BPA's HERMES Project: a Multi-objective, Multi-user Approach to Reservoir Optimization

Damon Pellicori and Shane Mosier – BPA

RiverWare User Group Meeting

Boulder, Colorado

August 23-24, 2016

Presentation Outline

- Overview of Federal Columbia River System
  - Power/Transmission System
  - BPA's role in FCRPS/FCRTS
- System Complexities
  - Multiple sources of uncertainty
  - Multi-reservoir system with many power and non-power constraints
  - Derive value from the limited flexibility
- HERMES Application
  - BPA's model uses
  - Current Simulator and Optimizer products
  - Modeling approaches within the RT and ST groups
  - Coordination and handoffs between the RT and ST groups
- Questions

Federal Columbia River Power / Transmission System

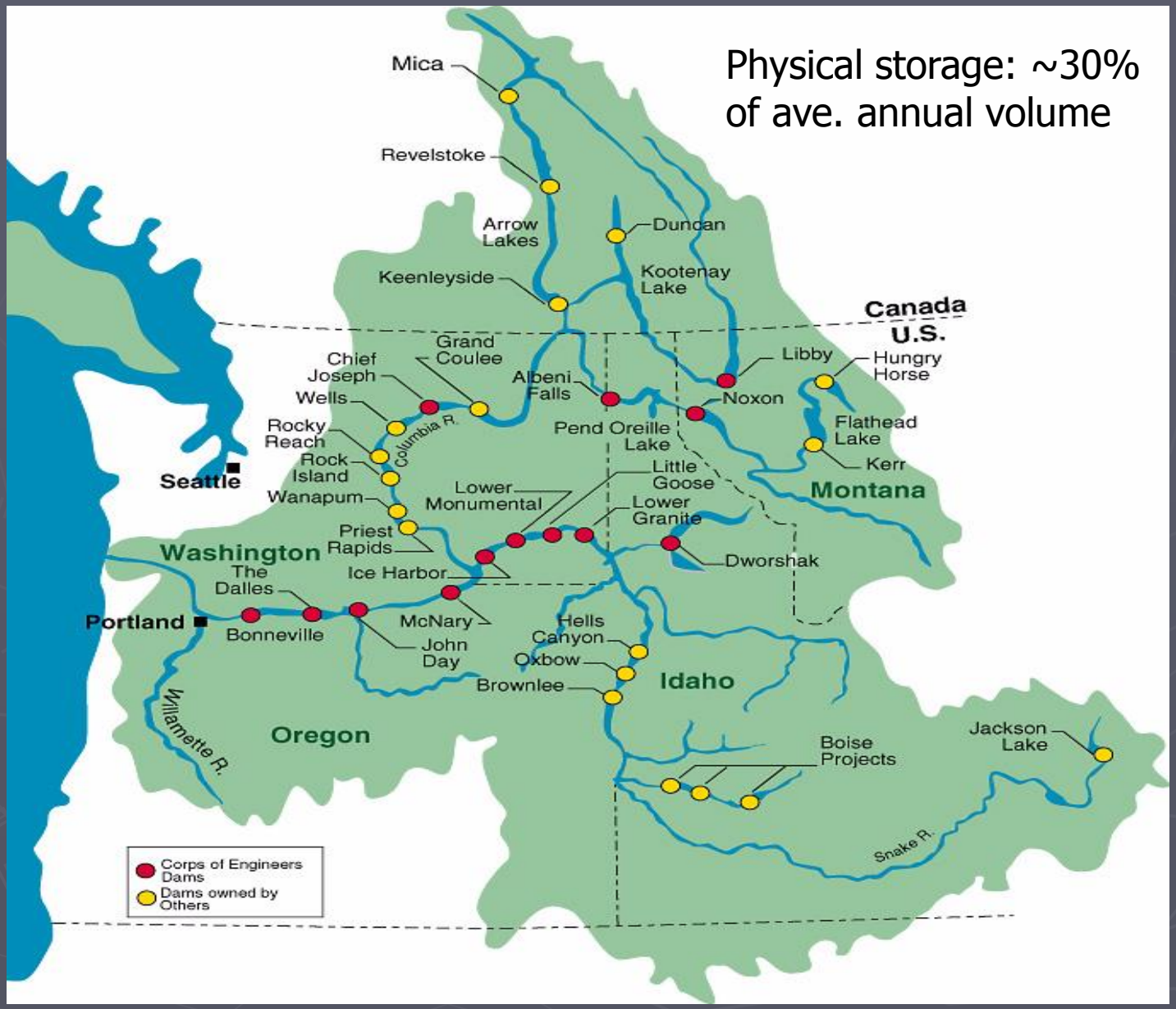
- The key federal agencies:
  - US Army Corps of Engineers
  - Bureau of Reclamation
  - Bonneville Power Administration
- The major physical assets:
  - 31 federal hydro-electric power plants
  - Columbia Generating Station (Nuclear Power Plant)
  - Federal high voltage transmission system

Federal Columbia River Power / Transmission System

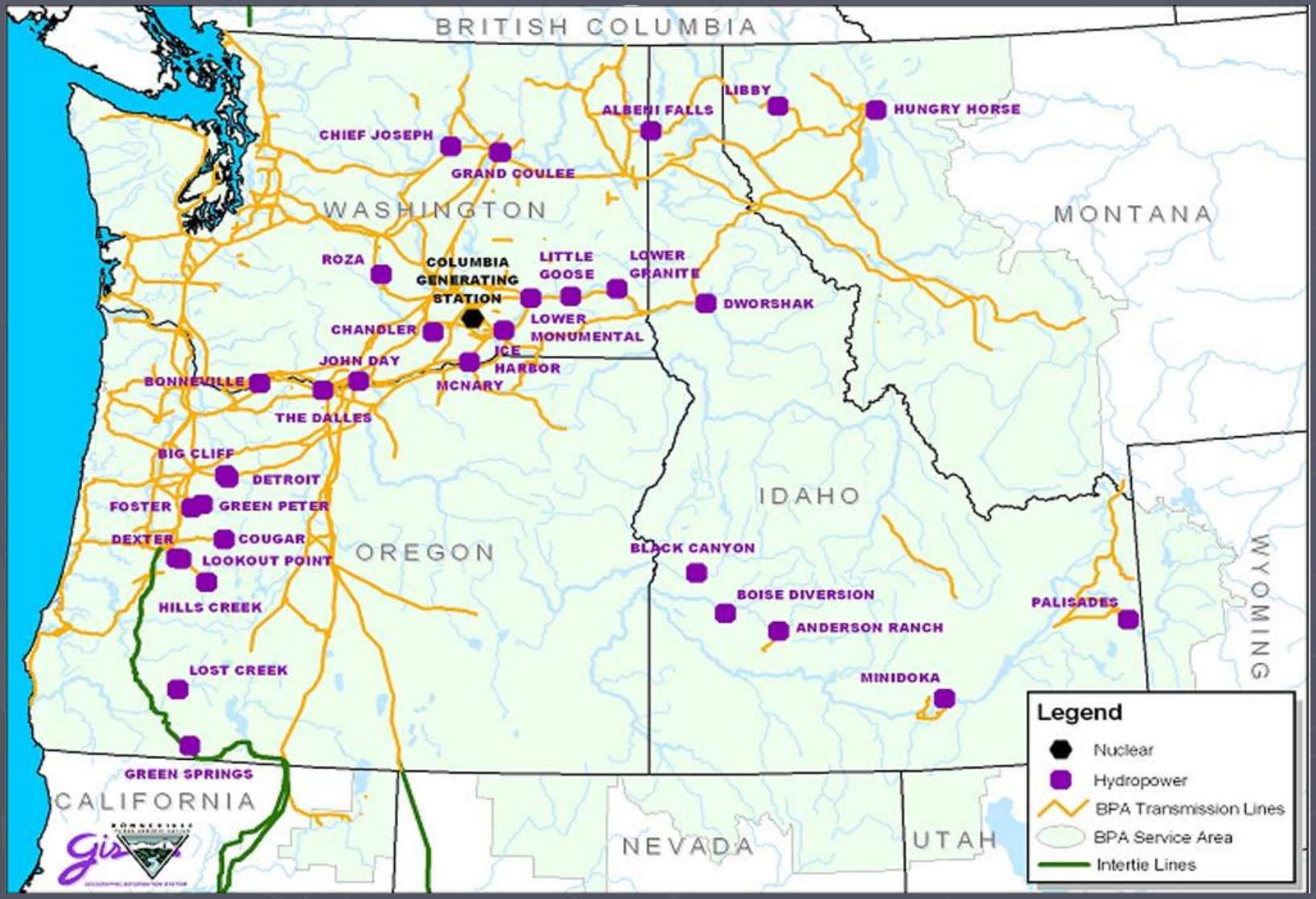
- The US Army Corps of Engineers and the Bureau of Reclamation operate the federal dams for multiple purposes:
  - Flood control
  - Navigation
  - Environmental - fish protection, water quality
  - Irrigation
  - Recreation
  - Power production

- BPA's Role
  - Markets the power produced from the federal dams within the many other non-power requirements
  - Provides ~28% of power in Northwest
  - Primary high-voltage transmission provider in the Columbia River Basin

Columbia River Basin – US and Canada



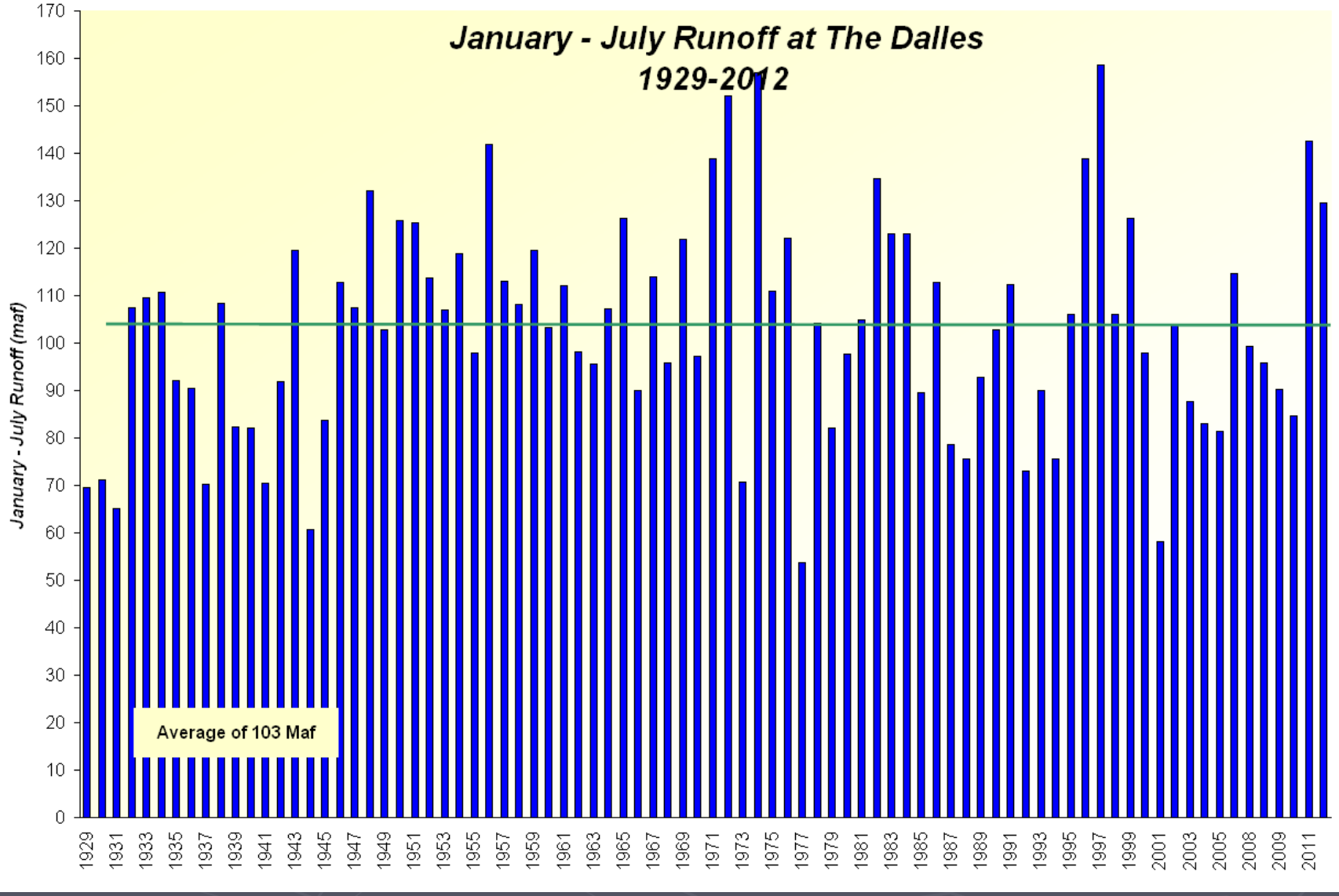
Federal Columbia River Power / Transmission System



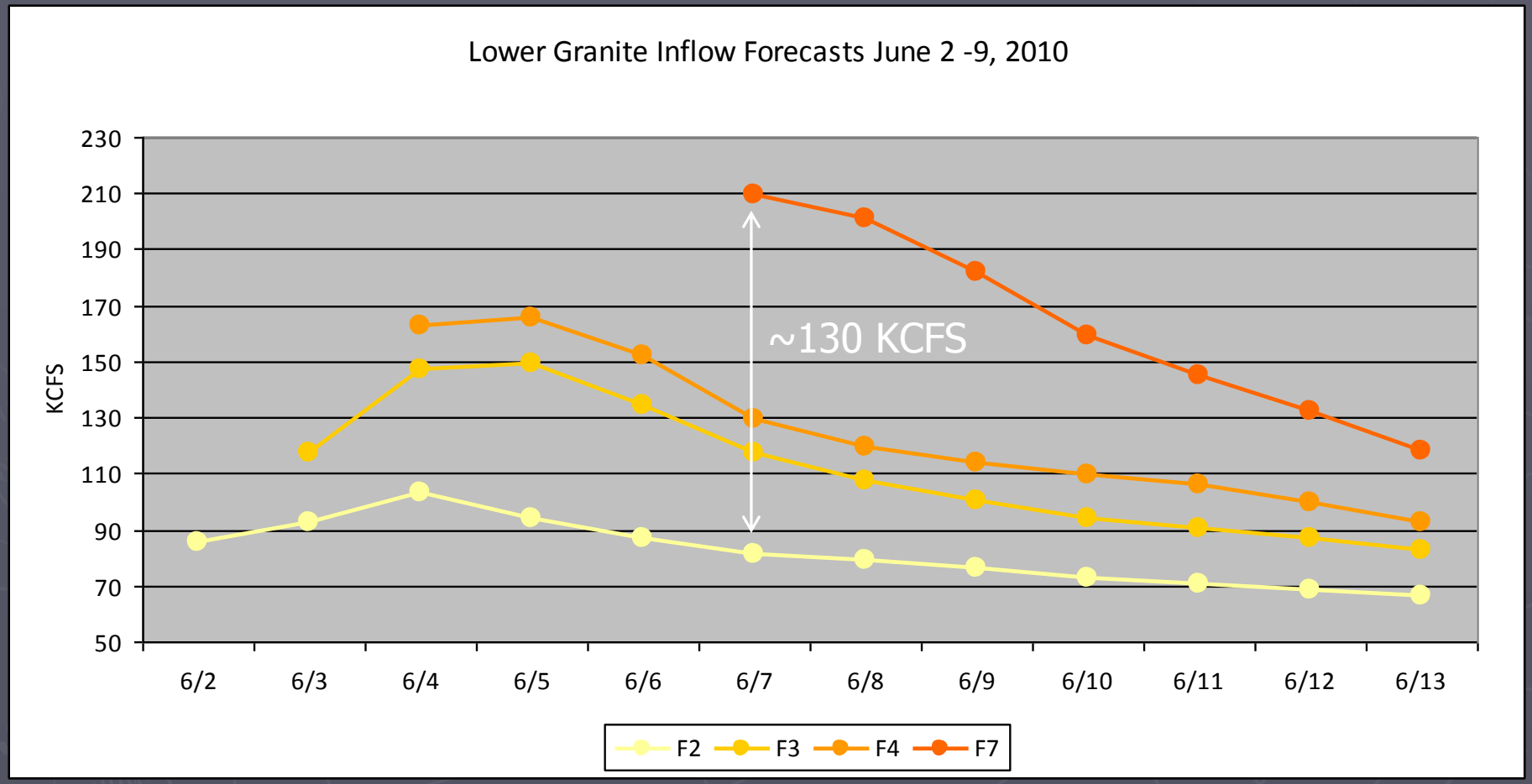
Modeling Challenge: Uncertainty

- Various types of uncertainty in power forecasting
  - Water supply - major influence on hydro-dominated system
  - Variable energy resources, call for balancing reserves
  - Weather and temperature departures
  - Mid Columbia (non-federal) shaping
  - Demand for energy (Load)
  - Unplanned and extended generator outages
  - Transmission limitations
  - Market liquidity, power prices

BPA Uncertainty - *Streamflow*

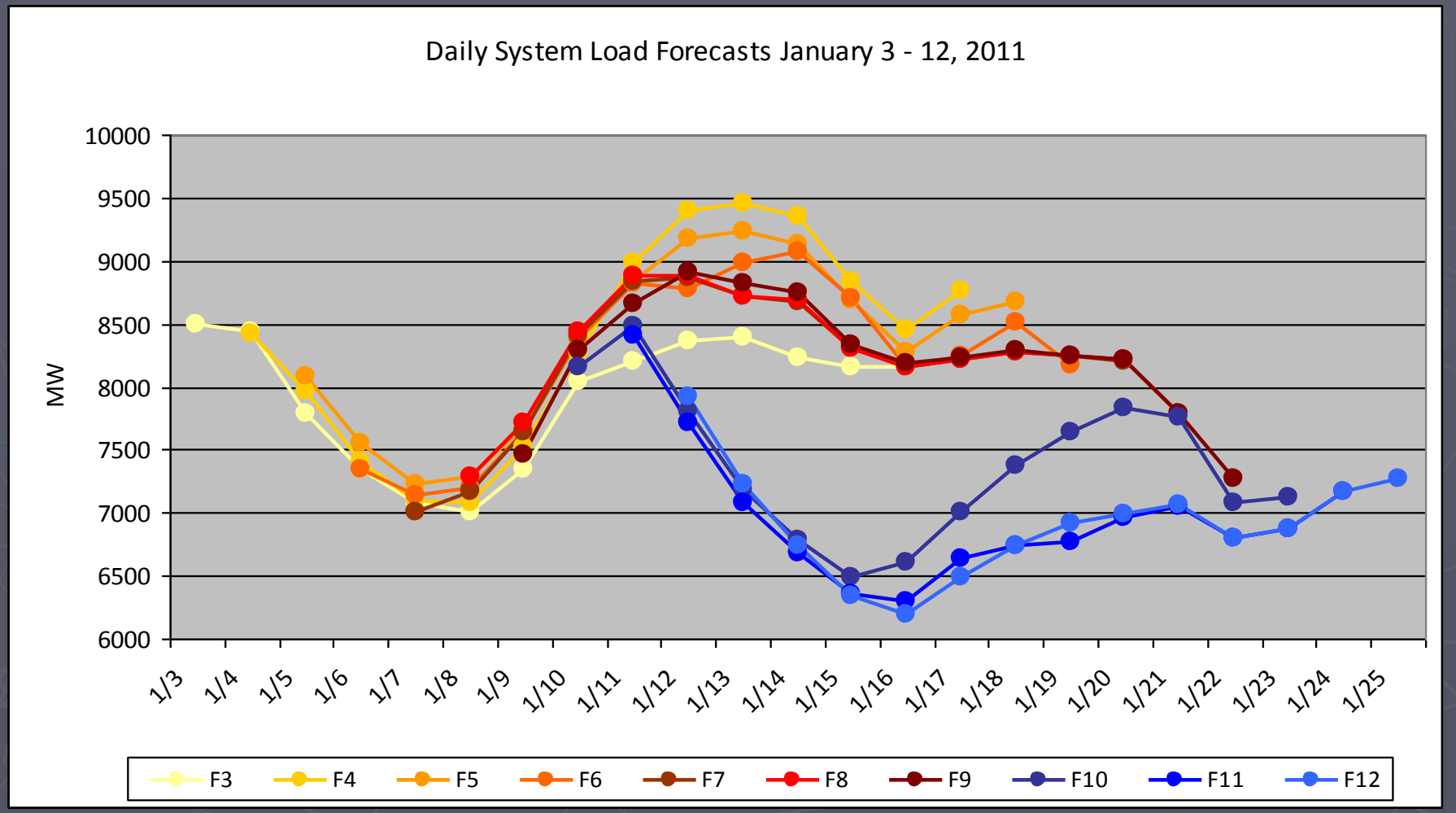


BPA Uncertainty - *Streamflow*



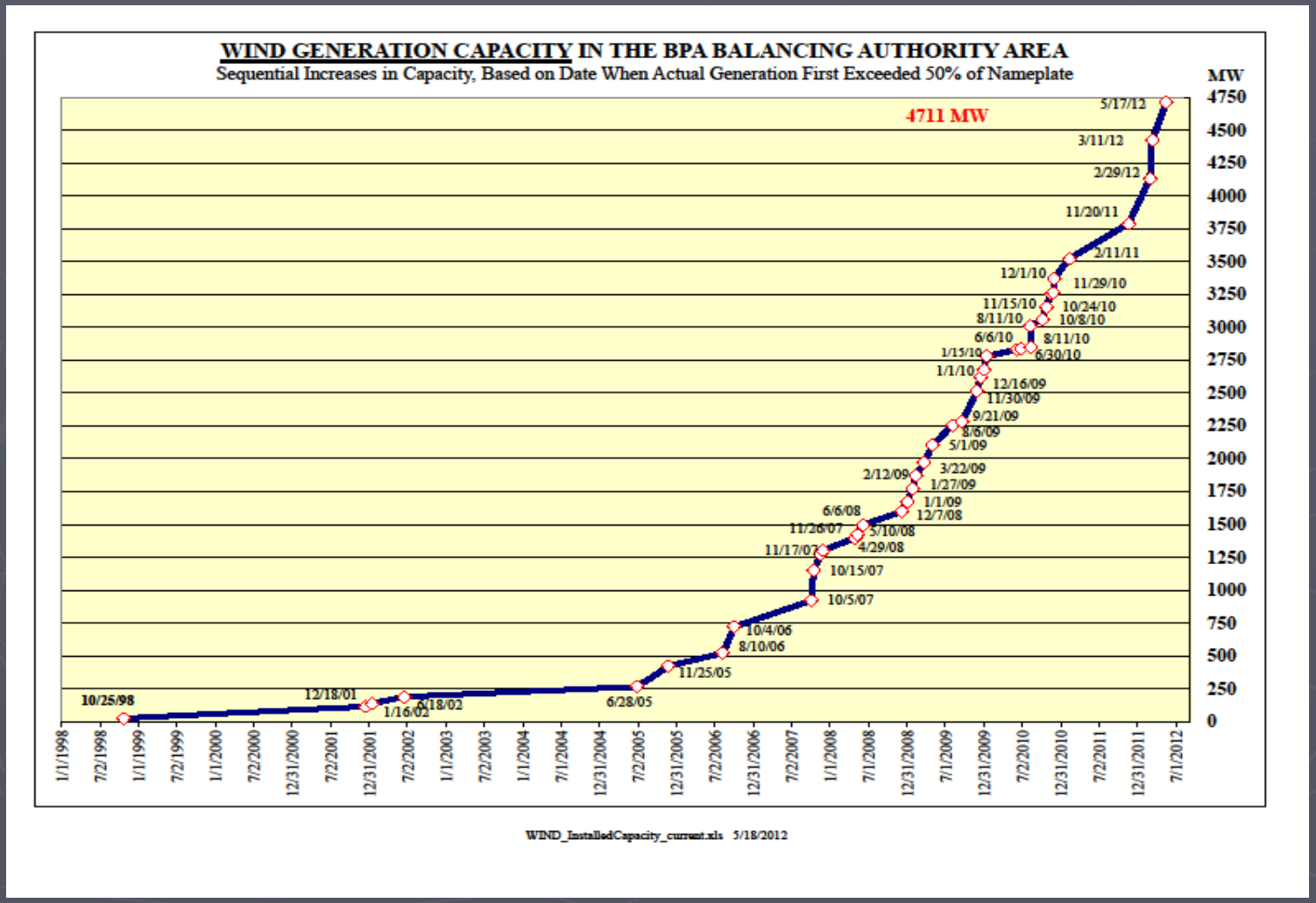
BPA Uncertainty - *Load*

Actual forecasts from January of 2011 - the system load forecast on January 14th ranged from 6,675 MW to 9,357 MW, nearly 3,000 aMW of variation in the week prior to the event.



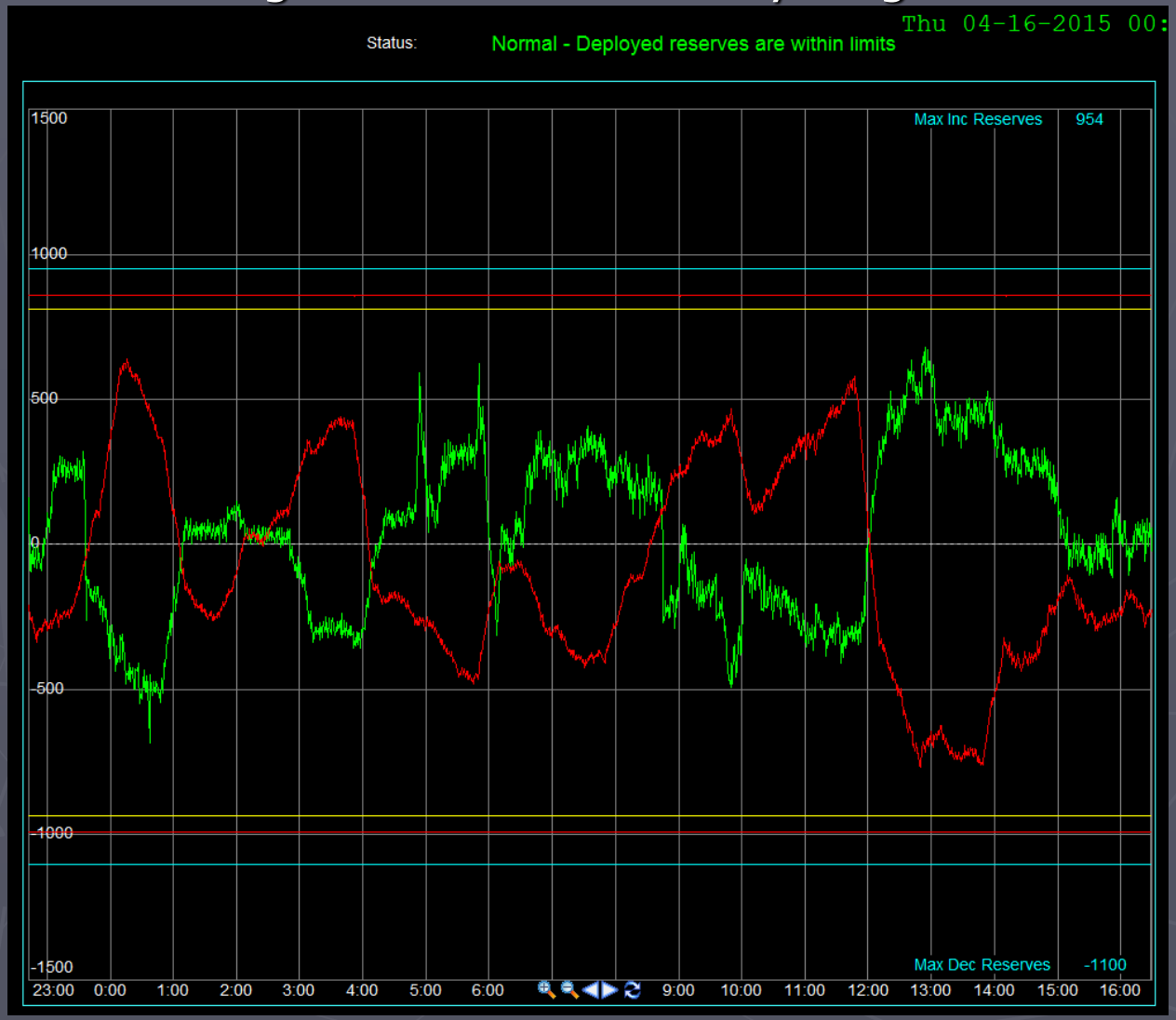
BPA Uncertainty - *Wind Integration*

BPA integrates approximately 4,500 MW of non-federal wind generating capacity using the flexibility of the power and transmission system. BPA provides balancing reserves to multiple wind entities.



BPA Uncertainty - *Wind Integration*

When wind generation differs from what is scheduled BPA balances the scheduling error with reserved hydro generation.



This image shows an observed 16 hour period from April 2015. BPA was providing +900 upwards and -900 MWs downwards of balancing reserves.

Modeling by BPA's Power Services

- Two groups share models at BPA
- Short-term Planning
  - 2-3 week planning study
  - Pre-schedule and day-ahead marketing studies
  - More marketing focused
- Real-time Hydro-Scheduling
  - Current day studies
  - Planning for next shift(s) and non-business day periods
  - More operations focused as load is mostly set during planning horizon
- Both Groups: optimize value of generation within remaining flexibility and uncertainty
- Given complexity, changing conditions, and multiple sources of uncertainty, BPA needed to enhance its modeling capabilities…

Enter "HERMES" - Hydro Reg. Model System

- Models to solve complex uncertainty and flexibility problems
  - High performance - fast run times
  - High resolution - hourly time steps
  - Multiple models and model objectives – more tools in toolbox
  - Accommodates ensemble modeling for streamflows, loads, etc.
  - High quality diagnostic information to troubleshoot model behavior

- Central platform for Real Time and Short Term Planning groups
  - Manage user inputs/constraints
  - Receive and send data from other systems
  - Execute multiple models within platform
  - Customize display of model results
  - Customize all data transfers, including model inputs and results
  - Ability to add new models without changing user interface
  - Archive

HERMES - Models

- HERMES is a FEWS-based platform with multiple models
- Current models in HERMES
  - RTC Tools – Deltares
    - Optimizer
  - RiverWare – CADSWES
    - Rule Based Simulator (RBS)
    - Optimizer
- RTC Tools and RiverWare models both have multiple model objectives
  - Real Time and Short Term groups run different scenarios and utilize separate constraint sets
- Able to run different models for different parts of the basin
- "Stitch" results from multiple models into one continuous data set

Design Criteria – Constraints and Logic

- BPA-Specific
  - Water routing – lag times
  - Conditional constraints
  - Reserves – project and system level
  - Feasible reserves – content, head, and ramp-based
  - Spill obligations - % and flat spill requests
  - Spill priorities – lack of load conditions
    - References a user-maintained table of spill levels
    - Redistributes generation and spill according to table
  - Minimize/maximize generation
  - Moderate operations logic
  - Fixed vs "float" options

Design Criteria - Model Inputs

- Expected streamflows
- Expected loads
- Unit outage schedules
- Non-allocator project schedules
  - Serve federal load but have rigid schedules
- Observed data
- Estimated uncertainty – load adjust
- System-level constraints
- Project and system-level constraints

BPA Real Time / Short Term Dynamic

- Real Time Group
  - Manage hourly generation and marketing for current day, create generation setpoints for 10 major hydro projects
- Short Term Planning Group
  - Plan operations and marketing for 2-3 week period
- Group Coordination
  - Model input/assumptions must be aligned between the two groups
  - Model output from each group becomes input to the other
  - Results from both groups feed other data consumers

Real Time Group

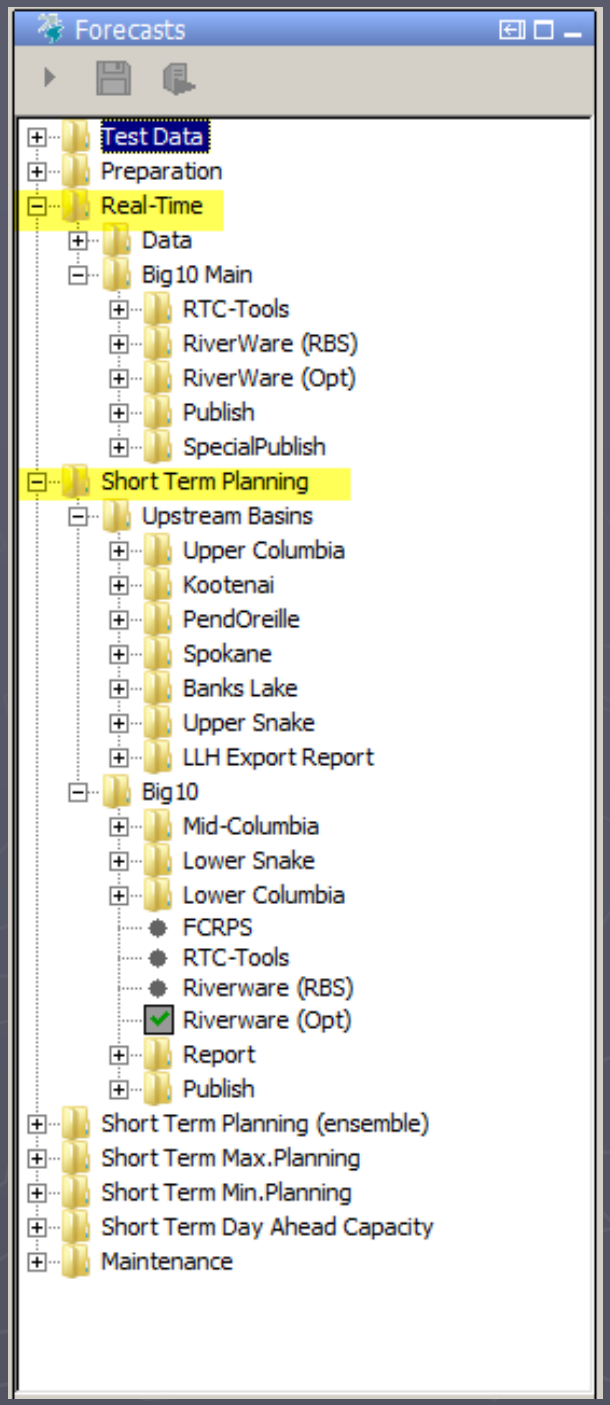
- Real Time – typical range: Day 0 – preschedule days
- Mostly use simulator
  - Expected case
  - Inflow to LCOL is largely set, less flow uncertainty
  - Often most marketing volume is performed day ahead
  - Hourly constraints entered to utilize safe amount of flexibility
    - Enter constraints to load factor (often HE6 and HE22 values)
    - Operations are generally well defined via constraints
- Primary run objectives
  - Fixed load
    - Evaluate marketing via load adjust
    - Float projects to balance load
  - Fixed Operations
    - Uses markets as necessary

Short Term Planning Group

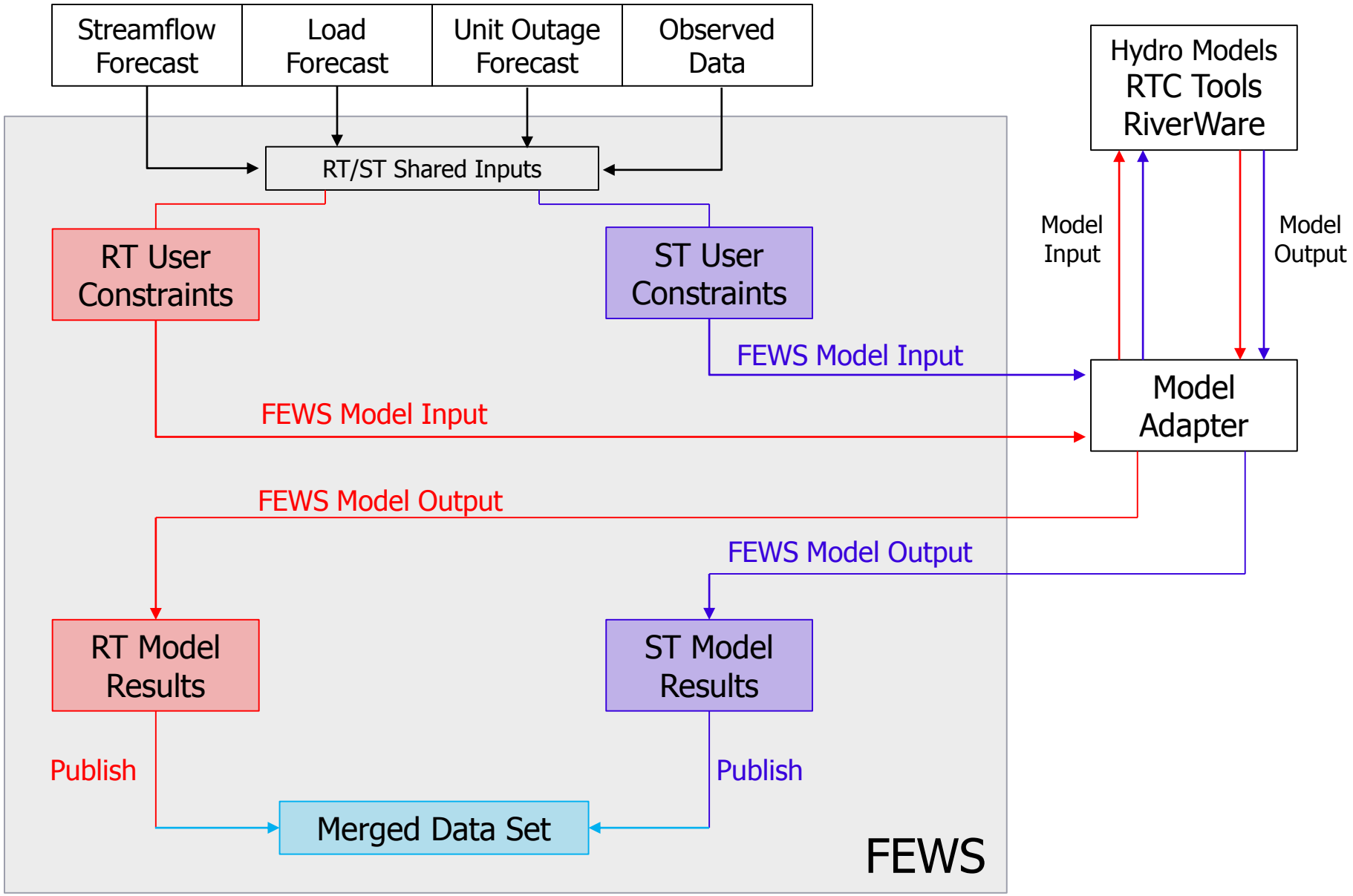
- Planning studies utilize optimizer models
  - More ability to shape water within the longer study period
  - Often greater ability to market day ahead than in the hour-ahead markets
  - Perform a 2-3 week planning study and min/max marketing studies as appropriate
  - Constraints are generally weekly targets
  - More uncertainty
  - Generally shape generation to price profile associated with heavy and light load hours
- Primary objectives
  - Maximize generation value
  - Maximize or minimize generation by specified hours

Data Sharing and Handoffs

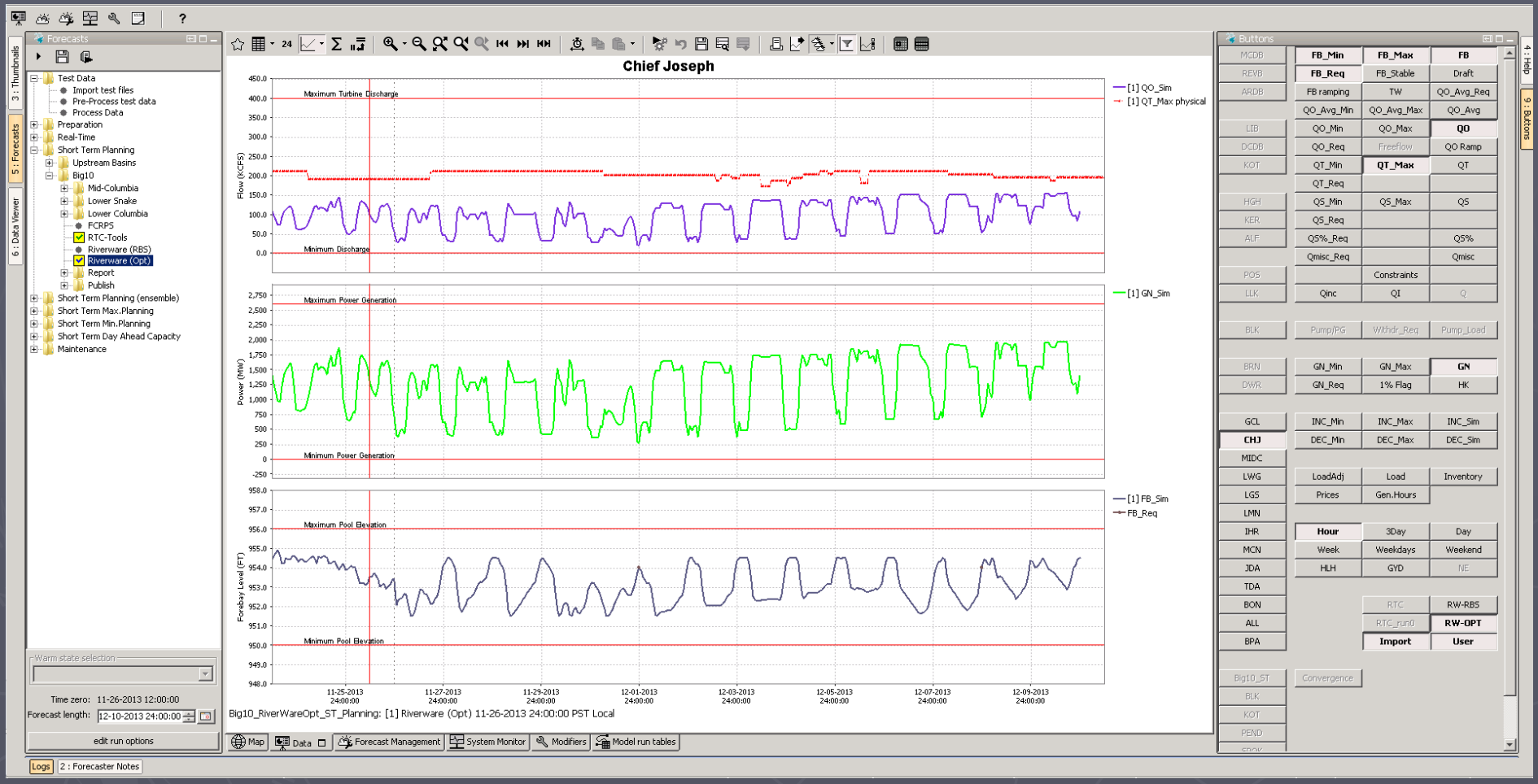
- Both groups maintain separate constraint sets
- Planning group runs upstream basins to produce inflows to downstream models
- Real-time runs Big10 model which provides starting conditions for Planning's Big10 studies
- Planning produces 2-3 week study
- Results are stitched and published to downstream consumers



HERMES Design in FEWS



HERMES Display – Model Results



- Custom button panel
  - Change or add time series attached to each button
  - Ideal for ad hoc displays and comparison of model input/output

HERMES Display – Solution Path

11-27-2013 00:00 to 12-08-2013 00:00

	FB		TW		QO		QS		QT		GN		QO_Avg		Mass Balance
GCL	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:2 V:0	0.0	B:0 V:0	0.0	-
CHJ	B:1 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	-
MIDC	B:170 V:0	0.0	B:- V:-	-	B:79 V:0	0.0	B:- V:-	-	B:- V:-	-	B:- V:-	-	B:0 V:0	0.0	-
LWG	B:1 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:63 V:0	0.0	B:0 V:0	0.0	-
LGS	B:1 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:76 V:11	3.7	B:0 V:0	0.0	-
LMN	B:1 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:75 V:0	0.0	B:0 V:0	0.0	-
IHR	B:1 V:0	0.0	B:0 V:0	0.0	B:69 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:6 V:0	0.0	B:0 V:0	0.0	-
MCN	B:1 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	-
JDA	B:1 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:31 V:39	5.2	B:0 V:0	0.0	-
TDA	B:1 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:43 V:157	11.9	B:0 V:0	0.0	-
BON	B:1 V:0	0.0	B:0 V:0	0.0	B:264 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	B:0 V:0	0.0	-

BPA	
B:0 V:7	16.3

- Solution Summary Display
  - Efficient way to view constraint behavior (binding, violations)
  - Display is linked to time series plots with more information

Questions?