Northwest Power and Conservation Council

February 8, 2006

MEMORANDUM

TO: Power Four Committee Members

FROM: John Fazio, Senior System Analyst

SUBJECT: Climate Change Discussion

How might changes in climate affect temperatures, demand, precipitation and river flows? What does climate change mean for irrigators? What might it mean for salmon? Are there mitigating actions that the region should take and if so, when? In its Fifth Power Plan, the Council addressed some of these issues in Appendix N (Effects of Climate Change on the Hydroelectric System).

Current hydrologic and temperature studies by the University of Washington show that the Northwest is likely to warm up over the next several decades. If this happens, the region should experience less snow and more rain in fall and winter months, thus reducing the amount of snowpack. Less snowpack translates into lower river flows in late spring and summer. And, with higher temperatures year round, electricity demand would likely decrease over winter but increase in summer. Under this scenario, summer months would show more stress on the power system while in-river migration conditions for fish would worsen due to declining flows and higher water temperatures.

While not all of the potential effects of global warming can be mitigated, adjusting the hydroelectric operation can make things better. By linking specific hydroelectric operations to temperature and precipitation forecasts, the system would be able to respond to changes more readily. It would be desirable, in fact, to make the operation more robust by considering such changes whether global warming occurs or not. The Council has an opportunity to lead this effort by:

- Scheduling a Council presentation on the state of the science for climate change.
- Releasing a white paper on climate change and the hydroelectric system.
- Encouraging planning entities to incorporate potential effects of climate change into their plans.
- Supporting efforts to enhance precipitation-forecasting methods (especially for the fall).
- Encouraging agencies to consider potential climate change as they revise the biological opinion.

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February 8, 2006

MEMORANDUM

TO: Power Four Committee Members

FROM: John Fazio, Senior System Analyst

SUBJECT: Climate Change and Hydroelectric Operations

On January 30, 2006[1] scientists at the NOAA National Climatic Data Center in Asheville, N.C., said that the average global temperature in 2005 matched the existing record high, which was set in 1998. They went on to say that nine of the 10 warmest years on record have occurred since 1995.

Headlines, like the one above, have many people in the region talking about climate change and what it might mean for the power supply. At a recent PNUCC board meeting, a panel addressed some of the questions that have arisen. How might climate change affect temperatures and correspondingly, electricity demands? How might climate change affect precipitation and river flows? What does climate change mean for irrigators? What might it mean for salmon? Are there mitigating actions that the region should take and if so, when?

In its Fifth Power Plan, the Council recognized that climate change could become a major issue for both power planners and for fish and wildlife managers. In its plan, the Council addressed the issue of climate change in Appendix M (Global Climate Change Policy) and in Appendix N (Effects of Climate Change on the Hydroelectric System). The plan called for the region[2] to continue to monitor climate change science and policy. As part of that process, this memorandum provides a synopsis of work done to date and identifies a number of actions that the Council could undertake to continue to move ahead on this issue.

Projected Changes in Northwest Climate and Hydrology

Hydrologic and temperature simulations for the Northwest were obtained from the Joint Institute for the Study of Atmosphere and Ocean (JISAO)[3] Climate Impacts Group[4] at the University of Washington. These simulations[5] were derived primarily from two Global Climate Models

[1] http://www.noaanews.noaa.gov/stories2006/s2568.htm
[2] This refers to action item MON-4 on page 65 of the plan's first volume.
[3] http://tao.atmos.washington.edu/main.html
[4] http://tao.atmos.washington.edu/PNWimpacts/index.html
[5] This data is somewhat out of date but it nonetheless illustrates the point of this memo.

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(GCMs), the Hadley Centre model (HC)[6] and the Max Planck Institute model (MPI)[7]. Results from other models were averaged for a composite case (comp). The projected average temperature increases for the Northwest from these studies are shown in Table 1.

Table 1: Forecast Temperature Increases for the Northwest (Degrees Fahrenheit)

Year	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
2020	3.4	2.0	2.1	3.5	3.4	2.6	3.1	2.6	2.8	3.7	3.5	3.9
2040	3.7	3.8	2.9	4.6	4.3	4.7	4.8	3.4	2.2	4.1	4.9	5.4

There is a clear relationship between temperature and electricity demand. In the Northwest, during winter heating months, electricity use will decrease as temperatures rise. In the summer, however, the opposite is true -- electricity demand will increase with higher temperatures (because of greater air conditioning use). Figure 1 illustrates this relationship.

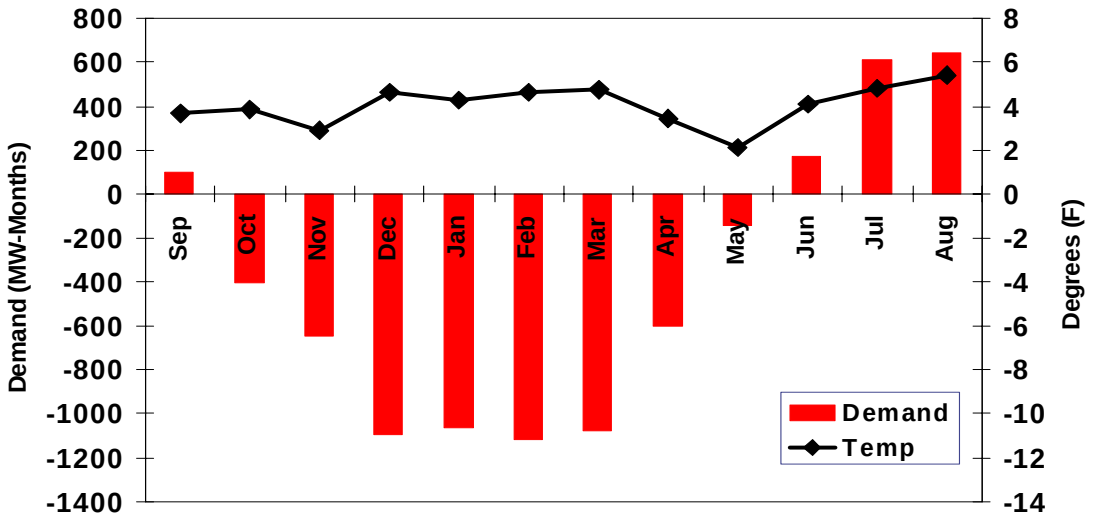

Figure 1: Illustration of Global Warming Impacts to Temperature and Demand

While the winter outlook appears to be better from a power system perspective, a more serious look at flood control operations is warranted. Some models not only indicate more fall and winter precipitation in the Northwest but also a higher possibility of extreme weather events, including heavy rain. This should prompt the Corps of Engineers to examine the potential to begin flood control evacuations earlier than they currently do. Evacuation of water stored in reservoirs during winter months for flood control purposes will add to hydroelectric generation and further reduce the need for thermal generation.

With a smaller snowpack, the spring runoff will correspondingly be smaller, translating into reduced river flows. Lower river flows translate into lower river velocity and longer travel times to the ocean for migrating smolts. Reduced river flows also mean that water temperature may increase, another factor contributing to smolt mortality. Figure 2 illustrates simulated changes in

[6] http://www.met-office.gov.uk/research/hadleycentre/models/modeltypes.html
[7] http://www.mpimet.mpg.de/en/web/

average natural (unregulated) river flows for the MPI scenario (warm and dry). Notice that river flows in the December through April period are higher while in May through June they are lower. Also, the total volume of water (area under the curves) passing through the hydroelectric system is projected to be less in this scenario.

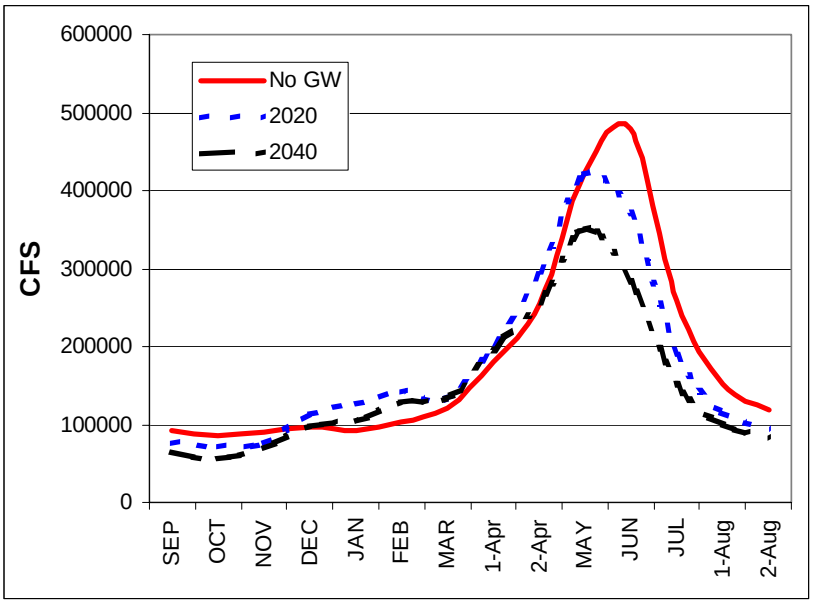

Figure 2: Average Unregulated Flow at The Dalles - MPI (dry scenario)

Figure 3 summarizes the average runoff volume for current conditions and for the three global warming scenarios examined in this study. The warm-and-wet scenario shows a greater volume and consequently a net increase in energy production and revenue, shown in Table 2. The other two scenarios show decreased volume and correspondingly lower energy production. More recent University of Washington studies indicate that warm-and-dry scenarios are more likely to occur than warm-and-wet scenarios. This implies a greater likelihood that overall hydroelectric generation and revenue will be lower in the future should a global warming scenario occur.

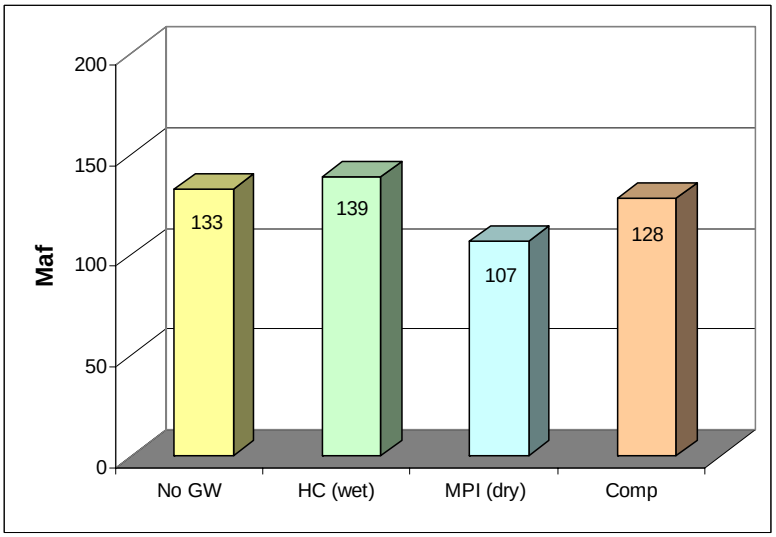

Figure 3: Annual Average Runoff Volume at The Dalles (2040)

Table 2
Summary of Energy and Cost Impacts

Scenario	Change in Annual Energy (average megawatts)	Change in Value (Millions)
HC (wet)	**300**	**$ 170**
Comp	**-500**	**$ -160**
MPI (dry)	**-2000**	**$ -730**

While no immediate actions regarding reservoir operations are indicated by this analysis, a scoping process could begin to identify potentially mitigating operations to offset global warming effects. Some potential actions could include:

- Adjusting reservoir operating rule curves to assure that reservoirs are full by June.
- Linking hydroelectric operations to temperature and precipitation forecasts, whenever possible, for example allowing reservoirs to draft below biological opinion limits in summer months in those years expected to have very dry summers but very wet falls and winters.
- Negotiating to use more Canadian water in summer.
- Using increased winter streamflows to refill reservoirs (US and Canadian).
- Exploring the development of non-hydro resources to replace winter hydro generation and to satisfy higher summer needs.

Next Steps?

The Council has an opportunity to take the lead on this issue. While work at the staff level is continuing, the Council may choose to additionally:

- Schedule a presentation on climate change for the full Council.
- Release a white paper summarizing potential future warming scenarios and their impacts.
- Encourage planning entities to incorporate potential effects of global warming into their plans.
- Support work on adaptive management methods that would link hydroelectric operations directly to climate forecasts.
- Support efforts to enhance temperature and precipitation forecasting methods (especially for the fall).
- Encourage NOAA Fisheries, Corps of Engineers, Bureau of Reclamation, Bonneville Power Administration and U.S. Fish and Wildlife Service to consider global warming effects as they re-design the biological opinion.

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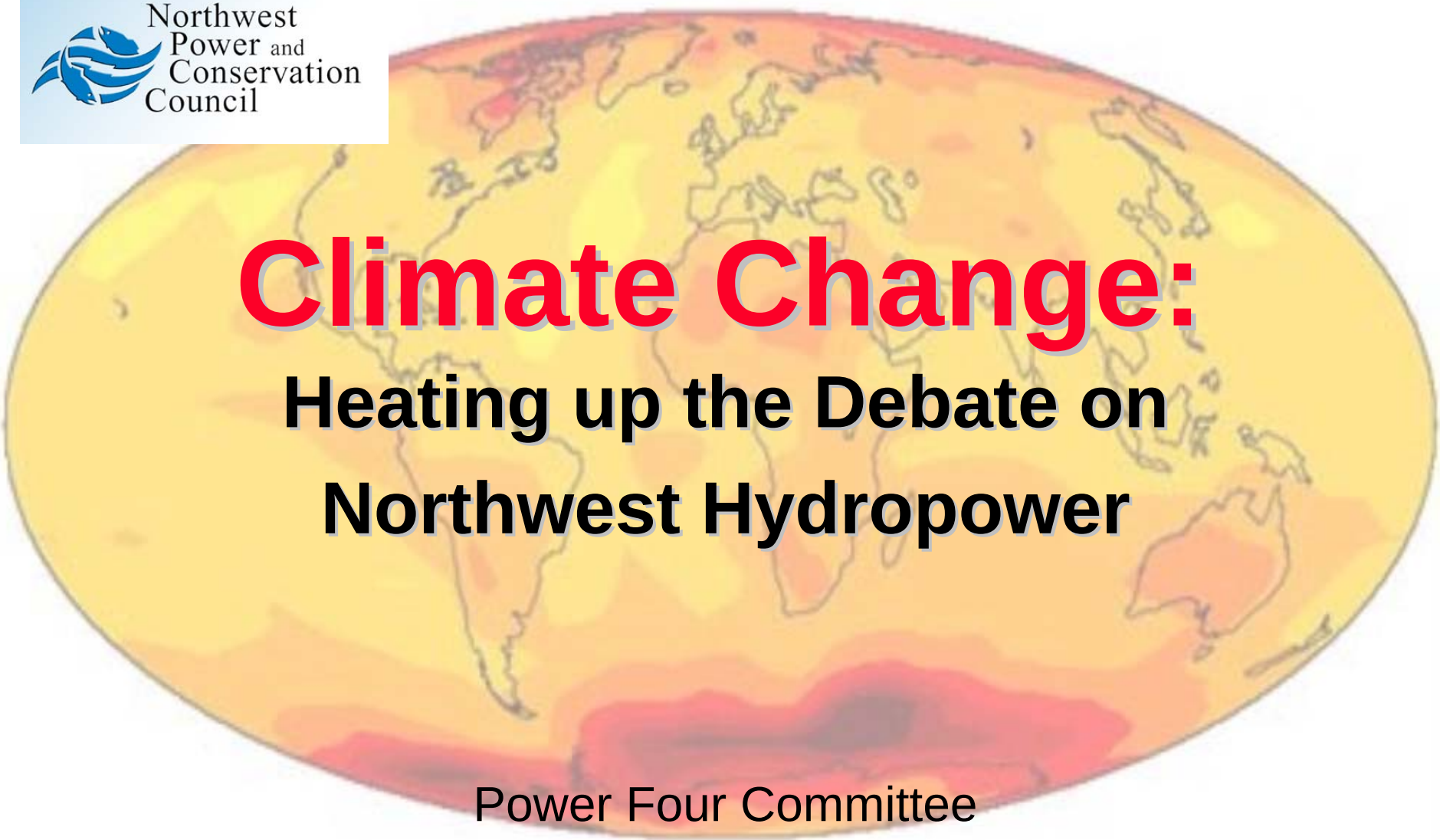


Climate Change:

Heating up the Debate on Northwest Hydropower

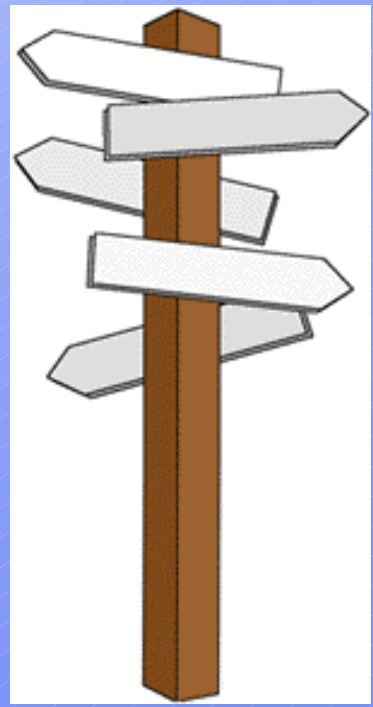
Power Four Committee

February 21, 2006

Portland, Oregon

Overview

1. Current Hydro Operations
2. Potential Impacts of Climate Change
3. Mitigating Actions
4. Proposal – Adaptive Management
5. Council Actions



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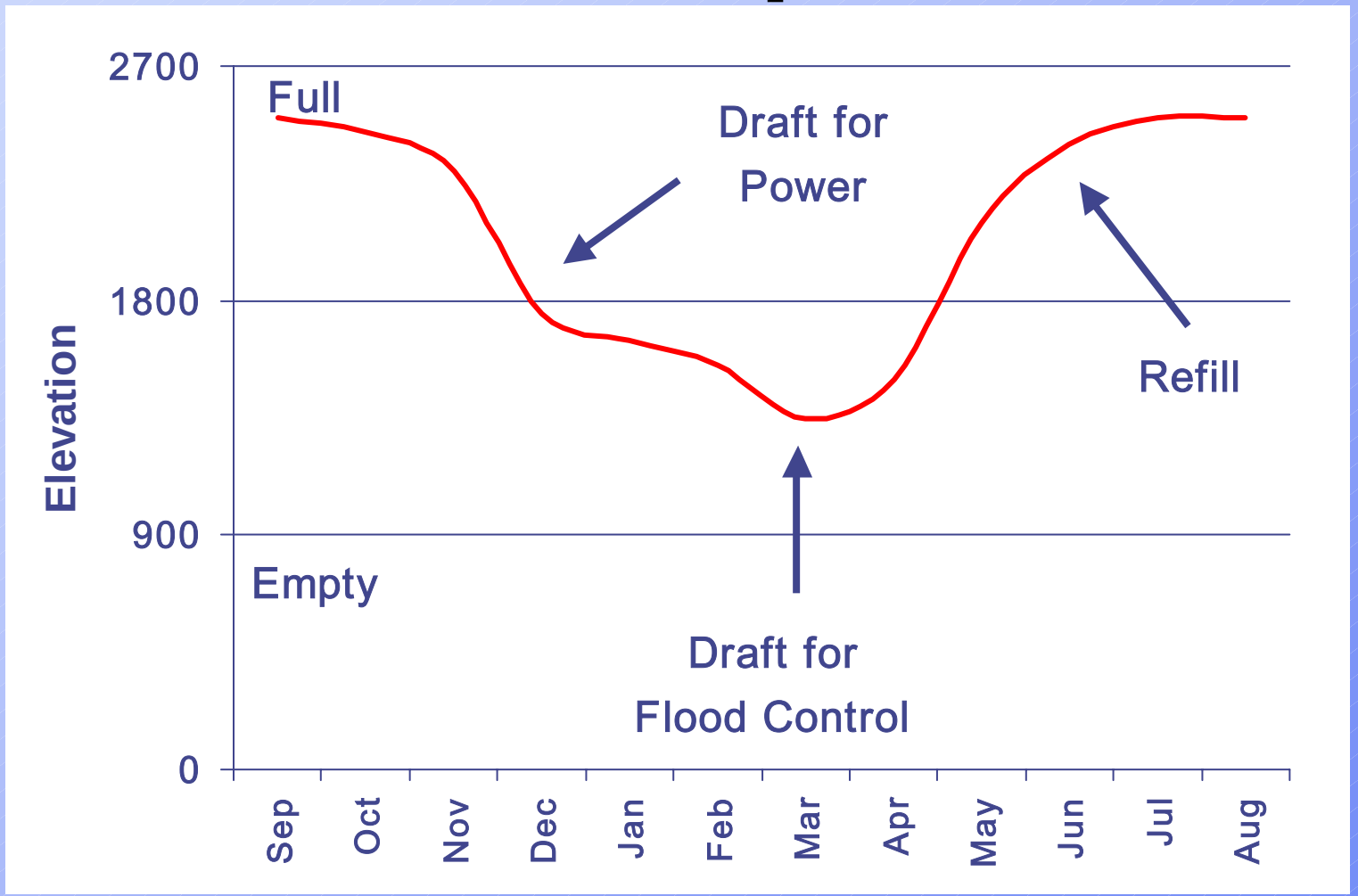
1. Current Operations



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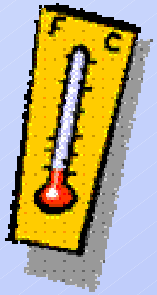
2. Global Warming Impacts



Temperature → Demand

Precipitation → River flows

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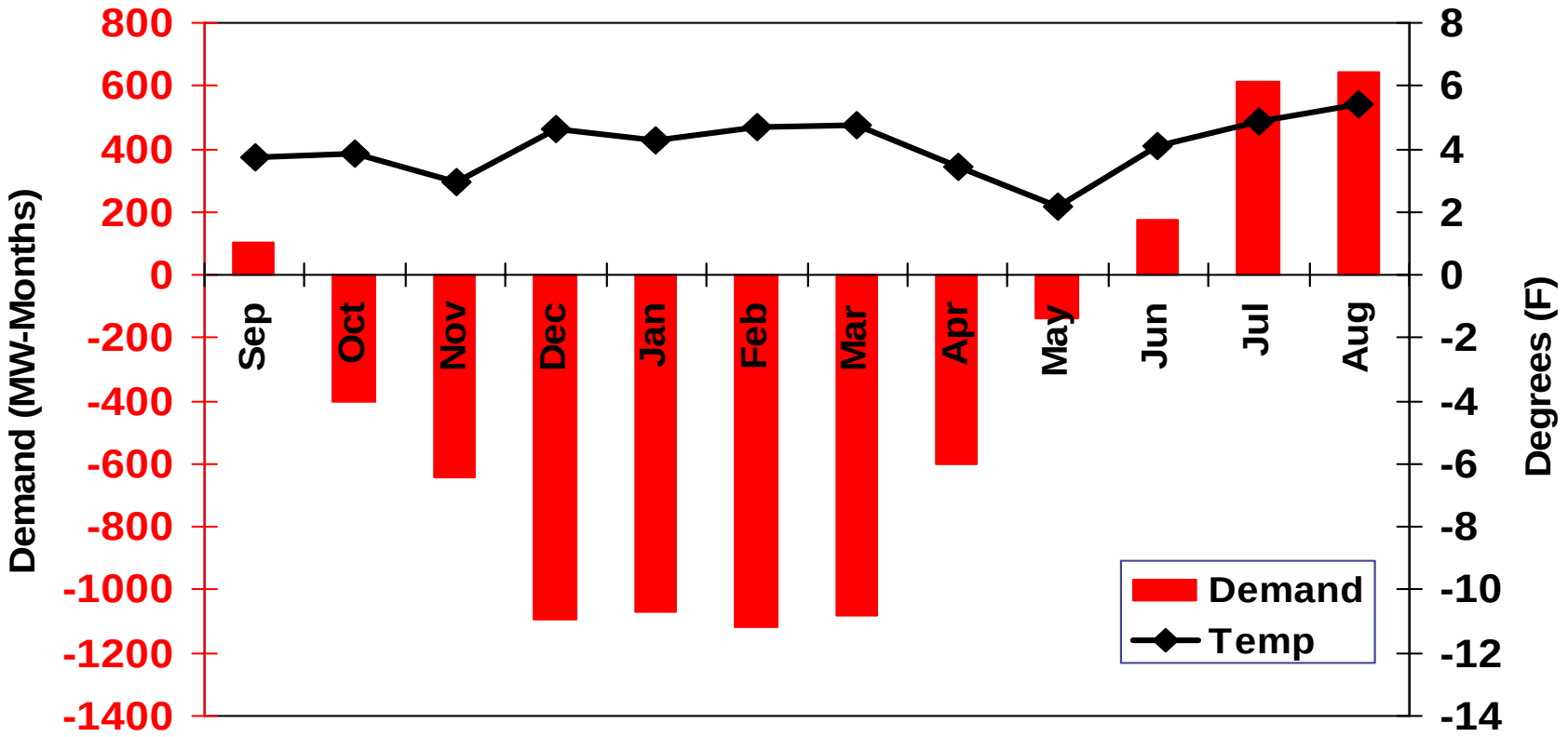
Temperature → Demand



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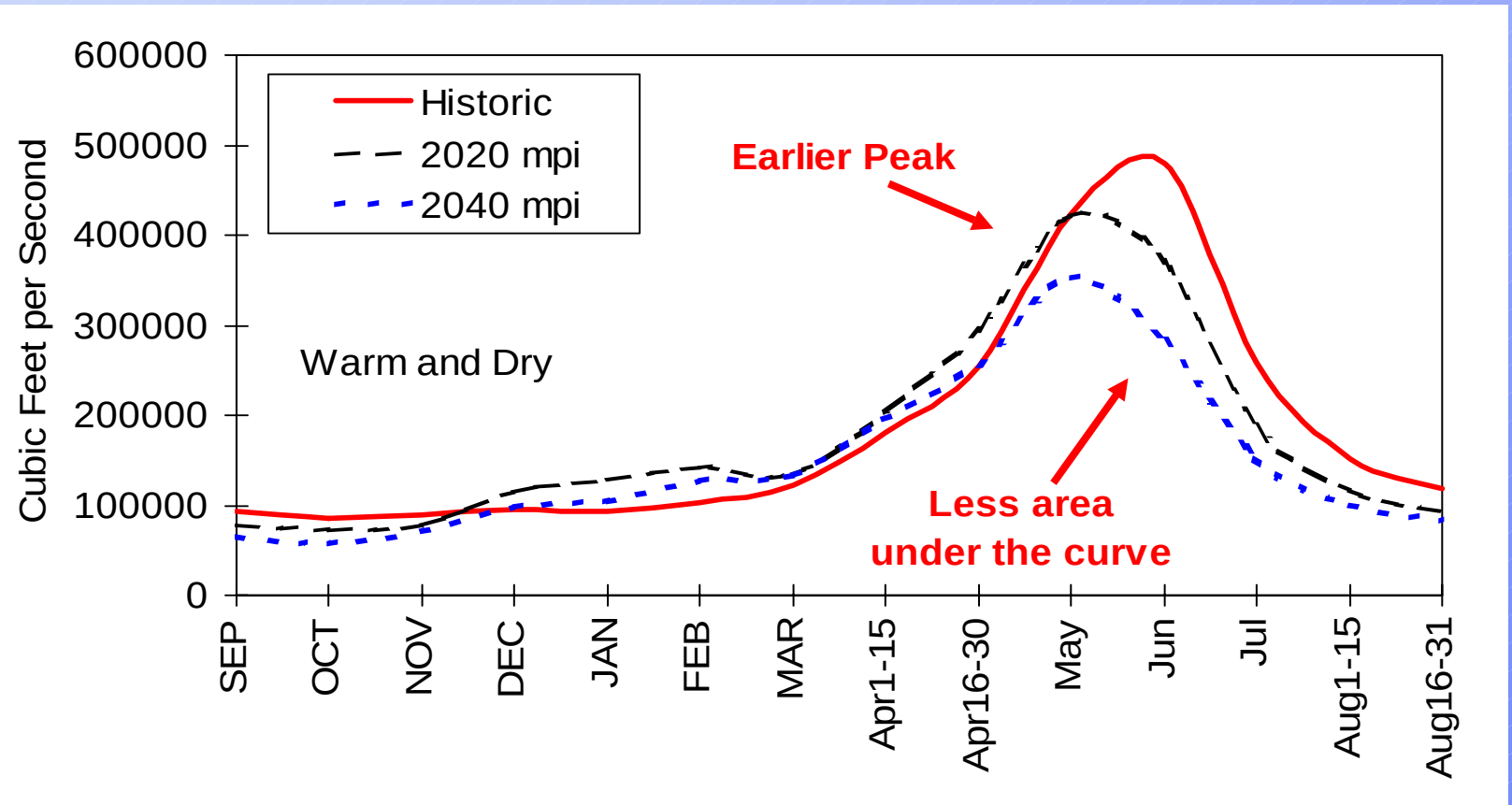
Precipitation → River Flows



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River Flows

- **Winter** – More rain (less snow) higher river flows
- **Summer** – Less snowpack lower river flows

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Power System

- **Winter** –

Better
less demand
more hydro generation

- **Summer** –

Worse
more demand
less hydro generation

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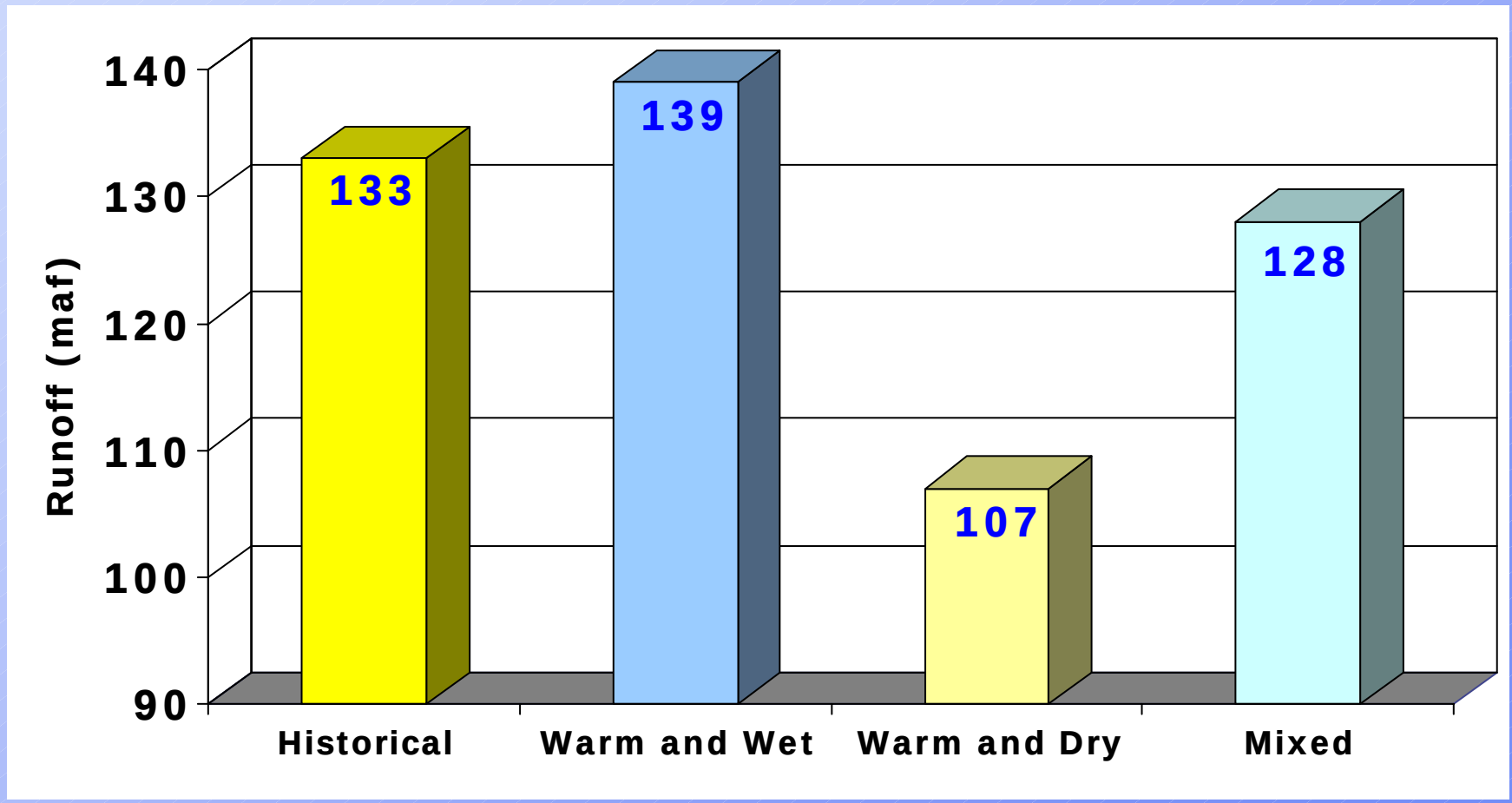
Runoff Volume

Fuel for the Hydroelectric System



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Energy and Cost

Scenario	Annual Energy (aMW)	Annual Benefit (Millions)
Warm/Wet	**300**	**$170**
Mixed	**-500**	**- $160**
Warm/Dry	**-2000**	**- $730**

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Fish

- **Winter** – **Neutral**

more flow

- **Summer** – **Worse**

less flow
higher water temps

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3. Mitigating Actions

1. Fill by June
2. Lower draft in summer
3. More Canadian water
4. Winter refill
5. Non-hydro replacement resources

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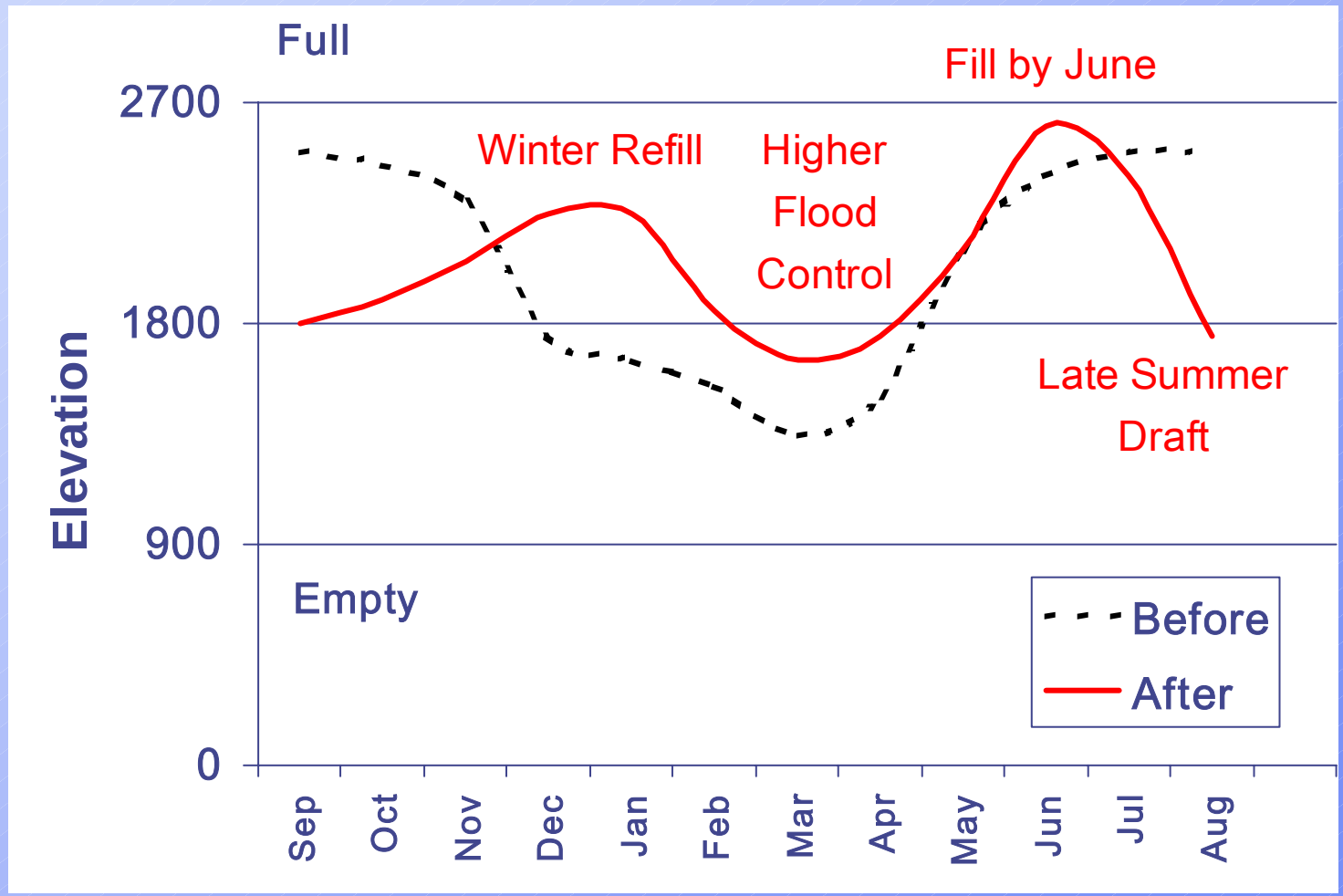
Changes in Reservoir Operation



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4. Proposal
Adaptive Management

- No climate change "bright line"
- Operations ⟷ Forecasts
- Mitigating actions built in

- Better forecasting

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Examples

- **Already being done**
  - Flood control
- **Could be done**
  - End-of-summer drafting limits
  - Resource expansion strategies should include GW uncertainty

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5. Potential Council Actions

- White paper
- Support further analysis
- Urge consideration in the BiOp
- Support better forecasting
- Presentation for full Council

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