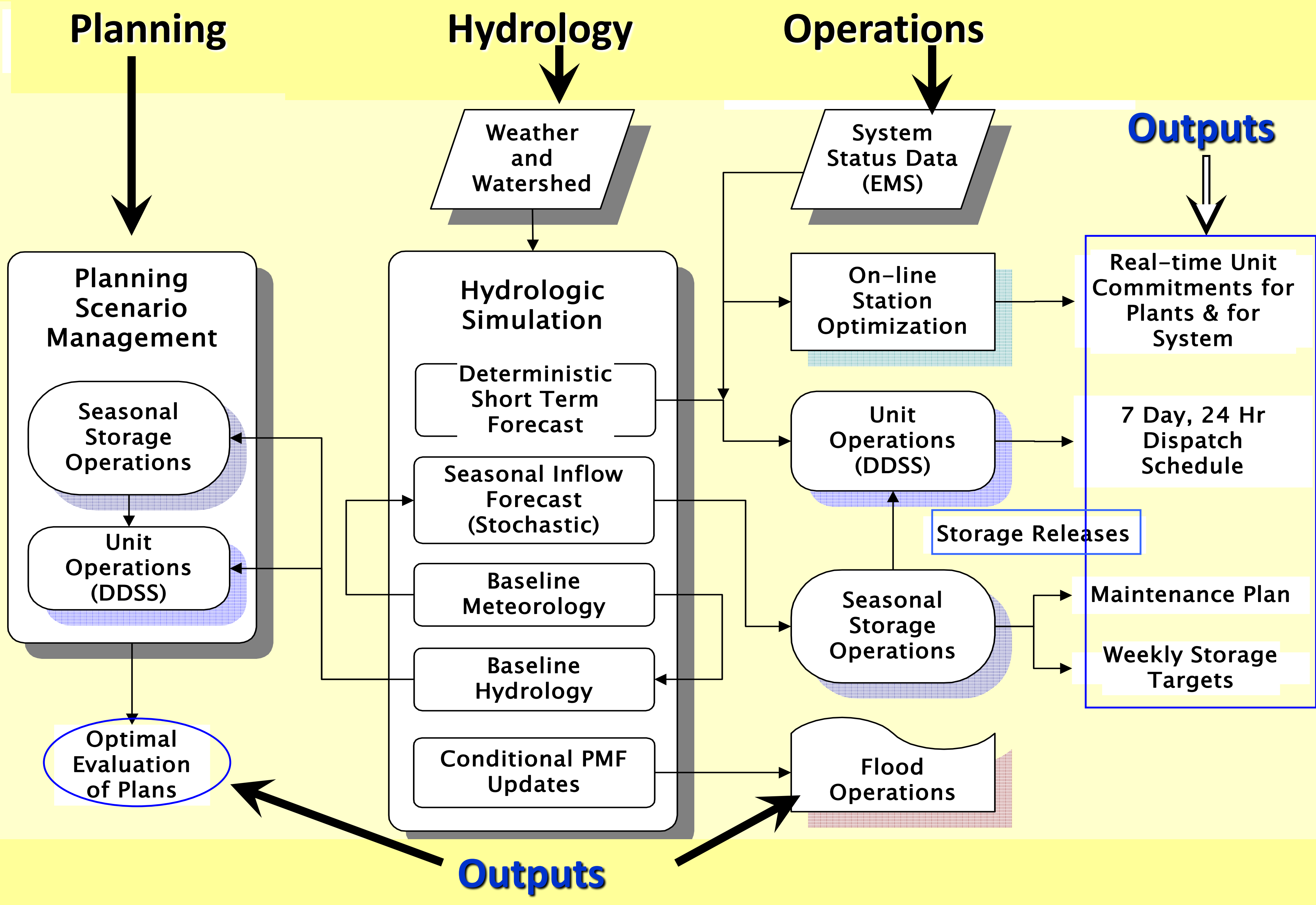
Some Decision Support Systems

Charles D. D. Howard, P.E., P.Eng.
CddHoward Consulting Ltd
Victoria, BC, Canada

http://www.CddHoward.com

Example Decision Support System



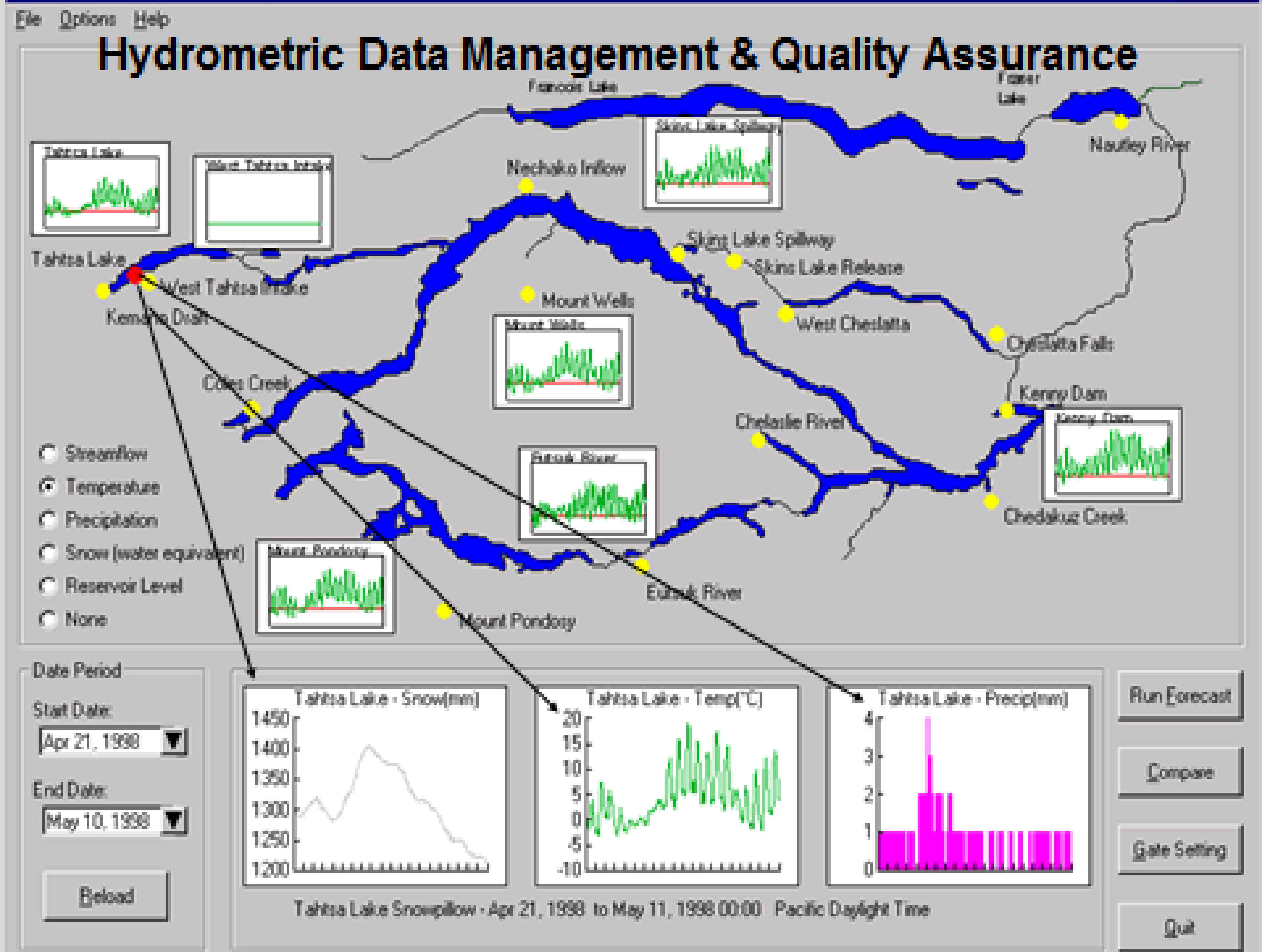
- **Overview of DSS Components**
- **Project Inflows**
- **Unit Commitment and Base Points**
- **Pre-Scheduling**
- **Generation Scheduling and Bidding**
- **Unit Maintenance Scheduling**
- **Project Sites: Some Specific Issues**

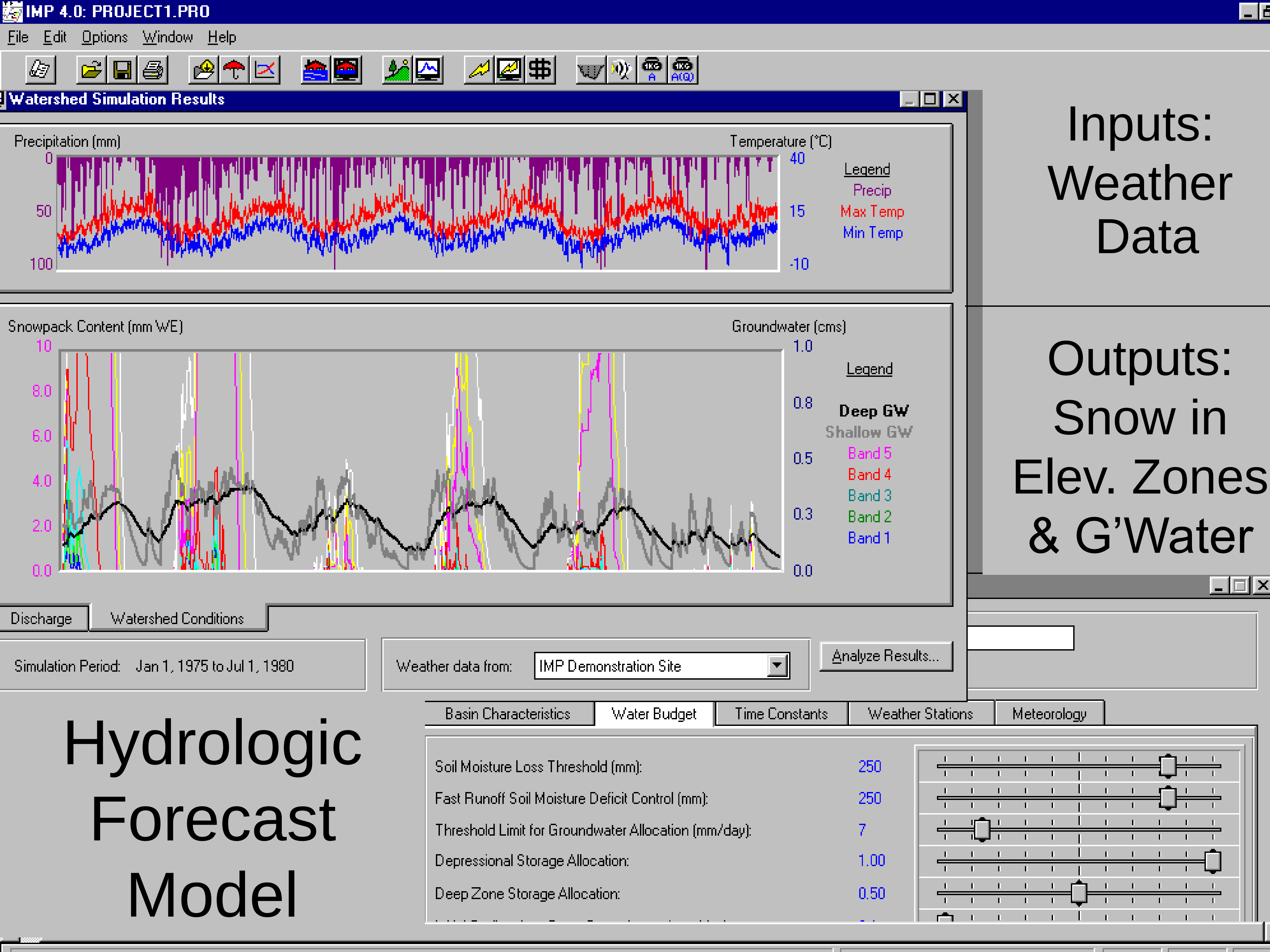
Project Inflows

- Hydrologic Data
- Hydrologic Forecasting

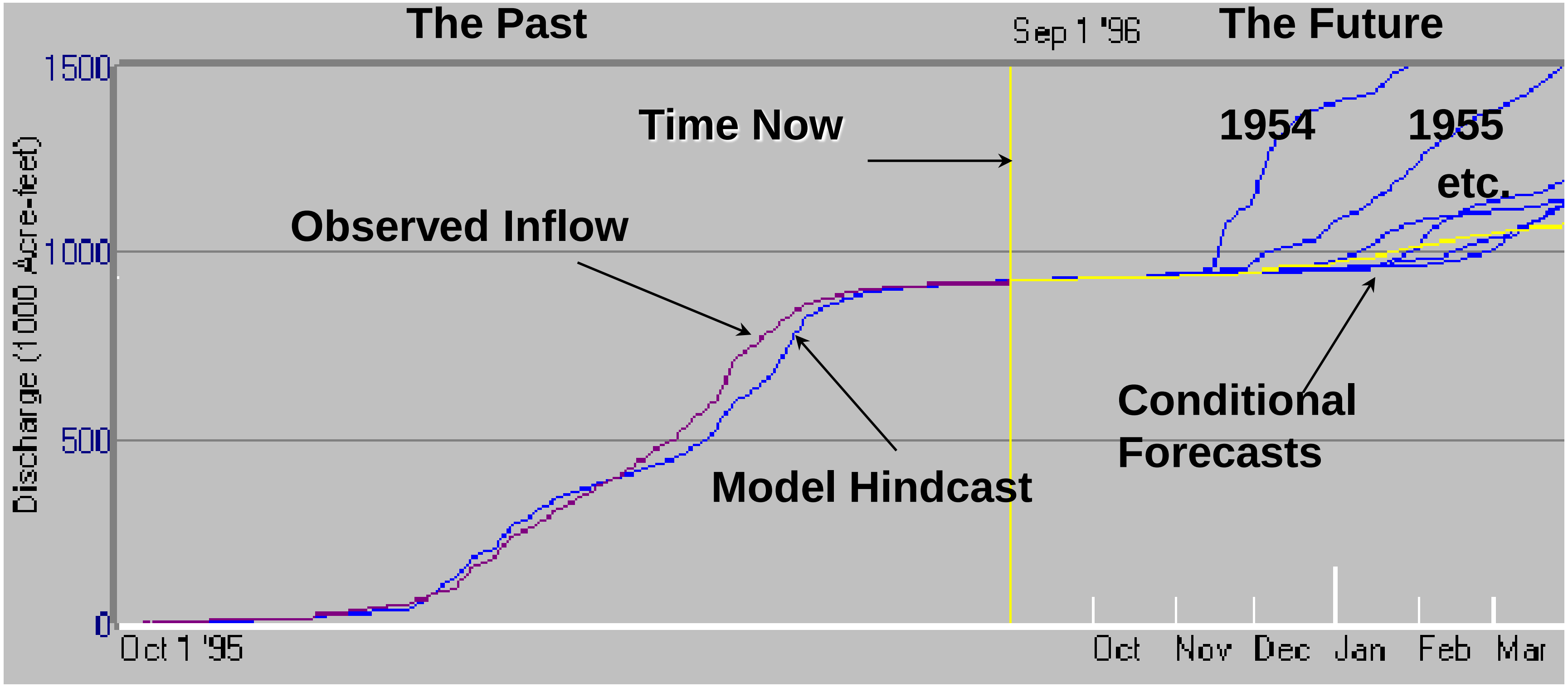
Powell River BC Basin

High Elevation Hydromet Station


File Options Help
Hydrometric Data Management & Quality Assurance
Francois Lake
Fraser Lake
Nautley River
Skins Lake Spillway
Nechako Inflow
Tahtsa Lake
West Tahtsa Intake
Kemano Drain
Skins Lake Spillway
Skins Lake Release
Mount Wells
West Cheslatta
Cheslatta Falls
Mount Wells
Coles Creek
Kenny Dam
Chelaslie River
Kenny Dam
Eutsuk River
Chedakuz Creek
Streamflow
Temperature
Precipitation
Snow (water equivalent)
Reservoir Level
None
Mount Pondosy
Eutsuk River
Mount Pondosy
Date Period
Start Date:
Apr 21, 1998
End Date:
May 10, 1998
Reload
Tahtsa Lake - Snow(mm)
Tahtsa Lake - Temp(°C)
Tahtsa Lake - Precip(mm)
Tahtsa Lake Snowpillow - Apr 21, 1998 to May 11, 1998 00:00 Pacific Daylight Time
Run Forecast
Compare
Gate Setting
Quit


IMP 4.0: PROJECT1.PRO
File Edit Options Window Help
Watershed Simulation Results
Precipitation (mm)
Temperature (°C)
Legend
Precip
Max Temp
Min Temp
Snowpack Content (mm WE)
Groundwater (cms)
Legend
Deep GW
Shallow GW
Band 5
Band 4
Band 3
Band 2
Band 1
Discharge
Watershed Conditions
Simulation Period: Jan 1, 1975 to Jul 1, 1980
Weather data from: IMP Demonstration Site
Analyze Results...
Basin Characteristics
Water Budget
Time Constants
Weather Stations
Meteorology
Soil Moisture Loss Threshold (mm): 250
Fast Runoff Soil Moisture Deficit Control (mm): 250
Threshold Limit for Groundwater Allocation (mm/day): 7
Depressional Storage Allocation: 1.00
Deep Zone Storage Allocation: 0.50
Inputs: Weather Data
Outputs: Snow in Elev. Zones & G'Water
Hydrologic Forecast Model

Cumulative Inflow Forecasts



Historical weather provides samples of possible future weather.

Forecasts are conditional on watershed conditions at Time Now, and possible future weather.

Stochastic Hydro-Thermal Scheduling

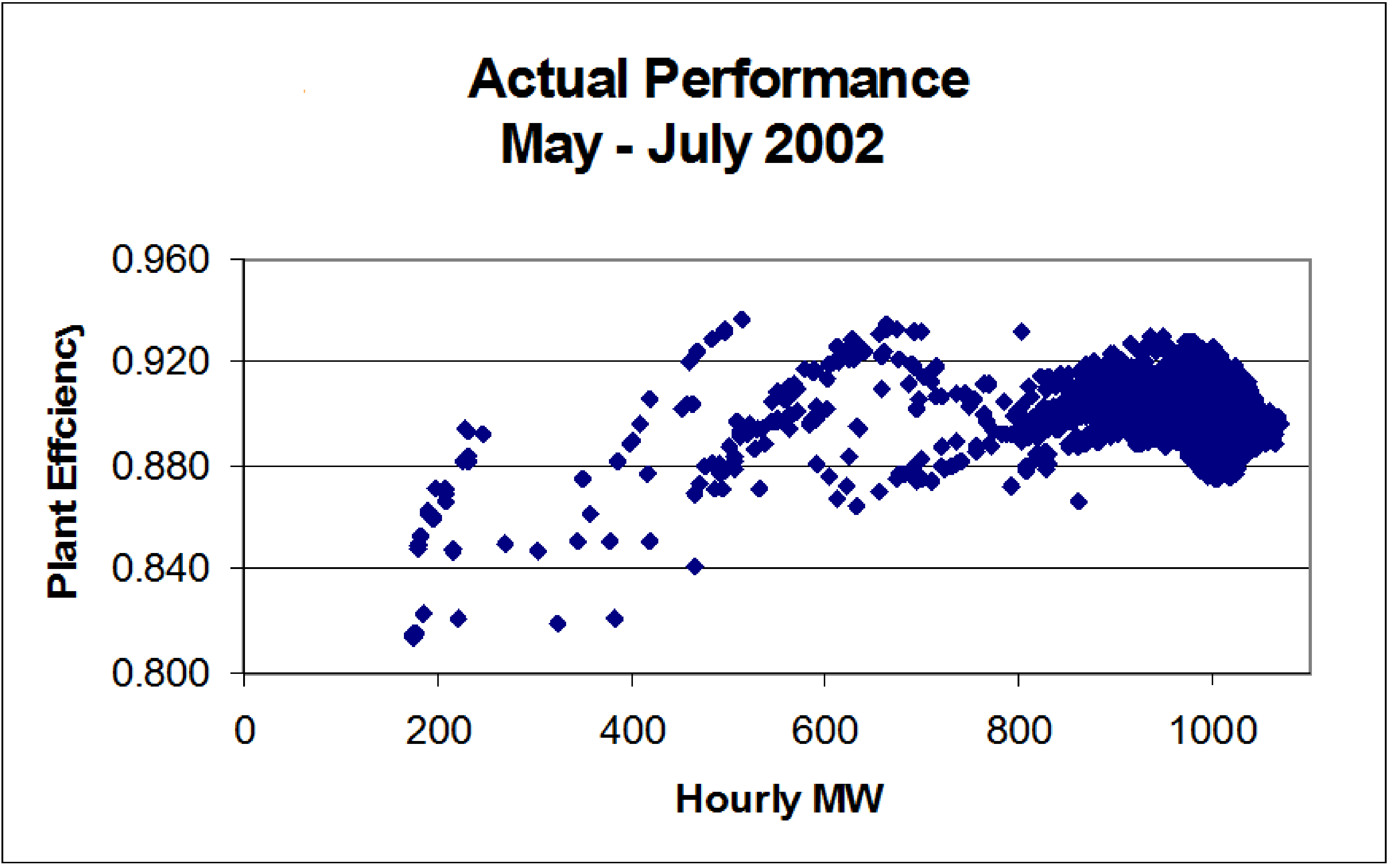
System Reliability Percent	Thermal Generation M$	Hydro Generation M$
90	1.75	47.29
92	1.84	48.33
94	1.90	50.47
96	1.96	53.10
98	2.04	55.84
99	2.07	59.04

Operations Center and Scheduling

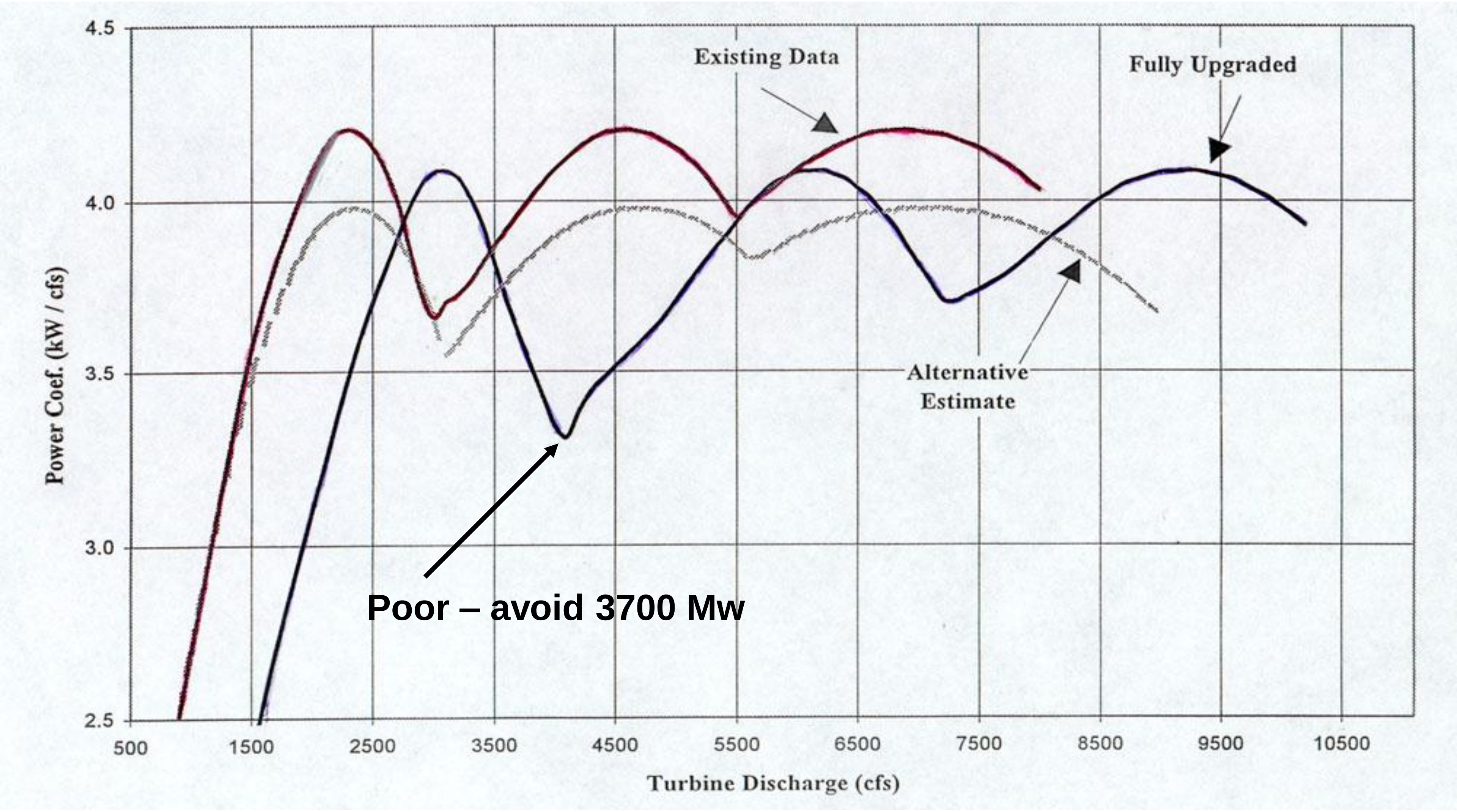
- Plant Efficiency
- Unit Operations


09:05:40
Reactive Power Reserve
Frequency Overview
TOTAL GENERATION
ACE TOTAL
MANITOBA LOAD
ACTUAL INTERCHANGE
SCHEDULED INTERCHANGE
9:05:40

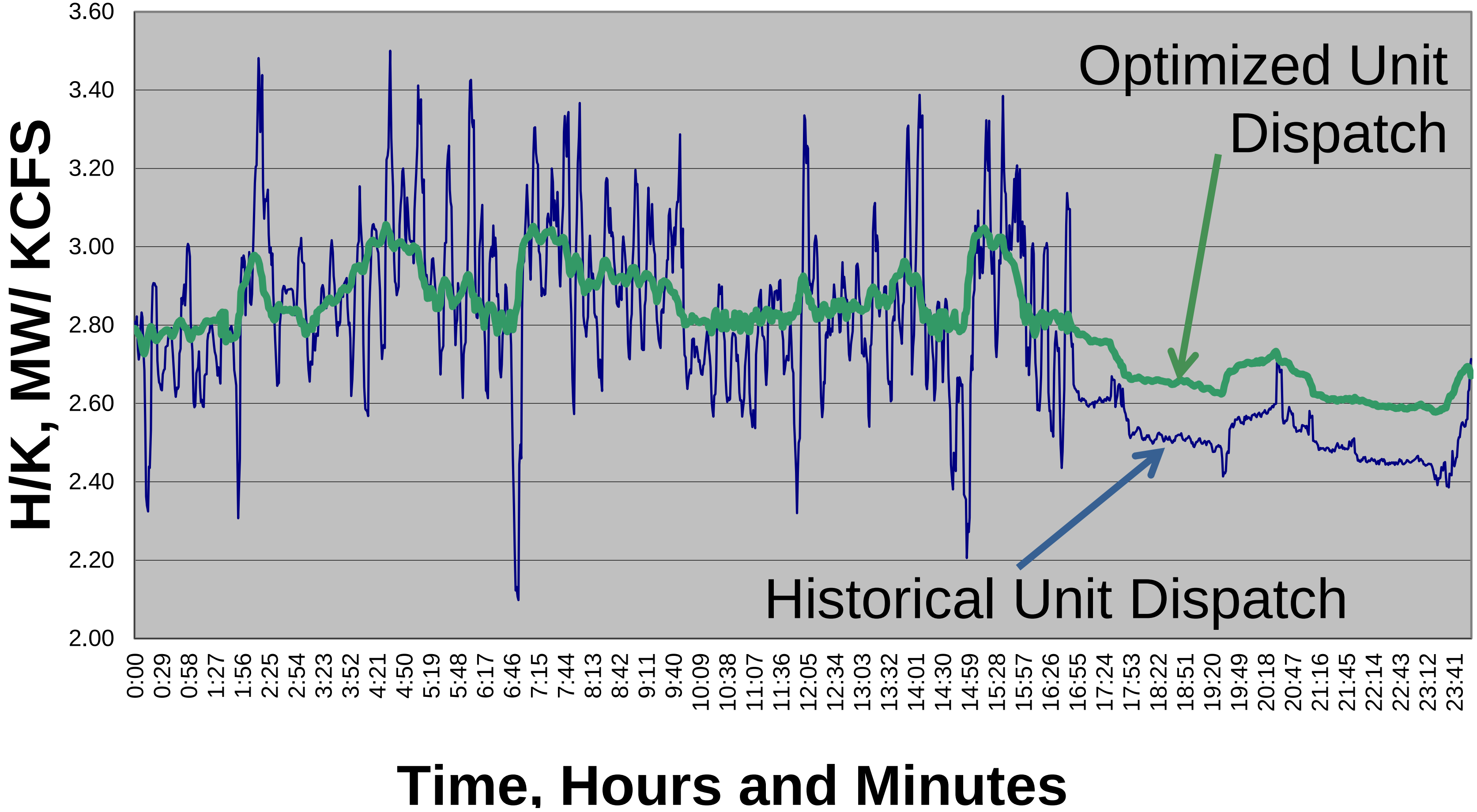
Can Plant Operate More Efficiently?



Optimized Plant H/K, Preferred Loading



1 Minute Hydroelectric Plant Operations
22 June 2009.



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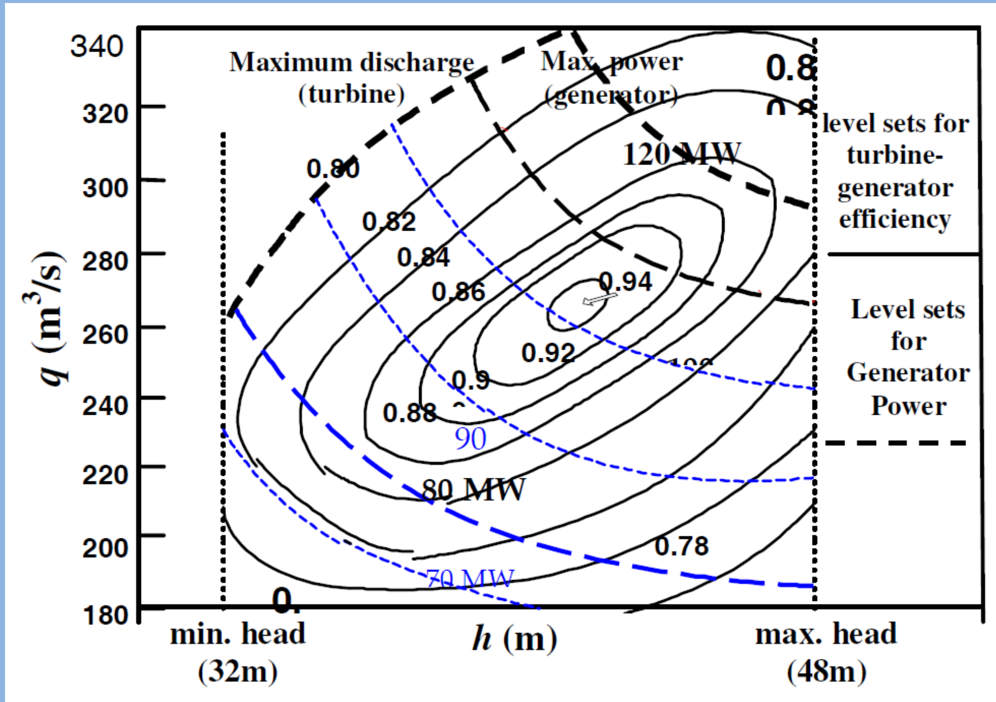

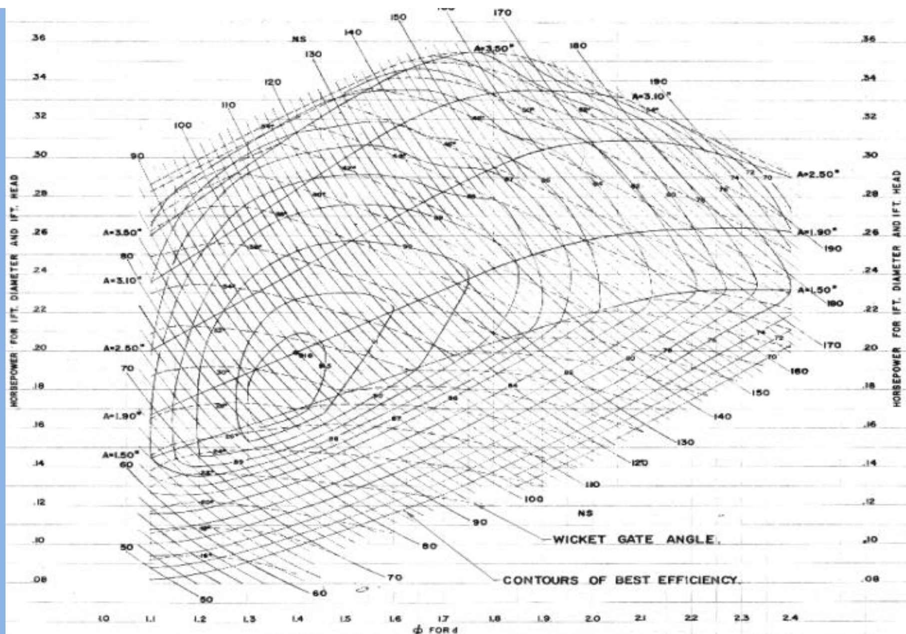

Idealized Hill Curve:
Monotonic
Symmetrical
Centered

Actual Hill Curve:
Not monotonic
Not Symmetrical
Not Centered

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File Options Help

GURI 20

Plant Selection

GURI 20
Unit1
Unit2
Unit3
Unit4
Unit5
Unit6

Controls

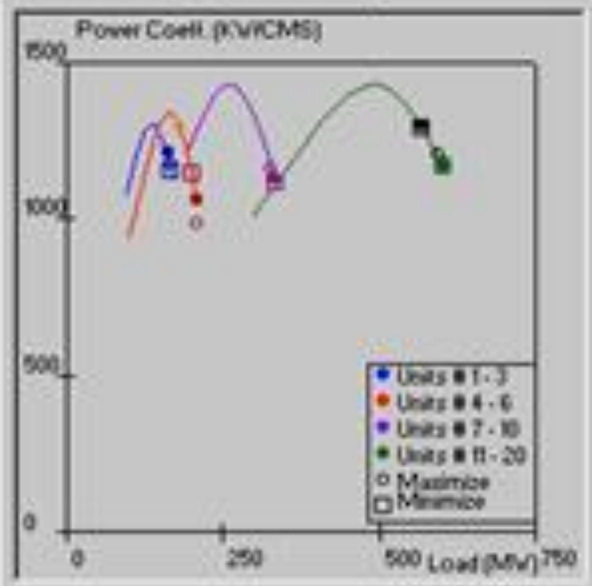
Turbine Data

Auto Optimize

Report

Optimize

Power-Discharge | KW/CMS



Zoom

Current Status for GURI 20

Time/Date :

Headwater Level : 0 m

Tailwater Level : 0 m

Current Status			
Unit #	Status	MW	CMS
12	On	600	513
13	On	600	513
14	On	600	513
15	On	600	513
16	On	600	513
17	On	600	513
18	On	565	435
19	On	565	435
20	On	565	435
Totals:		8322	7,045

Difference:

Optimal Dispatch

Time/Date : Jun 26 02:39:53

Headwater Level : 180 m

Tailwater Level : 50 m

Maximized MW		Minimized CMS	
MW	CMS	MW	CMS
591	490	599	511
591	490	599	511
591	490	599	511
591	490	599	511
591	490	599	511
591	490	599	511
591	490	566	437
591	490	566	437
591	490	566	437
8302	7,000	8322	7,034
-20			-11

Charles Howard & Associates Ltd.
Professional Water Resource Engineers

Near Real Time Unit Loading

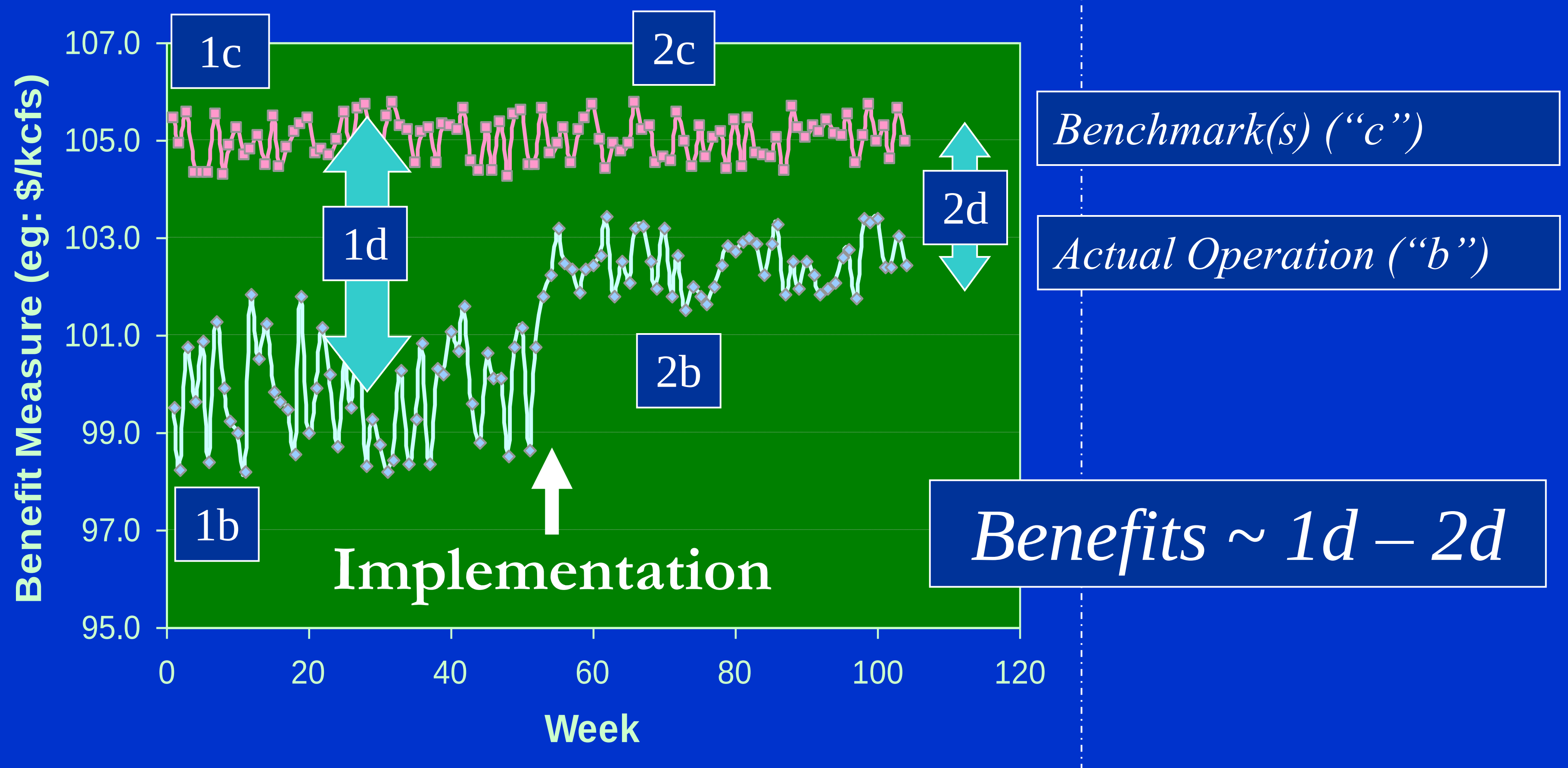
Optimized Loadings Table for 11 Units

No unnecessary On-Off

Plant Discharge	Plant 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10	Unit 11
2,298.3	2,298	0	0	0	0	0	0	0	0	0	0
4,596.6	4,597	0	0	0	0	0	0	0	0	0	0
6,895.0	6,895	0	0	0	0	0	0	0	0	0	0
9,193.3	9,193	0	0	0	0	0	0	0	0	0	0
11,491.6	11,492	0	0	0	0	0	0	0	0	0	0
13,789.9	13,790	0	0	0	0	0	0	0	0	0	0
16,088.3	16,088	0	0	0	0	0	0	0	0	0	0
18,386.6	12,768	5,618	0	0	0	0	0	0	0	0	0
20,684.9	13,117	7,568	0	0	0	0	0	0	0	0	0
22,983.2	13,790	9,193	0	0	0	0	0	0	0	0	0
25,281.6	14,158	11,124	0	0	0	0	0	0	0	0	0
27,579.9	15,044	12,536	0	0	0	0	0	0	0	0	0
29,878.2	15,699	14,179	0	0	0	0	0	0	0	0	0
32,176.5	16,088	16,088	0	0	0	0	0	0	0	0	0
34,474.9	15,716	12,675	6,084	0	0	0	0	0	0	0	0
36,773.2	15,616	13,601	7,556	0	0	0	0	0	0	0	0
39,071.5	15,528	14,026	9,517	0	0	0	0	0	0	0	0
41,369.8	15,640	14,631	11,099	0	0	0	0	0	0	0	0
43,668.2	16,062	15,058	12,548	0	0	0	0	0	0	0	0
45,966.5	16,164	15,659	14,144	0	0	0	0	0	0	0	0
48,264.8	16,591	16,088	15,586	0	0	0	0	0	0	0	0
50,563.1	16,020	15,519	13,016	6,008	0	0	0	0	0	0	0
52,861.5	16,110	15,607	13,593	7,552	0	0	0	0	0	0	0
55,159.8	16,046	15,545	14,041	9,528	0	0	0	0	0	0	0
57,458.1	16,129	16,129	14,617	10,584	0	0	0	0	0	0	0
59,756.4	16,069	16,069	15,567	12,052	0	0	0	0	0	0	0
62,054.8	16,515	16,014	15,514	14,012	0	0	0	0	0	0	0
64,353.1	16,591	16,088	16,088	15,586	0	0	0	0	0	0	0
66,651.4	17,039	16,538	16,538	16,538	0	0	0	0	0	0	0
68,949.7	16,608	16,105	15,602	13,589	7,046	0	0	0	0	0	0
71,248.0	16,558	16,056	15,554	14,049	9,031	0	0	0	0	0	0
73,546.4	16,510	16,010	16,010	14,509	10,507	0	0	0	0	0	0
75,844.7	16,575	16,073	16,073	15,068	12,055	0	0	0	0	0	0
78,143.0	16,530	16,530	16,029	15,528	13,525	0	0	0	0	0	0
80,441.3	16,591	16,591	16,088	16,088	15,083	0	0	0	0	0	0
82,739.7	17,049	16,548	16,548	16,548	16,046	0	0	0	0	0	0
85,038.0	16,507	16,507	16,007	15,507	13,506	7,003	0	0	0	0	0
87,336.3	16,564	16,564	16,062	16,062	14,054	8,031	0	0	0	0	0
89,634.6	16,525	16,525	16,024	16,024	14,522	10,015	0	0	0	0	0
91,933.0	16,578	16,578	16,076	16,076	15,071	11,554	0	0	0	0	0
94,231.3	16,541	16,541	16,541	16,039	15,538	13,032	0	0	0	0	0

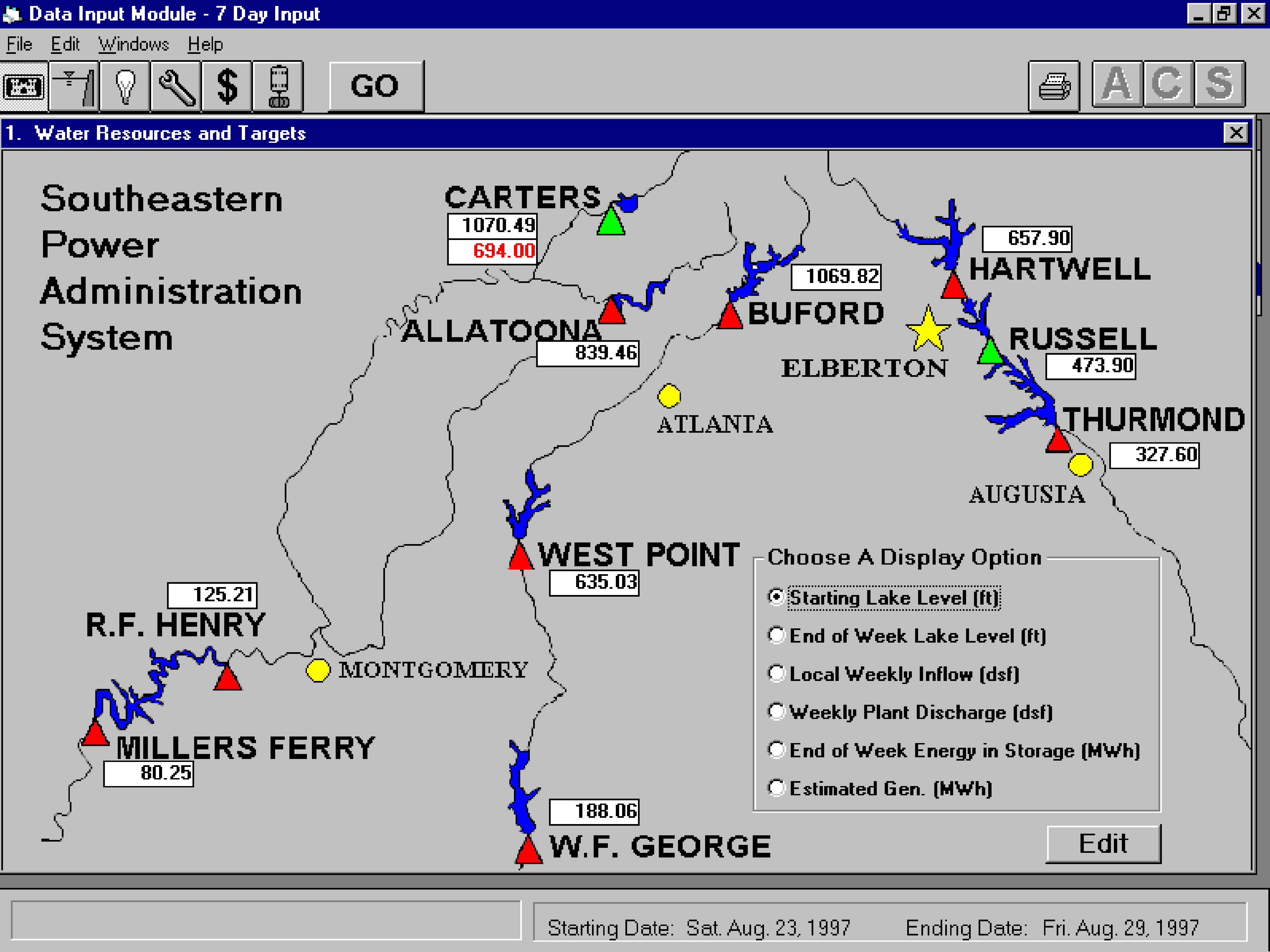
Unit Power	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
6,302	6,302	0	0	0	0	0	0
28,463	28,463	0	0	0	0	0	0
47,802	47,802	0	0	0	0	0	0
64,818	64,818	0	0	0	0	0	0
81,491	81,491	0	0	0	0	0	0
97,805	97,805	0	0	0	0	0	0
113,280	113,280	0	0	0	0	0	0
129,065	90,643	38,421	0	0	0	0	0
146,011	93,088	52,923	0	0	0	0	0
162,623	97,805	64,818	0	0	0	0	0
179,214	100,330	78,883	0	0	0	0	0
195,353	106,358	88,995	0	0	0	0	0
211,298	110,813	100,485	0	0	0	0	0
226,560	113,280	113,280	0	0	0	0	0
242,835	110,938	89,977	41,920	0	0	0	0
259,537	110,229	96,465	52,843	0	0	0	0
276,235	109,611	99,395	67,229	0	0	0	0
292,678	110,397	103,573	78,708	0	0	0	0
308,634	113,094	106,460	89,080	0	0	0	0
324,576	113,813	110,532	100,230	0	0	0	0
339,577	116,283	113,280	110,014	0	0	0	0
356,112	112,799	109,547	92,371	41,394	0	0	0
372,817	113,434	110,164	96,408	52,811	0	0	0
389,516	112,986	109,728	99,501	67,301	0	0	0
405,585	113,564	113,564	103,472	74,986	0	0	0
421,726	113,144	113,144	109,882	85,556	0	0	0
437,313	115,747	112,758	109,507	99,301	0	0	0
452,857	116,283	113,280	113,280	110,014	0	0	0
466,230	118,505	115,908	115,908	115,908	0	0	0
485,399	116,404	113,398	110,129	96,377	49,090	0	0
502,130	116,049	113,052	109,793	99,560	63,677	0	0
518,324	115,718	112,730	112,730	102,712	74,435	0	0
534,630	116,173	113,173	113,173	106,534	85,578	0	0
550,115	115,857	115,857	112,865	109,611	95,924	0	0
565,761	116,283	116,283	113,280	113,280	106,635	0	0
579,508	118,579	115,981	115,981	115,981	112,986	0	0
598,145	115,697	115,697	112,709	109,459	95,791	48,792	0
614,314	116,092	116,092	113,094	113,094	99,597	56,345	0
630,952	115,819	115,819	112,828	112,828	102,801	70,857	0
647,311	116,192	116,192	113,192	113,192	106,552	81,992	0
662,887	115,930	115,930	115,930	112,936	109,680	92,483	0

Short Term Operational Benefits

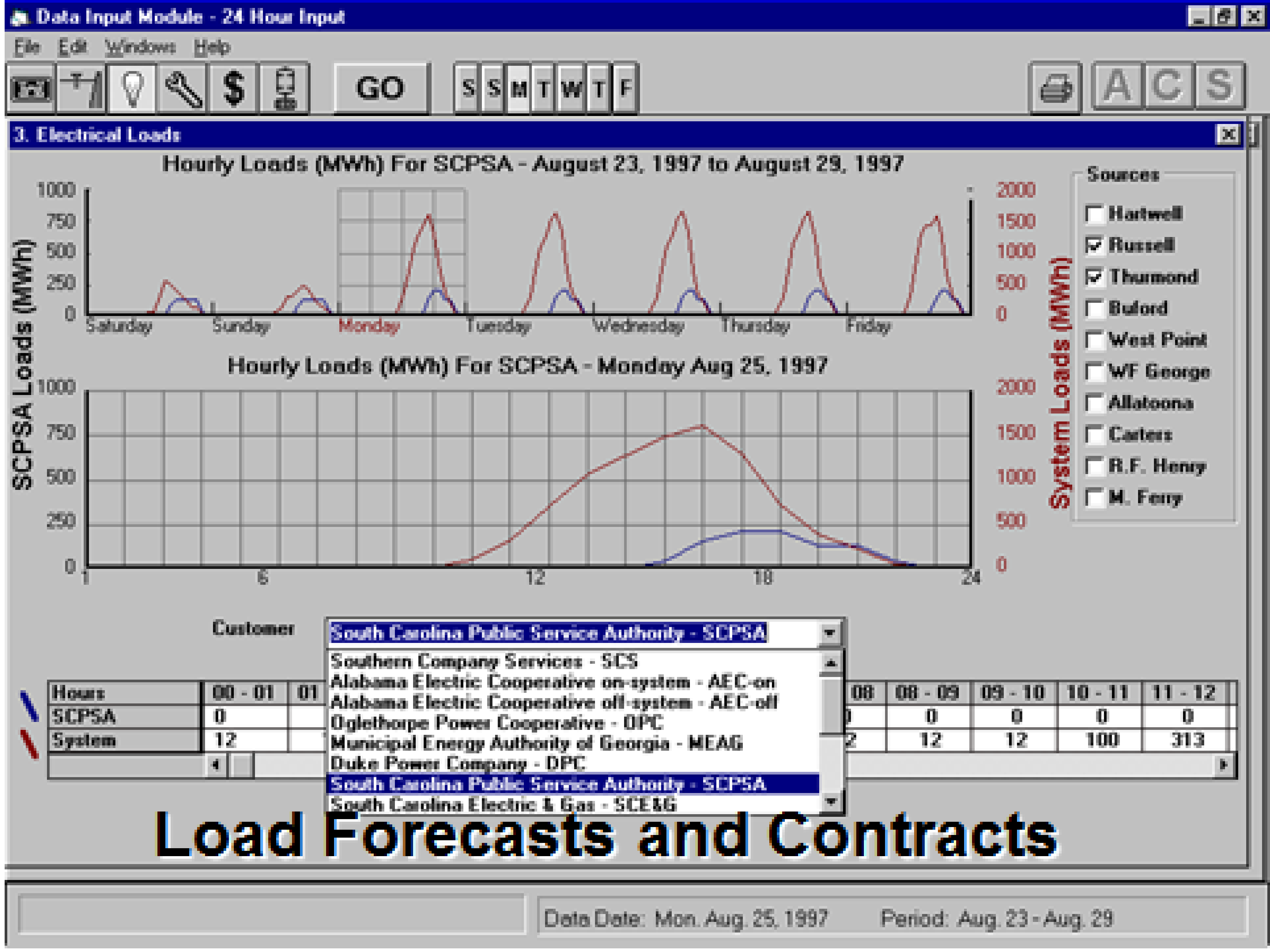


Project Base Points

- Contract Commitments
- Transmission Constraints


Data Input Module - 7 Day Input
File
Edit
Windows
Help
GO
A
C
S
1. Water Resources and Targets
Southeastern
Power
Administration
System
CARTERS
1070.49
694.00
ALLATOONA
839.46
BUFORD
1069.82
HARTWELL
657.90
RUSSELL
473.90
THURMOND
327.60
ELBERTON
ATLANTA
AUGUSTA
WEST POINT
635.03
R.F. HENRY
125.21
MONTGOMERY
MILLERS FERRY
80.25
188.06
W.F. GEORGE
Choose A Display Option
Starting Lake Level (ft)
End of Week Lake Level (ft)
Local Weekly Inflow (dsf)
Weekly Plant Discharge (dsf)
End of Week Energy in Storage (MWh)
Estimated Gen. (MWh)
Edit
Starting Date: Sat. Aug. 23, 1997
Ending Date: Fri. Aug. 29, 1997

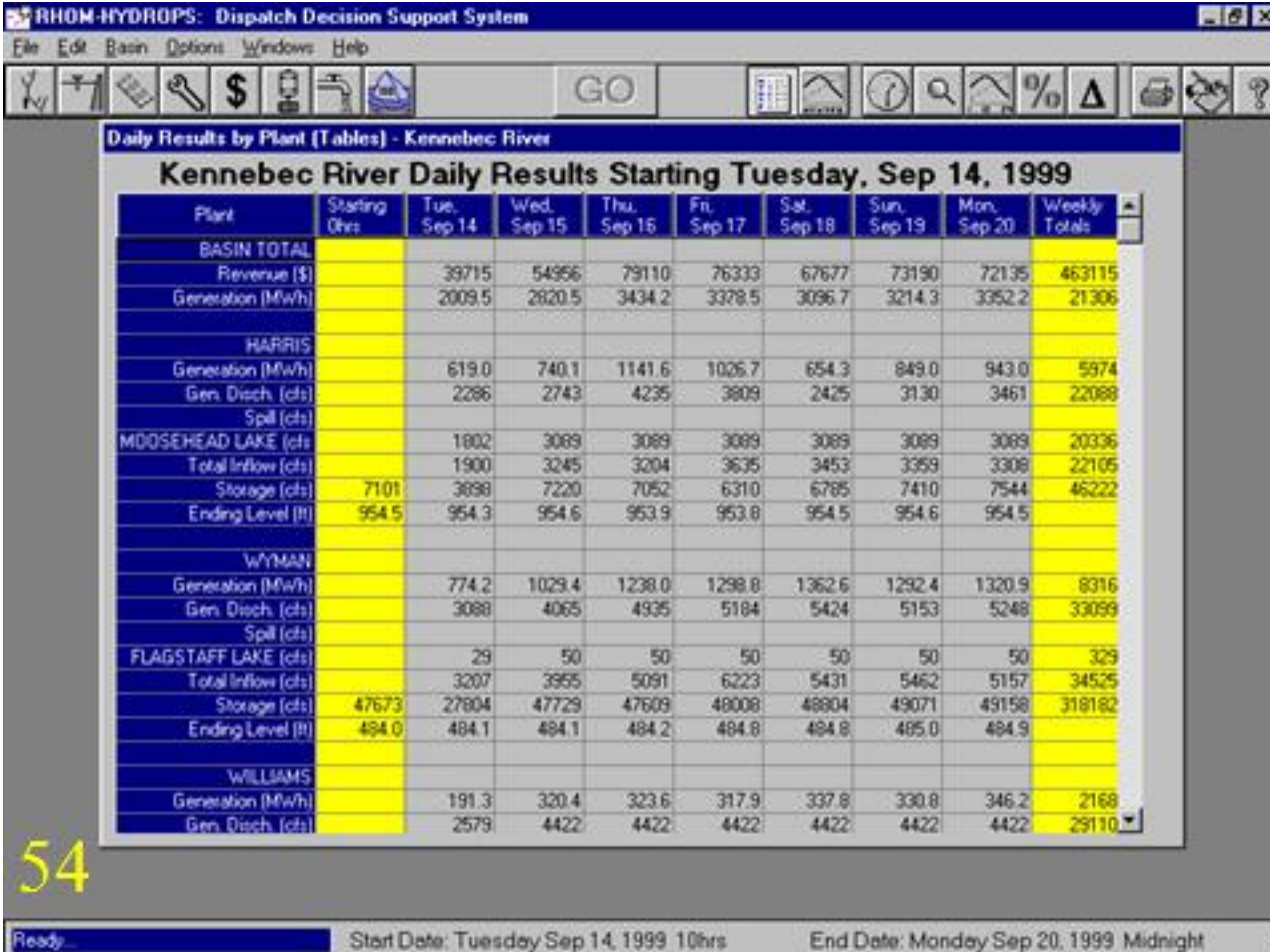
Load Forecasts and Contracts



Operations Scheduling

- River Basins
- Projects
- Market Bids

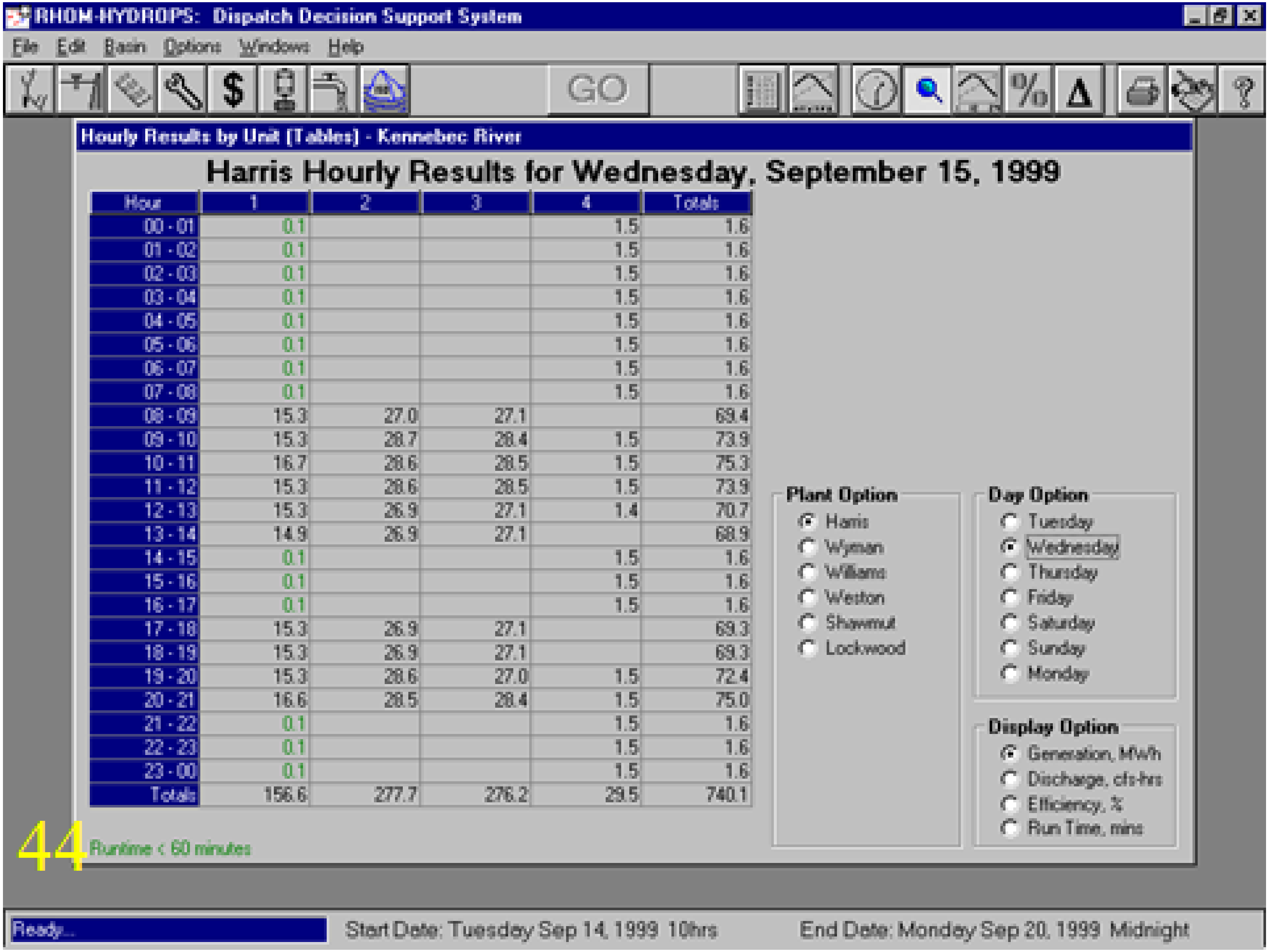
River Basin Week Summary



Kennebec River Daily Results Starting Tuesday, Sep 14, 1999

Plant	Starting 0hrs	Tue, Sep 14	Wed, Sep 15	Thu, Sep 16	Fri, Sep 17	Sat, Sep 18	Sun, Sep 19	Mon, Sep 20	Weekly Totals
BASIN TOTAL									
Revenue ($)		39715	54956	79110	76333	67677	73190	72135	463115
Generation (MWh)		2009.5	2820.5	3434.2	3378.5	3096.7	3214.3	3352.2	21306
HARRIS									
Generation (MWh)		619.0	740.1	1141.6	1026.7	654.3	849.0	943.0	5974
Gen. Disch. (cfs)		2286	2743	4235	3809	2425	3130	3461	22088
Spill (cfs)									
MOOSEHEAD LAKE (cfs		1802	3089	3089	3089	3089	3089	3089	20336
Total Inflow (cfs)		1900	3245	3204	3635	3453	3359	3308	22105
Storage (cfs)	7101	3898	7220	7052	6310	6785	7410	7544	46222
Ending Level (ft)	954.5	954.3	954.6	953.9	953.8	954.5	954.6	954.5	
WYMAN									
Generation (MWh)		774.2	1029.4	1238.0	1298.8	1362.6	1292.4	1320.9	8316
Gen. Disch. (cfs)		3088	4065	4935	5184	5424	5153	5248	33099
Spill (cfs)									
FLAGSTAFF LAKE (cfs)		29	50	50	50	50	50	50	329
Total Inflow (cfs)		3207	3955	5091	6223	5431	5462	5157	34525
Storage (cfs)	47673	27804	47729	47609	48008	48804	49071	49158	318182
Ending Level (ft)	484.0	484.1	484.1	484.2	484.8	484.8	485.0	484.9	
WILLIAMS									
Generation (MWh)		191.3	320.4	323.6	317.9	337.8	330.8	346.2	2168
Gen. Disch. (cfs)		2579	4422	4422	4422	4422	4422	4422	29110

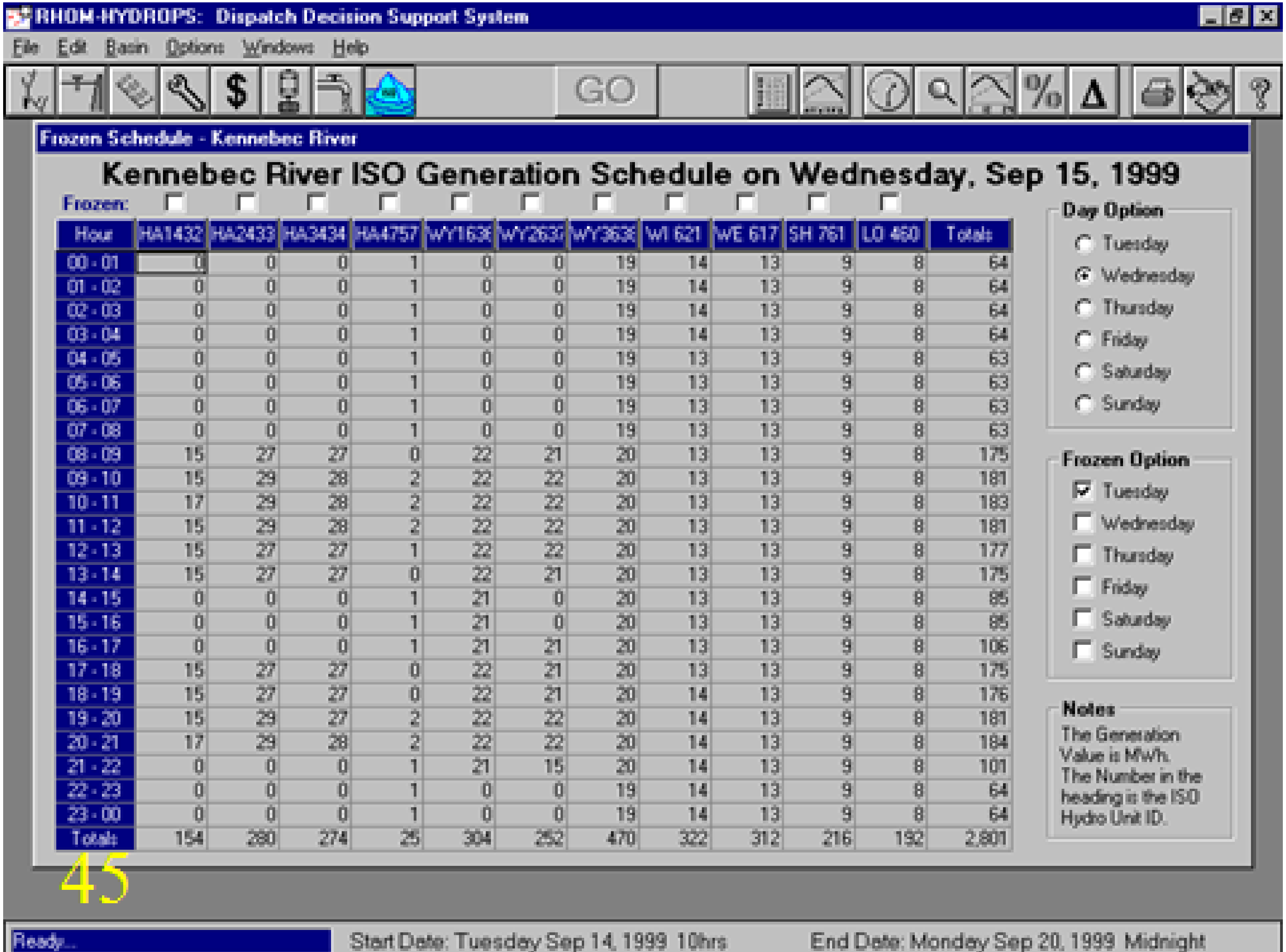
Daily Pre-Schedule



Harris Hourly Results for Wednesday, September 15, 1999

Hour	1	2	3	4	Totals
00 - 01	0.1			1.5	1.6
01 - 02	0.1			1.5	1.6
02 - 03	0.1			1.5	1.6
03 - 04	0.1			1.5	1.6
04 - 05	0.1			1.5	1.6
05 - 06	0.1			1.5	1.6
06 - 07	0.1			1.5	1.6
07 - 08	0.1			1.5	1.6
08 - 09	15.3	27.0	27.1		69.4
09 - 10	15.3	28.7	28.4	1.5	73.9
10 - 11	16.7	28.6	28.5	1.5	75.3
11 - 12	15.3	28.6	28.5	1.5	73.9
12 - 13	15.3	26.9	27.1	1.4	70.7
13 - 14	14.9	26.9	27.1		68.9
14 - 15	0.1			1.5	1.6
15 - 16	0.1			1.5	1.6
16 - 17	0.1			1.5	1.6
17 - 18	15.3	26.9	27.1		69.3
18 - 19	15.3	26.9	27.1		69.3
19 - 20	15.3	28.6	27.0	1.5	72.4
20 - 21	16.6	28.5	28.4	1.5	75.0
21 - 22	0.1			1.5	1.6
22 - 23	0.1			1.5	1.6
23 - 00	0.1			1.5	1.6
Totals	156.6	277.7	276.2	29.5	740.1

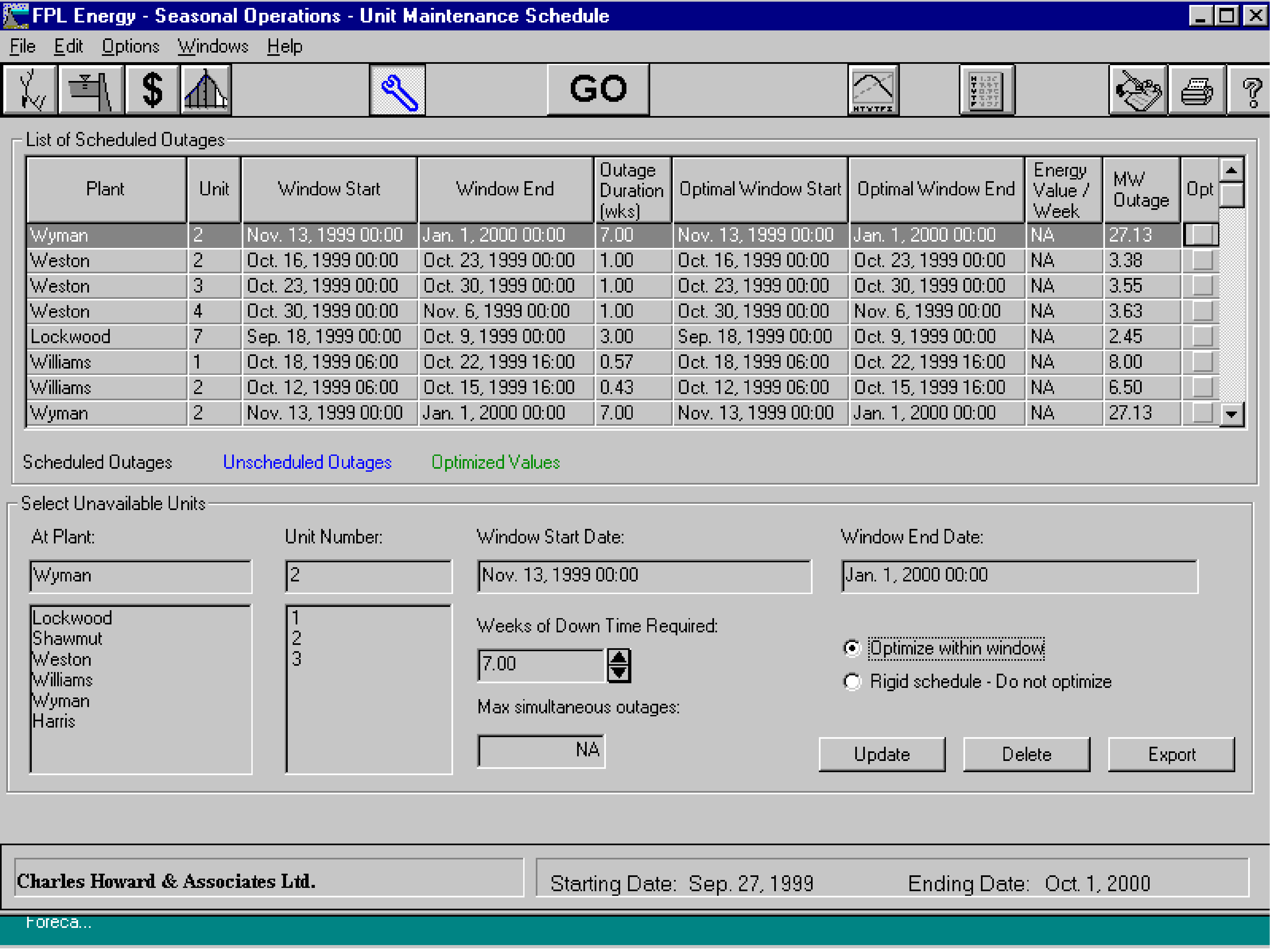
Bids to Independent System Operator



Hour	HA1432	HA2433	HA3434	HA4757	WY163	WY263	WY363	WI 621	WE 617	SH 761	LO 460	Totals
00 - 01	0	0	0	1	0	0	19	14	13	9	8	64
01 - 02	0	0	0	1	0	0	19	14	13	9	8	64
02 - 03	0	0	0	1	0	0	19	14	13	9	8	64
03 - 04	0	0	0	1	0	0	19	14	13	9	8	64
04 - 05	0	0	0	1	0	0	19	13	13	9	8	63
05 - 06	0	0	0	1	0	0	19	13	13	9	8	63
06 - 07	0	0	0	1	0	0	19	13	13	9	8	63
07 - 08	0	0	0	1	0	0	19	13	13	9	8	63
08 - 09	15	27	27	0	22	21	20	13	13	9	8	175
09 - 10	15	29	28	2	22	22	20	13	13	9	8	181
10 - 11	17	29	28	2	22	22	20	13	13	9	8	183
11 - 12	15	29	28	2	22	22	20	13	13	9	8	181
12 - 13	15	27	27	1	22	22	20	13	13	9	8	177
13 - 14	15	27	27	0	22	21	20	13	13	9	8	175
14 - 15	0	0	0	1	21	0	20	13	13	9	8	85
15 - 16	0	0	0	1	21	0	20	13	13	9	8	85
16 - 17	0	0	0	1	21	21	20	13	13	9	8	106
17 - 18	15	27	27	0	22	21	20	13	13	9	8	175
18 - 19	15	27	27	0	22	21	20	14	13	9	8	176
19 - 20	15	29	27	2	22	22	20	14	13	9	8	181
20 - 21	17	29	28	2	22	22	20	14	13	9	8	184
21 - 22	0	0	0	1	21	15	20	14	13	9	8	101
22 - 23	0	0	0	1	0	0	19	14	13	9	8	64
23 - 00	0	0	0	1	0	0	19	14	13	9	8	64
Totals	154	280	274	25	304	252	470	322	312	216	192	2,801

Optimized Unit Maintenance

- Work Required
- Crews Available
- Regular Hours and Overtime

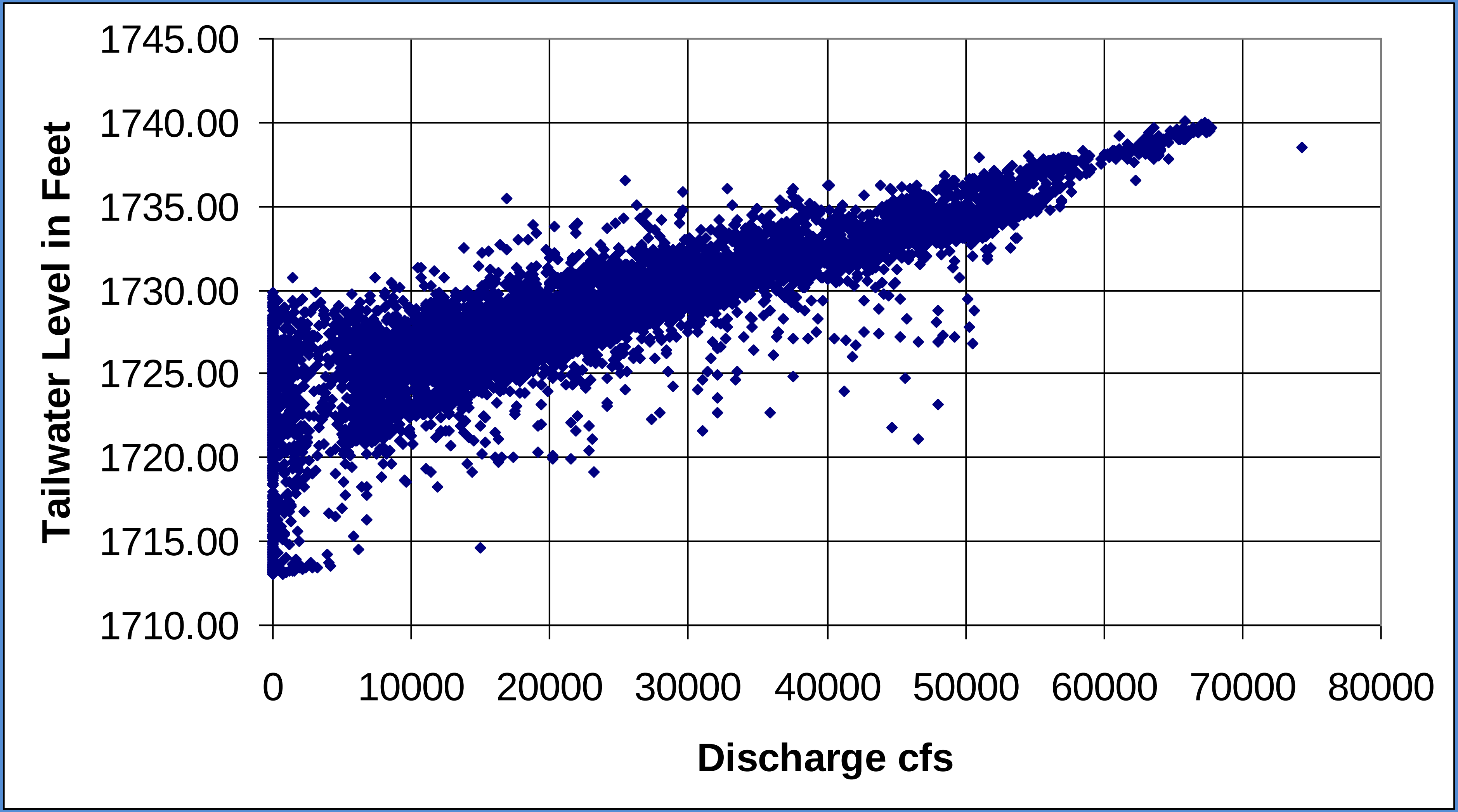


Plant	Unit	Window Start	Window End	Outage Duration (wks)	Optimal Window Start	Optimal Window End	Energy Value / Week	MW Outage	Opt
Wyman	2	Nov. 13, 1999 00:00	Jan. 1, 2000 00:00	7.00	Nov. 13, 1999 00:00	Jan. 1, 2000 00:00	NA	27.13	
Weston	2	Oct. 16, 1999 00:00	Oct. 23, 1999 00:00	1.00	Oct. 16, 1999 00:00	Oct. 23, 1999 00:00	NA	3.38	
Weston	3	Oct. 23, 1999 00:00	Oct. 30, 1999 00:00	1.00	Oct. 23, 1999 00:00	Oct. 30, 1999 00:00	NA	3.55	
Weston	4	Oct. 30, 1999 00:00	Nov. 6, 1999 00:00	1.00	Oct. 30, 1999 00:00	Nov. 6, 1999 00:00	NA	3.63	
Lockwood	7	Sep. 18, 1999 00:00	Oct. 9, 1999 00:00	3.00	Sep. 18, 1999 00:00	Oct. 9, 1999 00:00	NA	2.45	
Williams	1	Oct. 18, 1999 06:00	Oct. 22, 1999 16:00	0.57	Oct. 18, 1999 06:00	Oct. 22, 1999 16:00	NA	8.00	
Williams	2	Oct. 12, 1999 06:00	Oct. 15, 1999 16:00	0.43	Oct. 12, 1999 06:00	Oct. 15, 1999 16:00	NA	6.50	
Wyman	2	Nov. 13, 1999 00:00	Jan. 1, 2000 00:00	7.00	Nov. 13, 1999 00:00	Jan. 1, 2000 00:00	NA	27.13	

Site Specific Features

- Hydraulic Constraints
- Encroachment from below and above

Tailwater Encroachment Data



Effect of Hydraulic Control

Project Coordination Issues

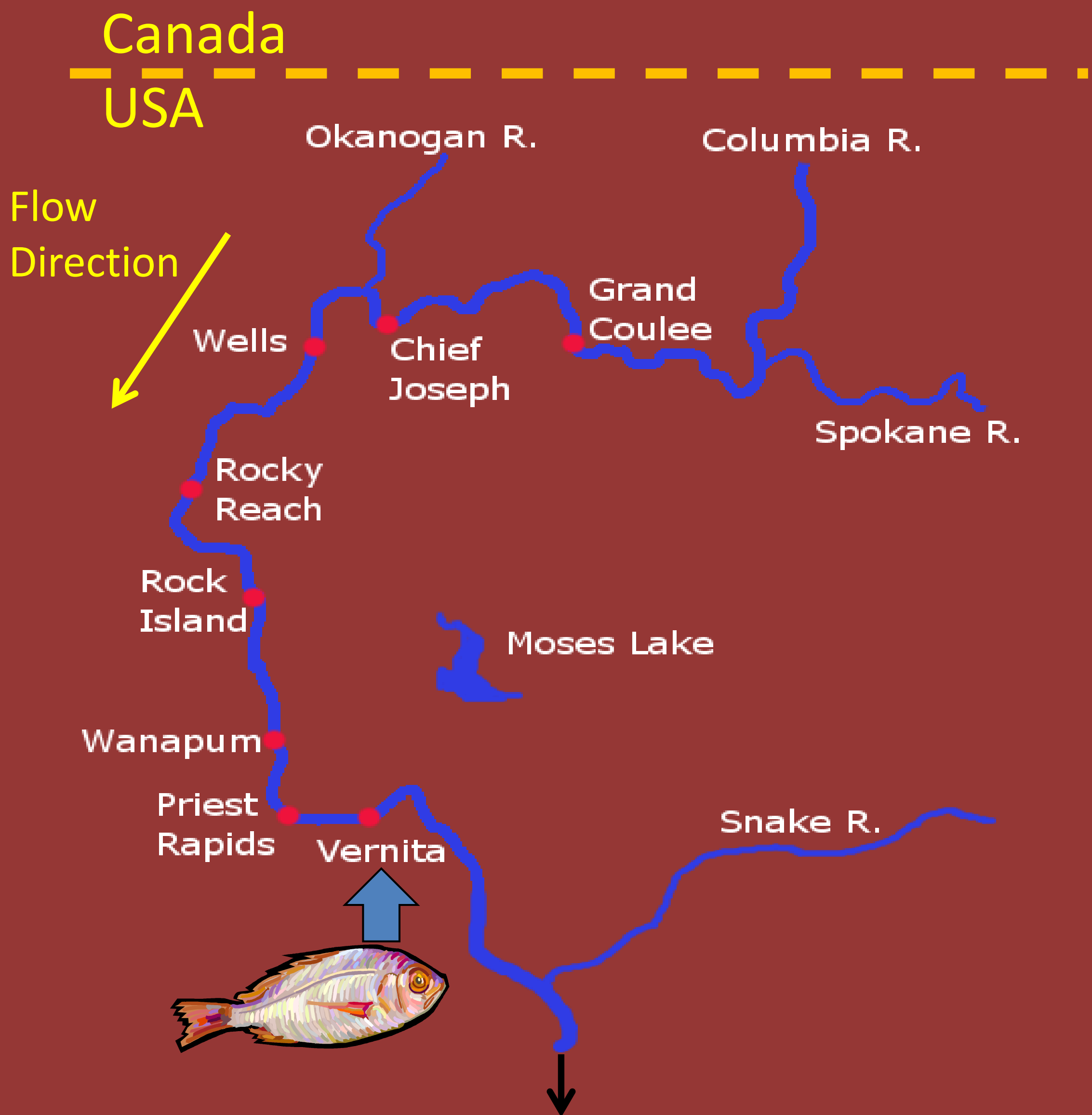
- Owners
- Governments
- Economics and Politics

Mid-Columbia Hydro System

Optimization Model of Fully Integrated Operations

SCALE IN MILES
25 0 25 50 75 100 125 150
COLUMBIA RIVER
DRAINAGE BASIN
BOUNDARY
COLUMBIA
RIVER
FRASER
RIVER
THOMPSON
Vancouver
BRITISH COLUMBIA
WASHINGTON
CANADA
UNITED STATES
Victoria
Bellingham
Seattle
Tacoma
Olympia
Portland
Spokane
Wenatchee
Yakima
Lewiston
Missoula
The Dalles
CHIEF JOSEPH
GRAND COULEE
WELLS
ROCKY REACH
ROCK ISLAND
WANAPUM
PRIEST RAPIDS
LOWER MONUMENTAL
LITTLE GOOSE
LOWER GRANITE
ICE HARBOR
McNARY
JOHN DAY
THE DALLES
BONNEVILLE
DWORSHAK
ALBENI FALLS
LIBBY
HUNGRY HORSE
SNAKE R.
RIVER
COLUMBIA
SALMON
RIVER
WASH.
OREGON

Mid-Columbia System (12,700 MW)



USA Government (10000 MW)
Grand Coulee
Chief Joseph

Douglas County (890 MW)
Wells

Chelan County (1684 MW)
Lake Chelan
Rocky Reach
Rock Island

Grant County (1865MW)
Wanapum
Priest Rapids

Objective of the Study

- Seven major hydro plants, two major reservoirs
- Four completely different owners.
- Determine the energy benefit of fully coordinated and integrated hourly operations.

Global System Water Management

- Conflicting Constraints, TDG vs Fish Spills
- Ramping Constraints
- Flood Management
- Water Level Management
- Water Quality Management
- Coordination with Downstream Projects
- Natural Channel Controls on Storage
- Hydro Plant Efficiency Curves
- System Base Points (Loads among Plants)

Optimal Generation Management

- Representation of Hill Curves
- Validation with Historical Operations Data
- Run Times for Operations Planning Studies
- Run Times for Scheduling Operations
- Run Times for Near Real-Time Operations
- Unit Priorities and Maintenance
- Hydro Plant Efficiency Curves
- Operations Constraints

Topics for Discussion

- 1. The hydro enterprise should recognize that optimization is a normal tool for hydro systems operations and it has been used in many systems, some more successfully than others.

- 2. Operations optimization will minimize errors in judgment and identify good choices from many that are feasible. This can be pivotal when changes in regulations, market conditions, the hydro system, or staff make past experience less valuable.

- 3. Data issues often dominate the design of the software and its ultimate acceptance. The model builder must anticipate that data was recorded for other prior purposes and is incomplete for the purposes of model design and verification.

- 4. Optimization software usually consists of several separate modules that deal with decisions on different time scales and spatial scope. These are sensitive issues for time and cost of model development, the execution time on a computer, and its verification and acceptance.

- 5. Models should be outwardly simple, understandable, and foolproof. User interfaces must be useful to the actual operators, not just modelers.

- 6. Before serious development effort begins, as the goals and expectations are discussed, the developer and the client should agree on criteria for acceptance, and what not to model.

- 7. For validation of its water management functions an optimization model can be run in a simulation mode using optimization output for selected variables as inputs.

- 8. Validation of optimized unit dispatch and loading should compare the optimized MW plant output with actual plant output over 24-hours at a one minute time step under a range of operating constraints and seasonal constraints.

- 9. The allocation of "base points" in a system of hydro plants should consider the oscillating shape of the plant efficiency curves as they are affected by the dispatch order of the generating units. Base points throughout the system should be selected from peaks of the plant curves to avoid asking a plant to generate in a lower efficiency trough.

- 10. Methods That are least risky for development, least expensive in time and money, and most reliable use some variant of linear programming, such as quadratic linear programming, stochastic linear programming, etc.

- 11. A useful optimization approach combines quadratic linear programming for managing the water balance with dynamic programming to dispatch generating units and construct optimized plant efficiency curves from the unit hill surfaces.

- 12. It is likely that stochastic, non-linear methods will become the methods of choice when new software makes modern multiprocessor boards with hundreds of processors more convenient for rapid integrated system-wide optimization.

- 13. The current advances in real-time wireless data acquisition and management will profoundly change the applications for optimization methods in water management and power operations.

- 14. Acceptance of the software relies on more than simply putting it in front of the intended users. The process of model validation can be an important step in training people to understand its limitations and advantages.

- 15. The software design should focus on fundamentals: reading, writing, and arithmetic of the software and its specific application. Users should not need a map to untangle a plethora of drop boxes that lead to still more drop boxes.

- 16. Stochastic optimization is a well understood method for dealing with uncertainty and probability in hydrology. It is well understood by modelers and has the potential to incorporate other factors like prices and loads to estimate risk on an ongoing basis