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Evaluating Potential Transmission Projects

Dynamic Dispatch of Cascaded Hydro Plants
What's involved and is it necessary?

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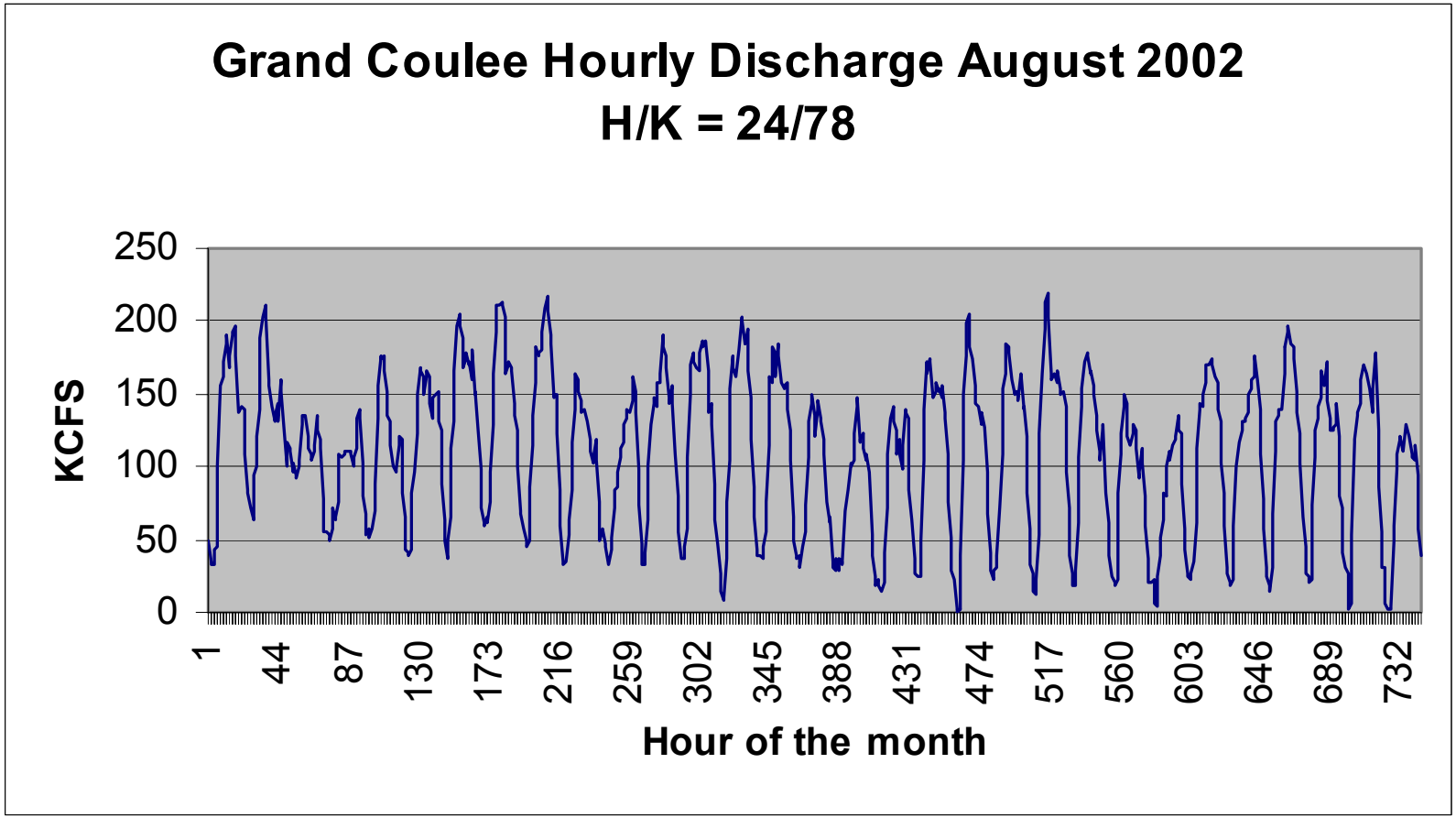
What are the rules regarding hydro?

- Pacific Northwest Coordination Agreement
  - Regulates hydro for power and non-power constraints
    - Fish, Recreation, Irrigation, Navigation, Et al
  - Provides monthly reservoir elevation guidelines
  - Generation dependent on forecast inflows
  - Hourly Coordination
    - The PNCA does not establish hourly generation levels. It established monthly reservoir elevation targets
    - Hourly load patterns and prices are a key to hourly generation levels
  - In practice, hourly generation patterns strictly developed from a cascading computer model are generally not used. Computer models may give guidance to some extent, but system operators make the ultimate decision based on a myriad of factors and their expertise.

Hourly Discharge at Grand Coulee

Hourly pattern driven primarily by load, not fish, etc



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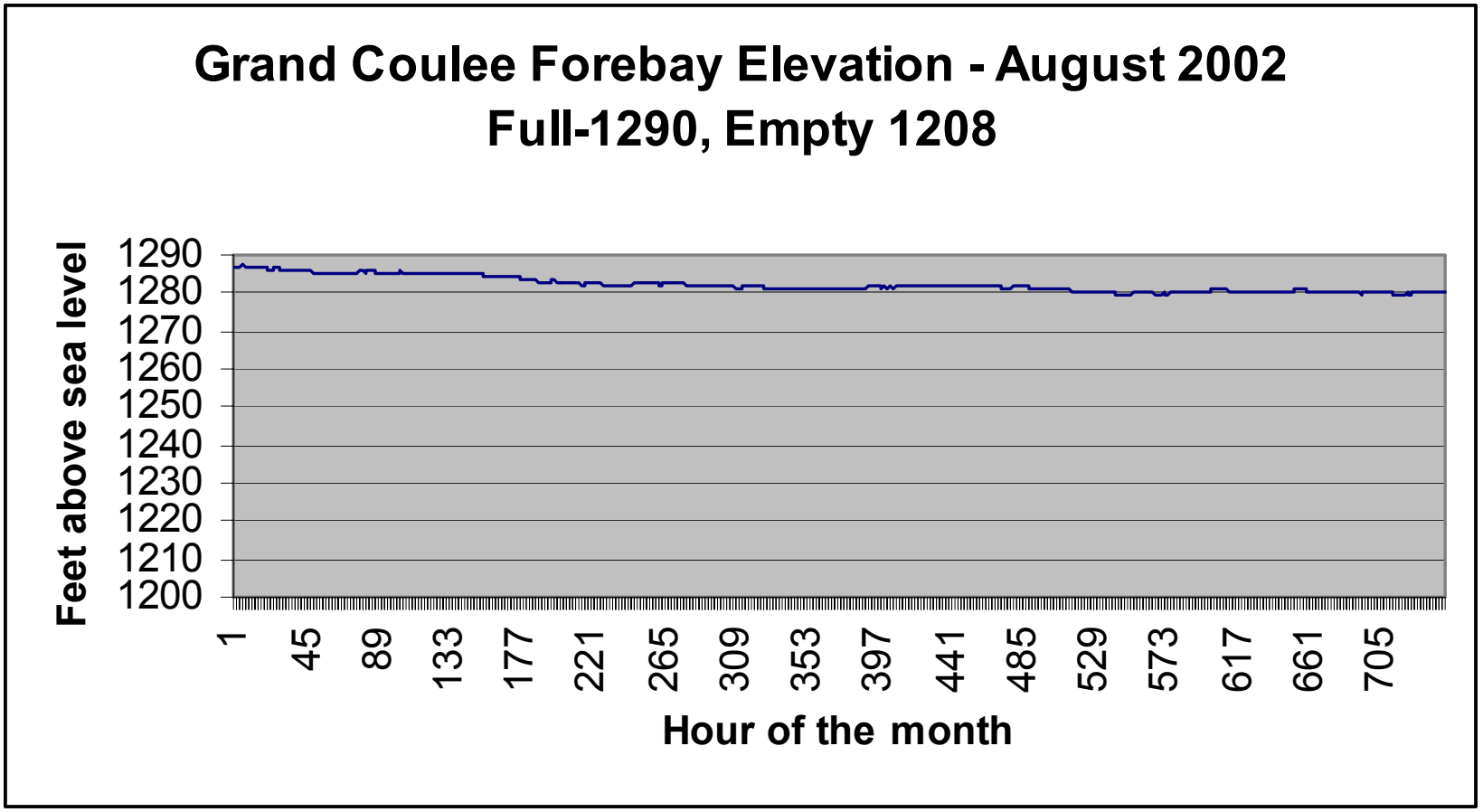
Grand Coulee Elevation

[While hourly pattern varies, reservoir elevation meets targets]



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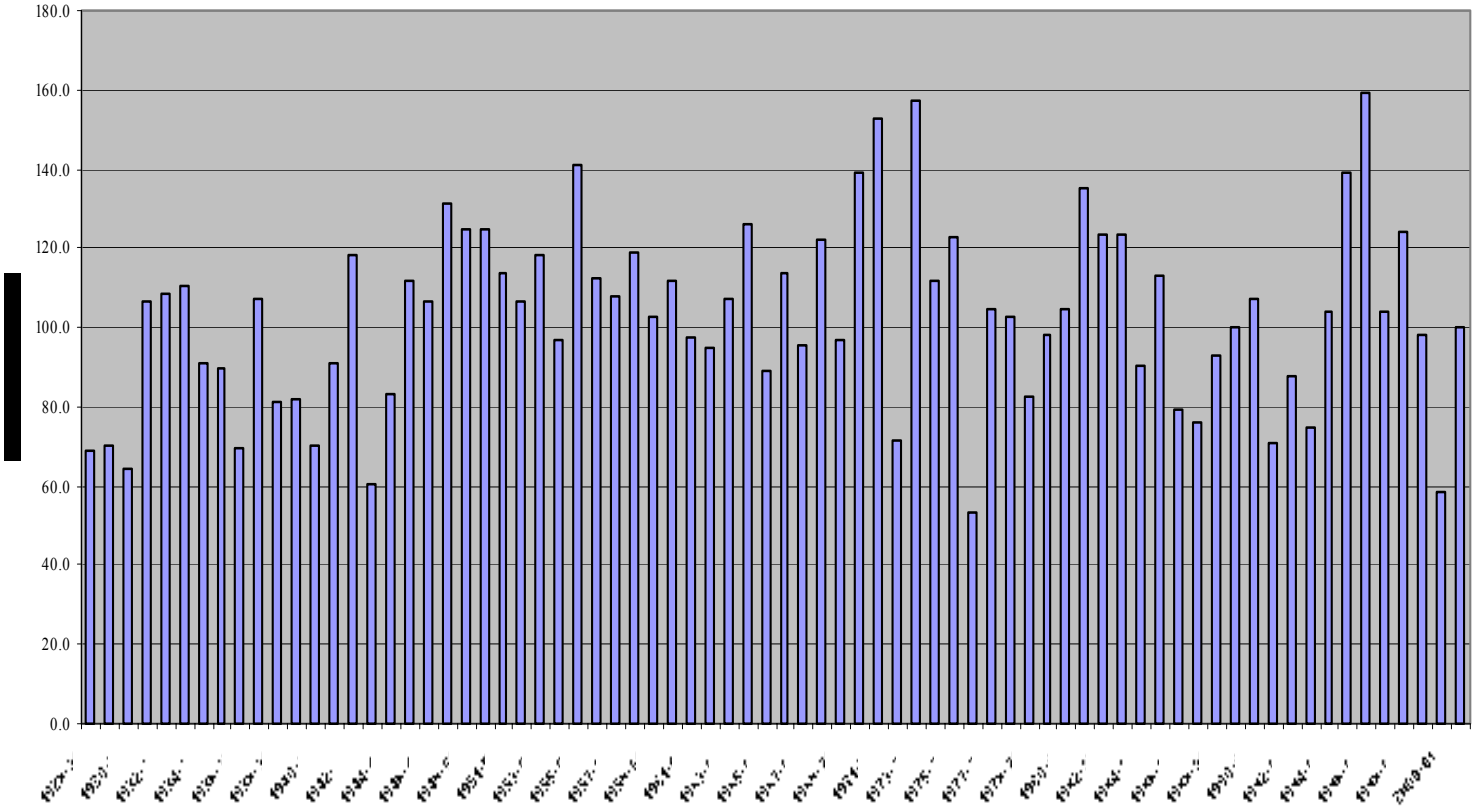
Hourly hydro modeling for long term transmission planning and analysis

- Monthly energy uncertainty is the most important aspect in modeling hydro for long term transmission planning
  - There is huge uncertainty in inflow variability
- We can get a handle on the variability from historic data
- Hydro regulators such as PNCA and the White Book hydro regulator
- The hydro regulators give monthly energy amounts estimated based on historical inflows and non-power requirements

Jan-July Runoff Dalles

72 year Ave = 102.8 MAF



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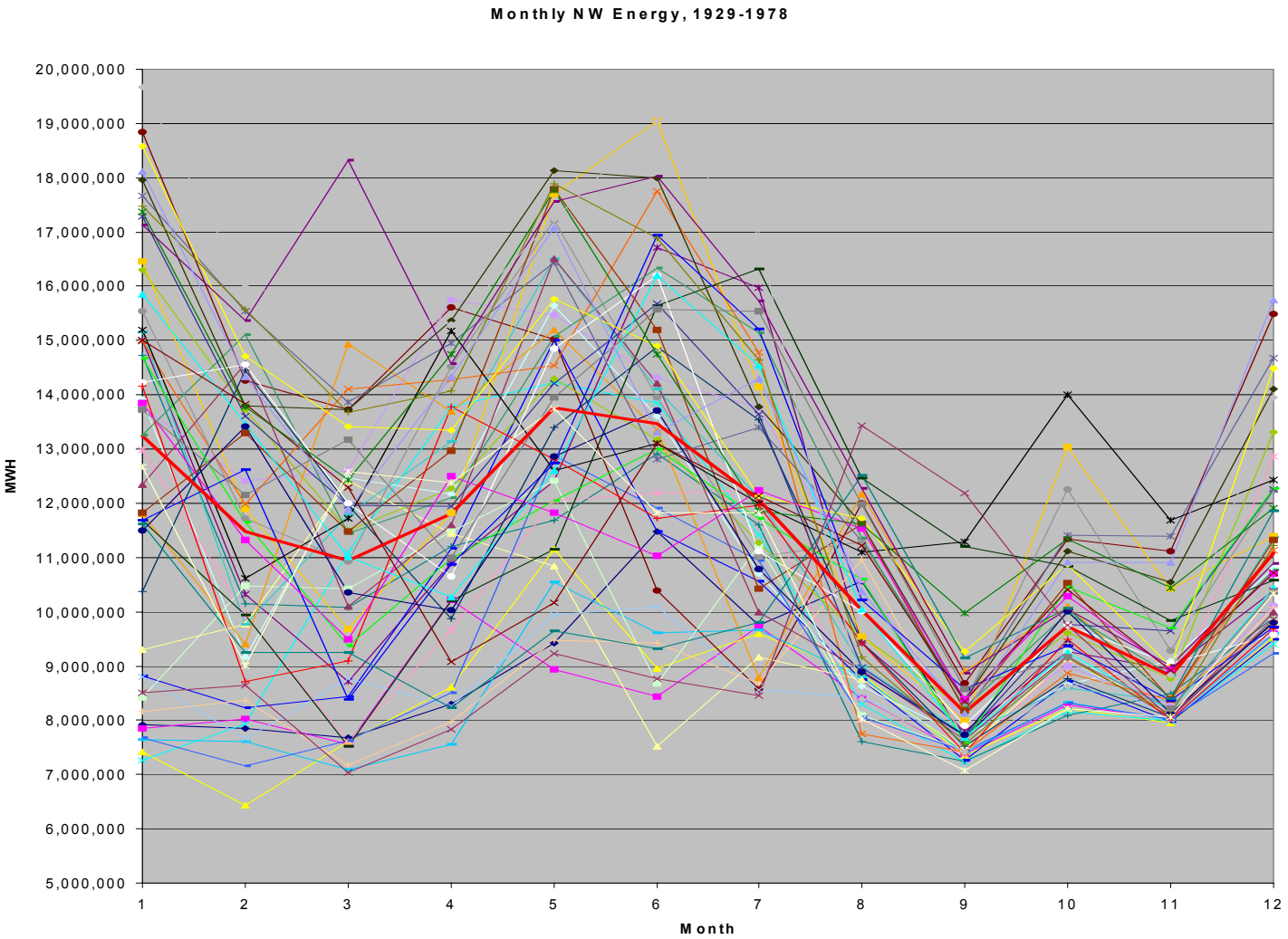
Northwest Hydro Monthly Generation Volatility



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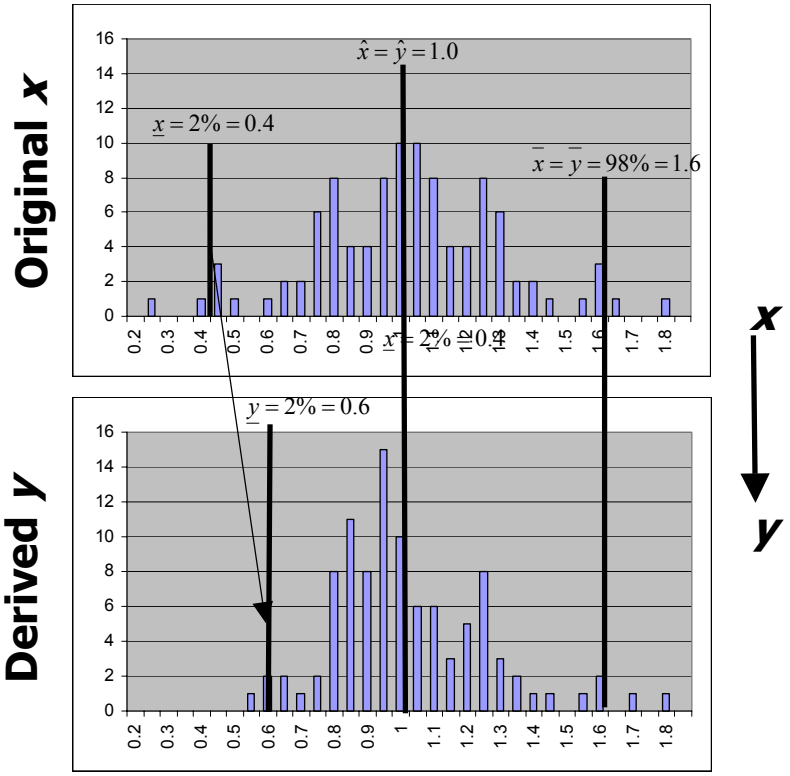
Procedure to develop accurate representations of monthly energy

- Use normal distribution to estimate volatility, mean reversion, and cross driver correlation parameters
- Create derived index to transform the normal distribution to the observed distribution
  - Mean and high/low calibration points preserved
- Use the derived index for hydro generation energy
  - Correlation preserved with spot electric price
  - Matches actual behavior



$$y_i = ax_i + b \text{ if } y_i > \hat{y}$$

$$y_i = cx_i + d \text{ otherwise}$$

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Converting the Monthly numbers to hourly numbers…

- Storage Plants
  - Minimum generation (discharge) portion
  - Shapeable portion (peak shaving)
    - It appears that peak shaving pretty closely reflects actual hydro plant dispatch – recognizing that the peak shape likely includes WECC wide peaks (reflecting higher value in peak load hours)
- Stream flow plants use historical hourly shapes

Hydro uncertainty matters in transmission planning

- For modeling regarding future possible transmission lines it is more important to reflect volatility in the monthly hydro numbers than to try to improve upon a peak shaving hydro algorithm
- Stochastic modeling of hydro should be the focus
- Not just streaming 50 years of history because need to add this uncertainty to other uncertainties (e.g. gas prices, load volatility, etc)

Conclusion

- For transmission planning modeling, no need to model dynamic dispatch of cascade hydro plants
  - Such models do not drive hourly dispatch today
  - Peak shaving to convert monthly numbers to hourly numbers is a reasonable approach
  - The big concern is “how much monthly energy”
  - Monthly energy is volatile, but history provides valuable guidance
  - Stochastic analysis with stochastic variables that duplicate monthly volatility is key
  - These stochastics must be combined with other volatilities in a full hourly commitment and dispatch model (more on this later today).