constraints** (eg flood control, summer drought, fisheries migration, spawning, incubation, emergence, and rearing flows)
- By the way - the fisheries criteria are secondary to the flood control criteria – I've hard people say that Shaun saved fish in preference to avoiding lake shore flooding – its true that he considers fish but he eventually overrode the incubation criteria – in other words released lots of water that risked flushing sockeye eggs out of the gravels and killing them. By the way - that's what he's doing right now)
- The **Inflow forecasts were all too low** (Why? I'll get into that a bit later …) – mainly because they don't include weather forecasts
- So the Water Manager was **expecting a normal** runoff
- But then it really **rained a lot in spring (and snowed up high**)
- The Water Manager **overrode the Operating Plan and increased the outflow** at Penticton to equal the capacity of the downstream channel by May 1, then couldn't increase it much (or any) further
- Then (you can see this on this plot) **May produced the highest inflow on record (528 million cubic metres** - equal to entire inflow in an average year) – **AFTER Shaun had lost the ability to increase** the outflow
- So the **lake levels rose and flooding occurred** around all the lakes in May that

Okanagan Lake levels - 2017

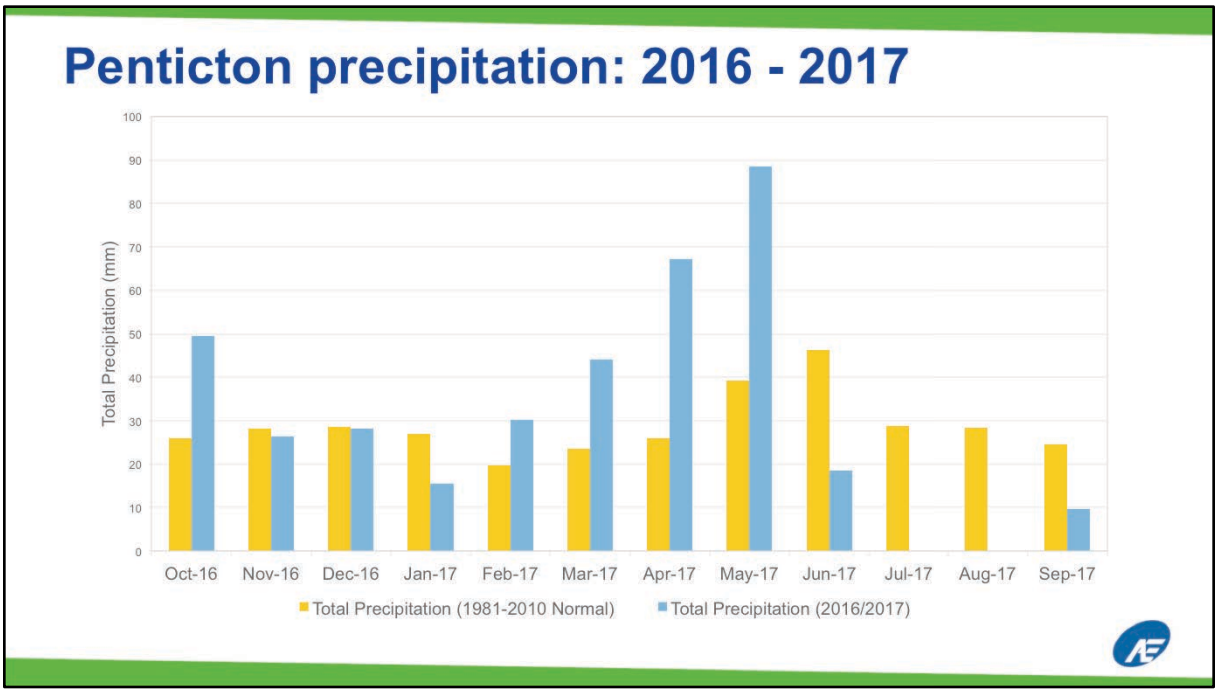


- Here's what happened on Okanagan Lake in graphical format:
- Green Line is at Full Pool – the normal target high water level (342.48 m)
- Red Line is the 200-year return period lake level (343.05 m)
- Blue Line is the Flood Construction Level (343.66 m)
- So the lake rose past the full pool level and past the 200-year level and set a new high record, eclipsing the old record of 343.065 m set in 1948
- And peaked at **343.25 m on June 8**
- Then it dropped back down during the hot dry summer to normal around mid-August
-

Penticton daily mean temperature: 2016–2017

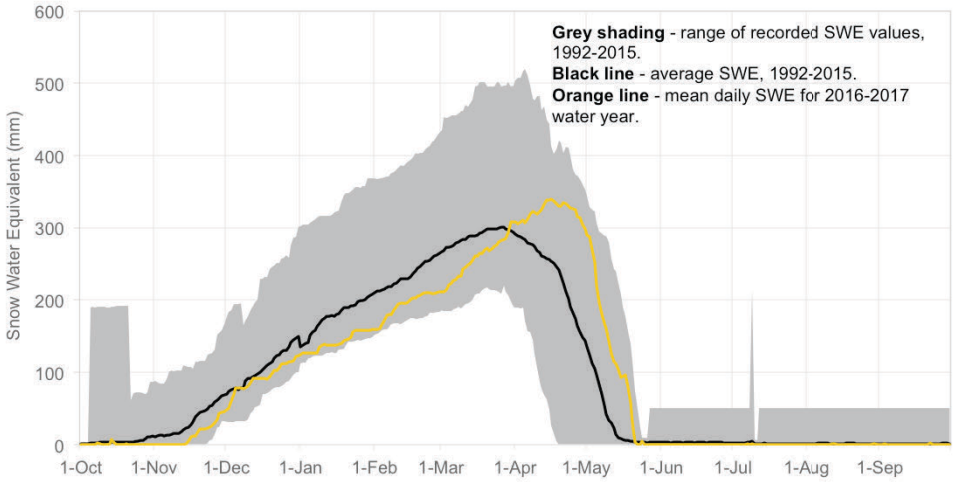


- So that's what happened
- **How about why.**
- Well the answer is mostly the very unusual weather but there are also some issues with the forecasting data and models
- Our report goes into some detail about the weather story but I'll just highlight some key points here … and we'll talk about models later too
- This is showing Penticton temperature from October 2016 through September 2017
- Black line is a **30-year average line** for the mean daily temperature and the green line is the 2017 mean daily temperature – so compare the black and the green and ignore the blue and red lines
- 2017 was pretty much normal, but focus on Dec, Jan, and Feb – much colder than normal.
- Same story up and down the valley



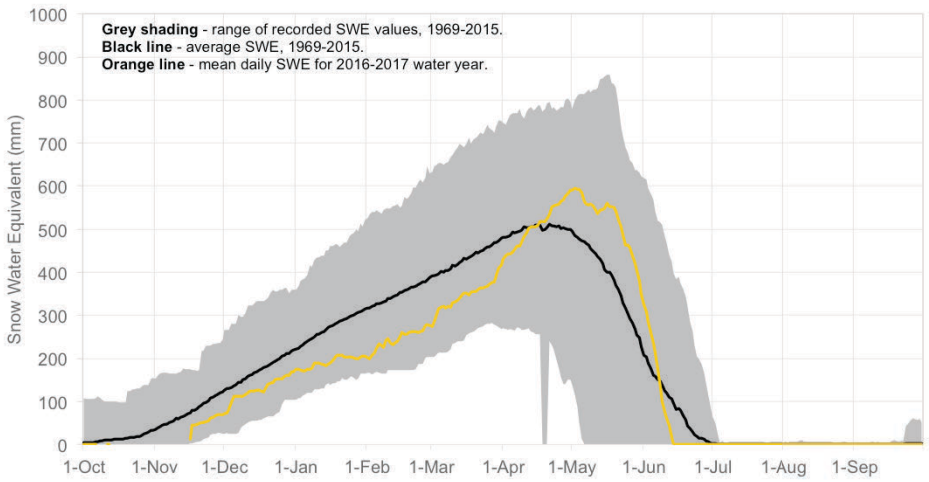
- Review the Penticton Precip. data
- **Wet fall – so soil wet**
- **Colder winter with normal precip. led to more snow at lower elevation**s than normal
- This **was picked up by the inflow forecasting models**
- But it may have conveyed a false impression to the residents that there was way more snow than usual all through the winter – which wouldn't have helped the perception that the province was not keeping an eye on things
- Then a **very wet spring – March, April and May had record** or near record rainfall throughout the valley.
- Summer was **bone dry**
- **So four odd seasons** in a row …

2017 Brenda Mines snowpack

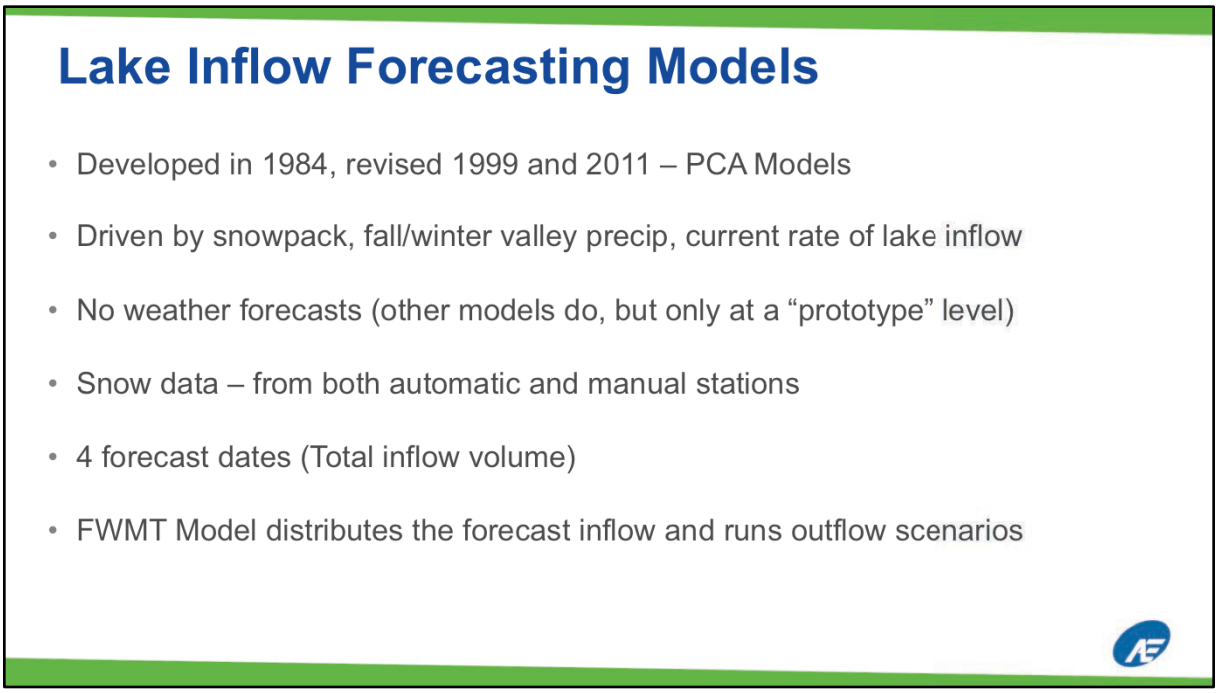


- So – with that background on the winter and spring weather lets take a look at the snowpack at mid and high elevations through the winter and spring
- At **Brenda Mines**, which is a mid elevation station **(1460 m),** the snowpack was tracking **below normal until about March 15 when it began to** rise.
- It crossed the average line about April 1, then it rose to **above normal and peaked on April 19**.

2017 Upper Mission Creek snowpack



- **Same story at Upper Mission Creek (1780 m**):
- below normal snow through most of the winter,
- starting to rise in mid-March, and
- peaking in this case on May 6 because its at a higher elevation than Brenda Mines



- Ok, so that's the weather and snowpack background – unusual …
- Now let's look at the **inflow forecasts** that the Water Manager uses to make decisions about releasing water.
- The models used are known as **PCA models** – which stands for Principal Components Analysis – they are driven by three types of variables: snowpack conditions on the date of the forecast (that's the biggest driver of the forecasts); fall and winter precipitation in the valley-bottom, and existing baseline inflows to Okanagan Lake.
- **They don't make use of weather forecasts** – so they couldn't look ahead and account for the looming high rainfall in spring that I just showed you.
- The Province is actually developing a model that does include a weather forecast, and maybe ultimately it will be better, but as of now – weather forecasting is not that accurate beyond a few days.
- On the snow data – the province has a **mix of real-time automated stations and manual stations** that are read monthly (Jan 1, Feb 1, March 1, April 1, and May 1 – some are also read May 15.
- Because historically the network was dominated by the manual stations the **PCA models are run after the Feb. March, April, and May 1 snow surveys are completed manually.**
- So the RFC **supplies only 4 forecasts** to the Water Manager during the spring – and the forecasts consist of the **TOTAL INFLOW VOLUME** from the forecast date to the end of the spring snowmelt period (July 31) (they also produce forecasts to June 30).
- Now these forecasts are run through another model (the **FWMT Model**) that distributes the forecast inflow volumes into weekly and daily increments and allows Shaun and others to play around on the computer and run hypothetical lake outflow scenarios to see what will happen and

2017 Okanagan Snow Water Index - % o Normal

January 1	79
February 1	79
March 1	86
April 1	105
May 1	147
May 15	151
June 1	228

- Before I showed you the pattern of snowpack accumulation and melt at Brenda Mine and at Upper Mission Creek.
- Well, here's a **more generalized picture of the snowpack conditions** throughout the Basin at different times in 2017.
- **Around 80% of normal until April 1, then just above normal, then rising to about 150% of normal in May and even higher on June 1 (over double the normal snow)**

- So as you would expect, the **PCA models, driven largely by the snowpack** conditions were providing normal or less than normal inflow forecasts in early February and early March.
- The forecasts didn't reach normal until early April, and were significantly above normal in May.
- However, **every one of the forecast underestimated the actual inflows.**
- Let's take a look …

Information flow and decision-making process

- RFC develops inflow forecasts (early Feb, March, April, May)
- Manager input forecasts to FWMT (which splits inflow forecast into daily components), and runs outflow scenarios with the FWMT Team
- Manager consults Operations Plan and sets lake outflow based on inflow forecast and input from FWMT Team
- While waiting for the next monthly forecast, Manager may adjust lake outflows based on actual inflows

- But first –
- Lets review the **process** for taking in all this information and using it to make decisions ...

- I've already mentioned that the **RFC develops 4 forecasts (early Feb, March, April, May**) – and I've already talked about the type of forecasts they use
- Then the **Water Manager runs the inflow forecast through the Fish Water Management Tool (FWMT**) to split it out into daily components
- He also **considers the output of other models** (like the CLEVER model for Mission Creek), and the new RAVEN model (that attempts to use weather forecasts to make inflow forecasts) and he **also looks out his window … and takes walks** up into the upper forests to see what's going on …
- Then the **Water Manager sets lake outflow according to the Operational Plan** (and input from FWMT Team)
- Then during the next month, the Manager and the FWMT team may meet **to adjust the lake outflow depending on actual experience of inflows** since the previous FRC forecast was received.

Inflow forecasts, Operating Plan targets, and actions taken

Period	Forecast Inflow		Operating Plan Target	Action Taken
	(kdam^3)	(% of normal)		
Feb – July	518	101%	341.64 m by end-Feb	Set outflow to achieve 341.64 m by end-Feb
March – July	485	98%	As high as possible	Ignored OP. On March 22, increased outflow to 28.3 m^3/s
April – July	570	122%	341.44 m by end April	Initially set outflows to meet multiple constraints, then overrode on April 24 and increased outflow to 60 m^3/s
May – July	554	147%	342.48 m by end-May (full pool)	Edged outflow up to 78 m^3/s

Ok so now lets take a closer look at the forecasts sent to the Water Manager in 2017 and the actions he took in response.

4 rows – one at a time …

Feb. 8: Shaun received a forecast from Dave Campbell of **518 million cubic metres**. This was just about average. You may recall from earlier that we know now that May alone had an inflow of 528 million. The OP suggests targeting 341.64 m by end Feb and Shaun set the gates to do just that. He pretty much got there too.

March 8: Shaun received another forecast from Dave Campbell – **485 million cubic metres t**o the end of July. Again just about average, but a number for which the OP indicates you should **raise the lake as high as possible** because there's a reasonable chance of not having enough irrigation water through the summer. But Shaun by now was getting suspicious –he knew it was raining and the inflow was coming in higher than expected, so he overrode the plan and increased the outflow up to the egg scour threshold of 28 m3/s on March 22.

April 8: Shaun gets another inflow forecast – and finally this one is above normal. But the target of 341.44 is going to be impossible to reach because he was already above that and the lake was rising. The forecast was still not considered huge and the eggs were still in the gravel, so for a while he kept the outflow such that the eggs would not be scoured, but then overrode that on April 24 and increased the outflow right to the channel capacity of 60 m3/s, probably washing away and maybe killing some alevins . By the way the incubation max flow of 28.3 m3/s is in place usually to April 30.

Forecasts provided in 2017 vs actual

Period	Forecast Inflow		Actual Inflow	
	($kdam^3$)	(% of normal)	($kdam^3$)	(ratio of actual to forecast)
Feb – July	518	101%	944	1.8
March – July	485	98%	921	1.9
April – July	570	122%	853	1.5
May - July	554	147%	694	1.3

Back to those forecasts provided by the RFC to the Water Manager …

Lets take a look at what actually happened … and remember we only know the ACTUAL DATA in the final two columns after the fact – so this is the hindsight I was talking about.

You really just need to look at the last column here – the ratio of actual to forecast inflows.

- All four forecast were way too low – actual inflows beat forecast inflows every time, ranging from 1.8 times the forecast in Feb, to 1.9 times the forecast in March, to 1.5 times the forecast in April, to 1.3 times the forecast in May.
- There are some issues with the PCA models themselves that I point out in the report but won't go into here …
- But the **main thing is they don't forecast future weather and it really rained and snowed after** the forecasts were produced.
- **So we concluded that the Water Manager was taking appropriate action based on the information he had available**

Okanagan Lake – notable elevations

Full pool	342.48 m
200-year elevation	343.05 m
Flood Construction Level (FCL)	343.66 m
1948 peak	343.065 m
1990 peak	342.89 m
1997 peak	342.84 m
2017 peak	**343.25 m !!!**

- So, before we look at what if anything Shaun could have done to limit the lake level rise
- Lets put 2017 into context
- **Review the numbers**
- **So in 2017 the lake rose to its highest level ever, above the 200-year level and within 41 cm of the FCL**

2017 date needed to reach max outflow s) to keep lake below certain elevations

Full pool	342.48 m	Febr
200-year elevation	343.05 m	
Flood Construction Level (FCL)	343.66 m	
1948 peak	343.065 m	Ap
1990 peak	342.89 m	Mar
1997 peak	342.84 m	Mar
2017 peak	343.25 m !!!	

- Now – what if anything could Shaun have done to create a different outcome?
- This slide shows the dates that he would have had to start releasing water at the channel design capacity in order to prevent the lake from rising above certain elevations.
- So if he wanted to keep the lake from **rising above full pool**, he would have had to start releasing water at 60m3/s on **February 28.**
- But at that time the snowpack was only 80% of normal, and the PCA models were forecasting normal runoff, so there is no way it would have been reasonable to do that.
- To keep the lake below the 1997 peak, he would have had to start releasing water at a high rate on March 19, and again, the models were still forecasting a normal inflow, so again, not a choice that would have seemed rational with the information on hand, and would have been completely contrary to the OP.
- Even to keep the lake below the huge 1948 peak, he would have had to release at 60 m3/s starting April 10. By then he was beginning to think about that, but even then the forecasts were for 122% of normal – above for sure, but still not huge – so this would have really been offside vs the models and the operating plan.

65 recommendations in 3 categories

- Data and models
- Operational
- Organizational

- So that's the story …
- By the way - I haven't covered this in any detail here, but we looked at **the specific data** used by the models, at the **details of the models** themselves, and at **organizational issues** like staffing levels, communication, succession planning and other issues during our review
- But I will talk briefly about some of these issues in these final slides that summarize our recommendations.

- So - despite our conclusion that the Water Manager did a good job last spring, our investigation identified several issues that we cover in 65 recommendations in the report.
- I'll boil them down into about 15 under these three categories.

Strategic recommendation

- Province should increase its commitment to flood preparation, preparedness, response, and recovery
- Province should develop a comprehensive flood risk strategy that considers all 4 of these elements

- The report did not prioritize the recommendations, nor did it summarize them at a high level, but that's the first thing I've done here to create these two strategic summary recommendations – that don't appear in the report because it was focussed only on 2017 and only on two geographic areas – so I've taken a bit of liberty to expand my observations.

- Review them …
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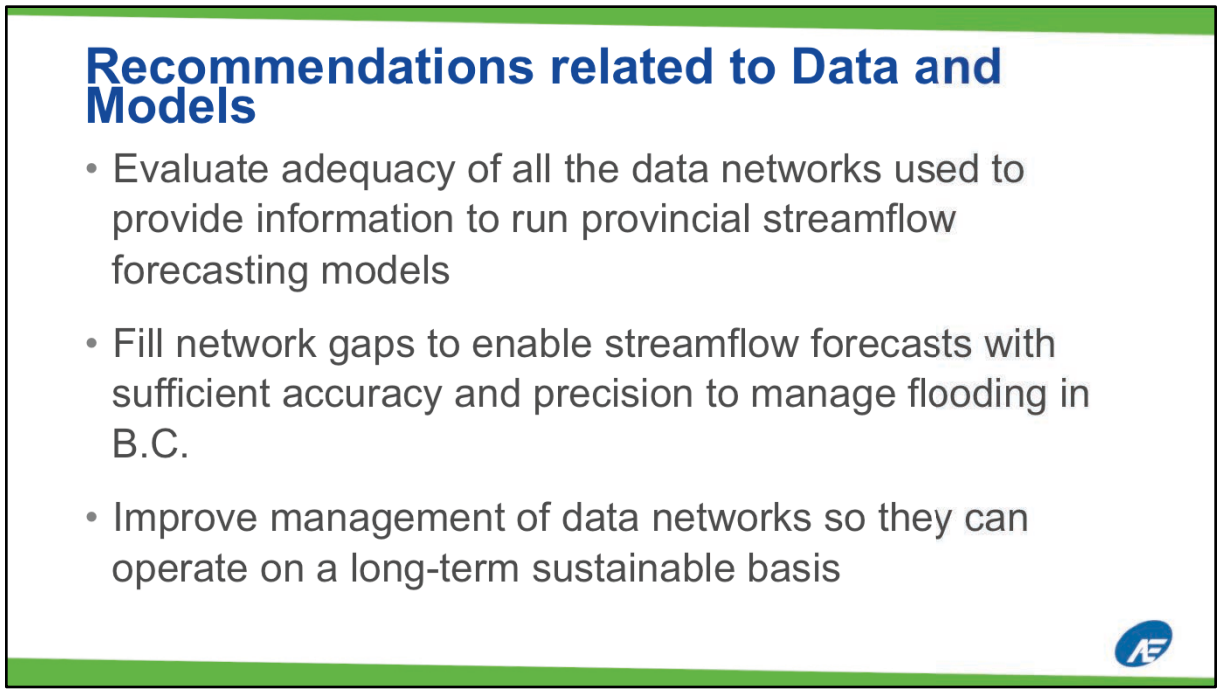
- This enhanced commitment will require additional staffing, additional expertise, and additional long-term committed funding.



- I've boiled the recommendations related to data and models down to 8 and here's the first 3.
- Evaluate the adequacy of all the data networks (**snow, weather, streamflow, groundwater level, and lake level)** used to provide information to run provincial streamflow forecasting models, and
- Fill gaps to allow the province to **meet its mandate to deliver streamflow forecasts with sufficient accuracy and precision to manage flooding** in B.C.
- Improve the long-term management of these data networks such that they can operate effectively on a sustainable basis, e.g. **provide increased and sustaining funding, regularly evaluate network density, identify and fill gaps, and convert manual stations into real-time automated stations**.

Recommendations related to Data and Models

- Upgrade the models used by the provincial River Forecast Centre for forecasting streamflow and flooding
- Develop backup models for use when any of the required model input data is missing
- Increase the frequency at which the models are run
- Investigate the utility of including weather forecasts in the models
- Regularly review and update the models

- Here's the other 5:
- Evaluate and **upgrade the models** used by the provincial River Forecast Centre for forecasting streamflow and flooding:
- Develop **backup models** for use when any of the required model input data is missing;
- **Increase the frequency** at which the models are run;
- Further investigate the utility of including **weather forecasts** in the models;
- Regularly **review and update** the models.

Recommendations related to Operations

- Revise Operating Plan to explicitly include consideration of uncertainty in streamflow forecasts
- Re-evaluate the 200-year return period flood elevations in all mainstem lakes, and the associated Flood Construction Levels and horizontal setbacks
- Reconsider the delegation of responsibility to local governments for establishing local flood elevations and setback requirements

- I've boiled the recommendations related to Operations down to 6:
- Revise the Operating Plan to explicitly include consideration of uncertainty in streamflow forecasts.
- Re-evaluate all 200-year return period flood elevations in B.C., and the associated Flood Construction Levels and horizontal setbacks.
- Reconsider the delegation of responsibility to local governments for establishing local flood elevations and setback requirements.

Recommendations related to Operations

- Reconsider the fragmentation of responsibilities for flood management that currently exists within the provincial government
- Improve the knowledge of specific flooding impacts at specific water levels – this may require improved ground elevation data (eg LIDAR)
- Evaluate capacity of existing infrastructure to pass flows, and consider modifications

- Here's the other 3 Operational recommendations:
- Reconsider the fragmentation of responsibilities for flood management that currently exists within the provincial government.
- **Around lakes for which the outflow is controlled by the province**, improve the knowledge of specific flooding impacts at specific water levels – this may require improved ground elevation data.
- Evaluate the capacity of provincially-owned water management infrastructure to pass flows, and modify the infrastructure as needed to keep it functioning as intended, **particularly in the face of ongoing climate change.**

Organizational recommendations

- Improve internal and external communication during flooding events
- Increase staffing (e.g. River Forecast Centre) as required to provide the needed level of expertise and capacity
- Improve training and succession planning such that the province is continuously able to meet its water management obligations

- Finally, 3 organizational recommendations …
- Improve internal and external communication during flooding events, e**.g. clarify** the roles and responsibilities for external communication among the agencies responsible for inflow forecasting, water management, and emergency management.
- **Examine staffing levels** in the River Forecast Centre and other water-related provincial departments, and increase staffing as required to provide the needed level of expertise and capacity on an ongoing basis. (We found that the BC RFC was notably understaffed relative to other provincial RFCs)
- Improve **training and succession planning** within water-related provincial departments, such that the province is continuously able to meet its water management obligations.

Key final messages

- Water Manager (and River Forecast Centre) did a good job with information available
- They could not have predicted the heavy spring rainfall and snow at high elevations
- Climate change is adding pressure on organizations responsible for water management
- Need stronger and long-term Provincial commitment to improve data networks and models, and flood resiliency

And finally, to leave you with some final thoughts …