Southwestern Power Administration (SWPA) Use of Riverware

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Civil Engineer (Hydrologic)

February 4, 2015

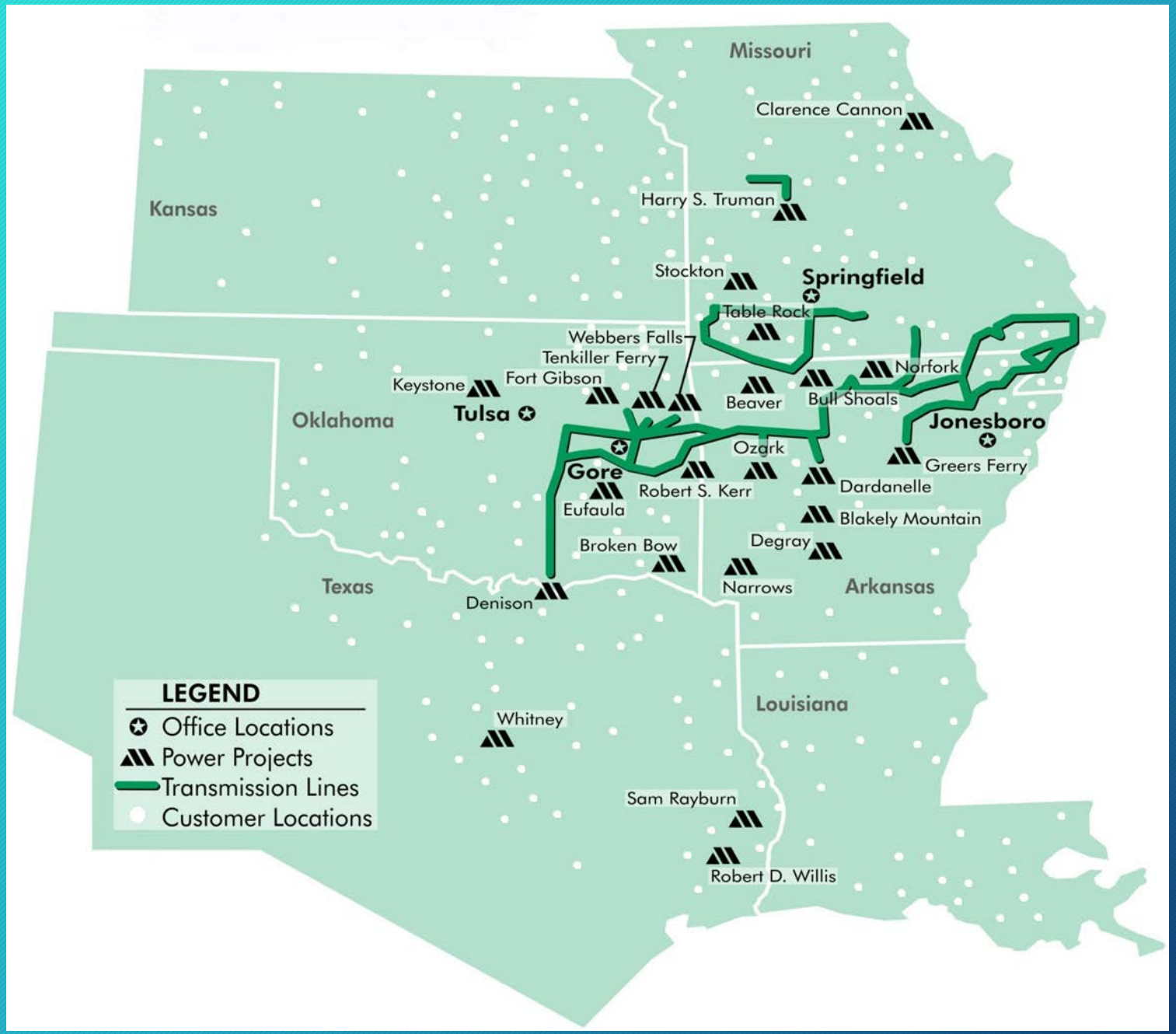
What is SWPA

Flood Control Act 1944 Section 5 Mission Statement

- "…encourage the most widespread use thereof at the lowest possible rates to consumers consistent with sound business principles… Rate schedules shall be drawn having regard to the recovery… of the cost of producing and transmitting such electric energy… Preference… shall be given to public bodies and cooperatives."
- "To market and reliably deliver Federal hydroelectric power with preference to public bodies and cooperatives. This is accomplished by maximizing the use of Federal assets to repay the Federal investment and participating with other water resource users in an effort to balance their diverse interests with power needs within broad parameters set by the U.S. Army Corps of Engineers, and implementing public policy."

Southwestern Hydropower Projects

- 24 projects with total installed capacity 2173.7 megawatts (MW), overload capacity 2478.4 MW
- Types of Projects
  - Storage projects – contain storage specifically allocated for power
  - Run-of-river projects – little, if any, allocated hydropower storage, dependent upon inflow and releases from upstream projects
- 17(19)-Reservoir Interconnected System
  - 11 storage, 6 run-of-river, and 2 exchange storage projects
  - 1867.7 MW marketed capacity, 1200-hour firm energy contracts
  - Scheduled by Southwestern and firmed-up with purchases
- Isolated Projects
  - 4 storage, 1 run-of-river project
  - 184.9 MW marketed capacity, full output to customers
  - Scheduled directly by customers' scheduling agent


Missouri
Clarence Cannon
Kansas
Harry S. Truman
Stockton
Springfield
Table Rock
Webbers Falls
Tenkiller Ferry
Keystone
Fort Gibson
Tulsa
Oklahoma
Beaver
Norfork
Bull Shoals
Jonesboro
Ozark
Greers Ferry
Gore
Robert S. Kerr
Dardanelle
Eufaula
Blakely Mountain
Broken Bow
Degray
Narrows
Texas
Arkansas
Denison
LEGEND
Office Locations
Power Projects
Transmission Lines
Customer Locations
Louisiana
Whitney
Sam Rayburn
Robert D. Willis

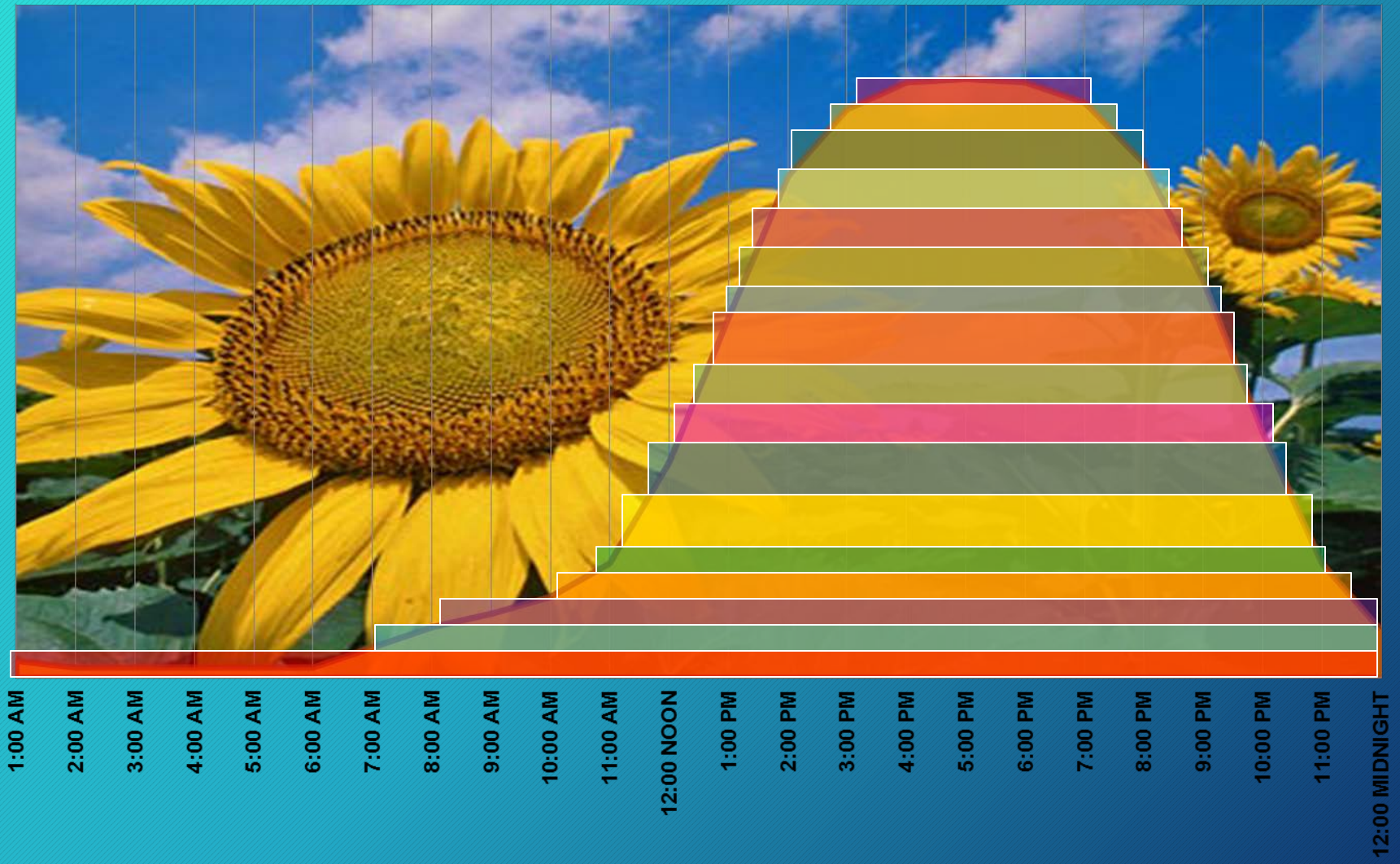
Project Characteristics and Hydrology Drive the Marketing Plan

- Water Resource Projects in Southwestern's Marketing Area
  - No snowpack, inflow is rain-dependent
  - Large variability in precipitation, seasonally and annually
  - Relatively small storage (months, not years)
  - One-third are run-of-river with minimal storage
- Current system 1200-hours Marketing Plan maximizes firm capacity and firm energy, and minimizes purchased power:
  - Max 200 hours per month and Max 600 hours per 4 consecutive months – based on inflow/storage/drawdown limits
  - Min 60 hours per month – allows Southwestern to market 1200 hours per by taking advantage of required generation (flood releases)
- With no inflow, system projects capable of producing 210 hours of energy (from 100% to 70% energy-in-storage

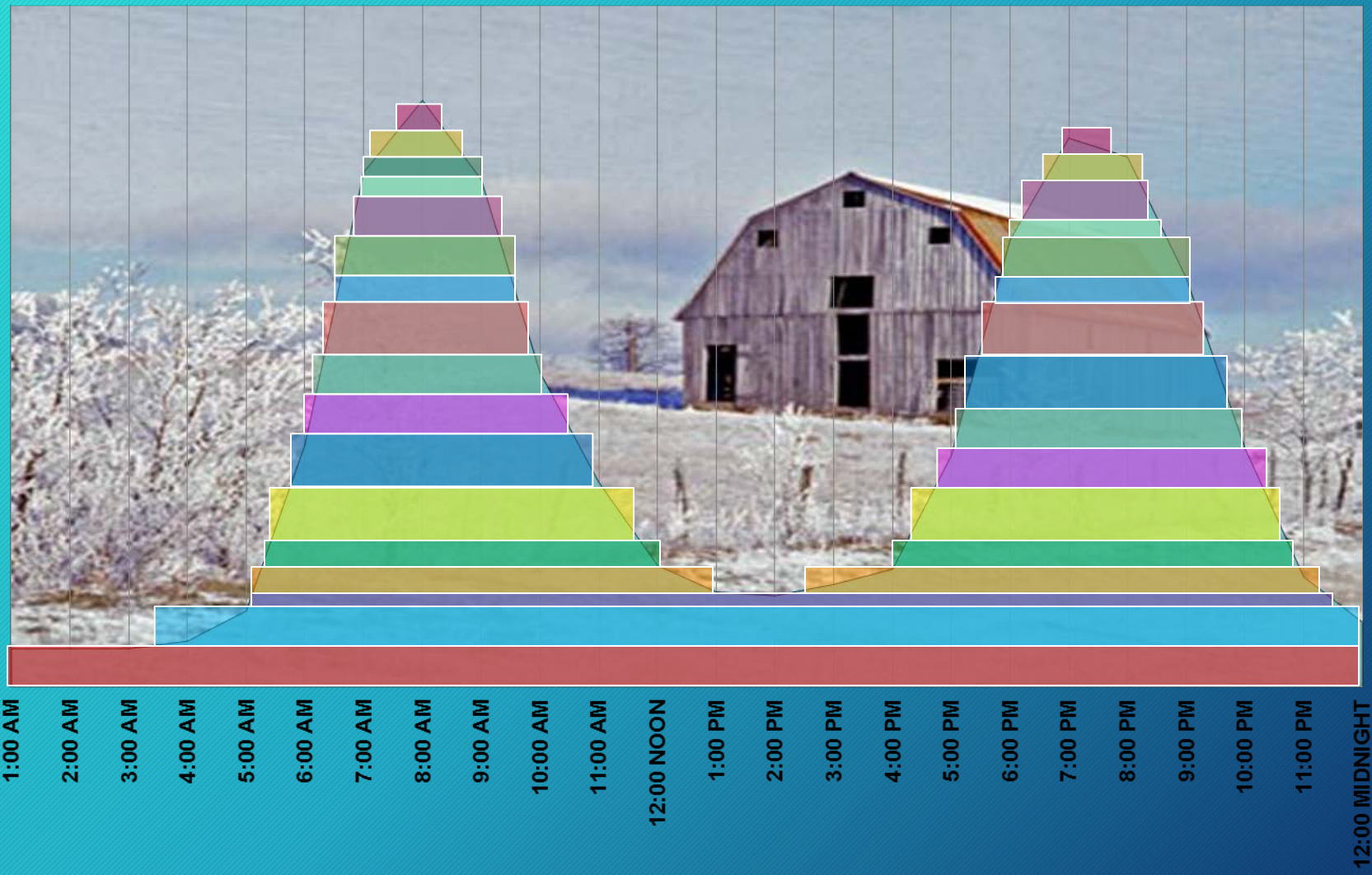
System Operations

- Just as the marketing plan is driven by the project characteristics, hydrology, and regulatory limitations, the criteria and guidelines developed for system operations are driven by the marketing plan
- Considerations
  - Operate within physical and regulatory limits (Water Control Plans, MOU with Corps)
  - Repay the financial obligations
  - Provide dependable capacity to meet the provisions of the 1980 Power Allocation
  - Provide customers with a beneficial product
  - Meet Federal responsibility for the water resource, including coordination with competing use users
  - Meet balancing area authority and NERC requirements

Summer Peaking Loads



Winter Peaking Loads



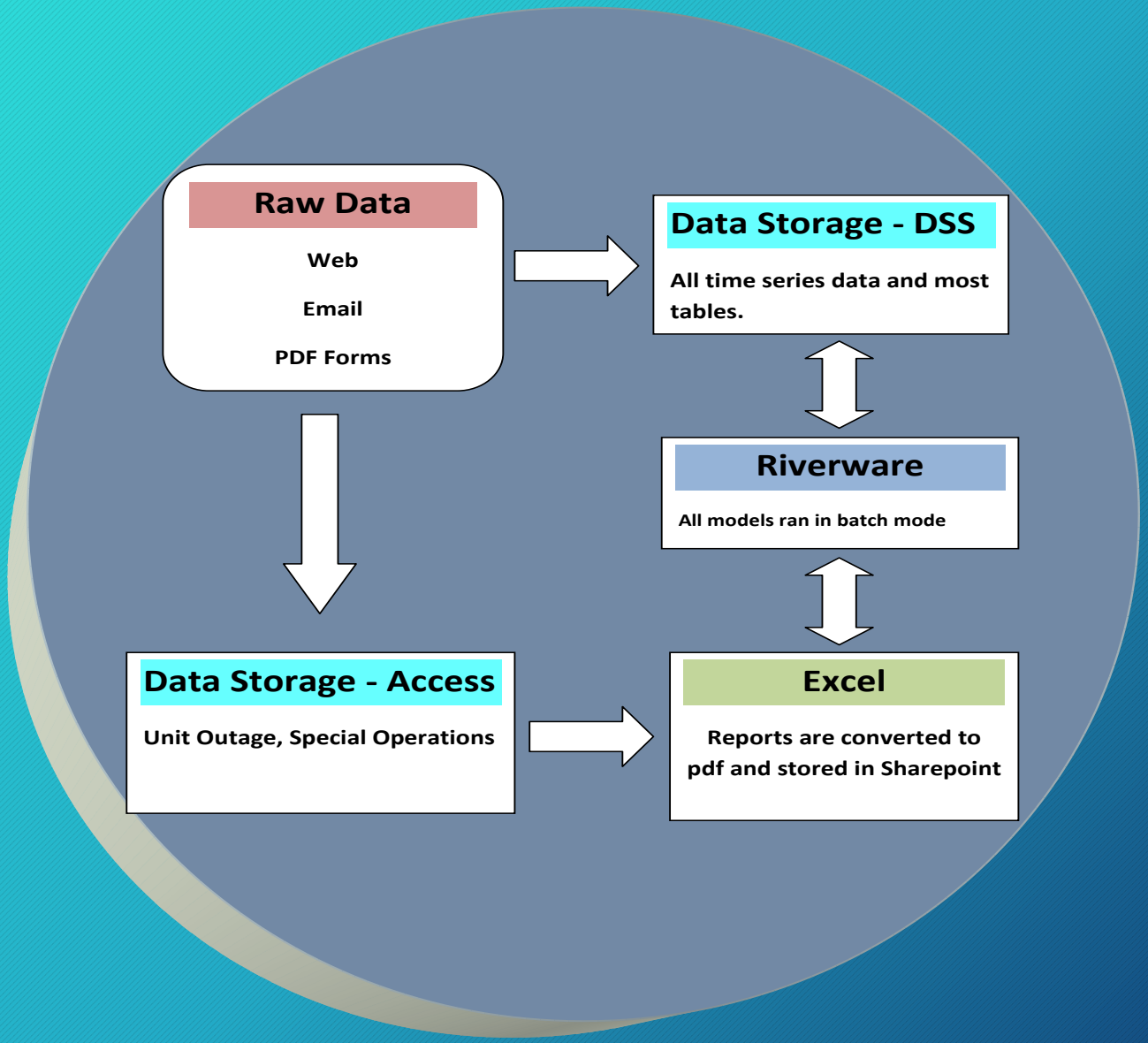
Management and Protection of the Hydropower Resource

Develop daily, weekly, and monthly resource plans:

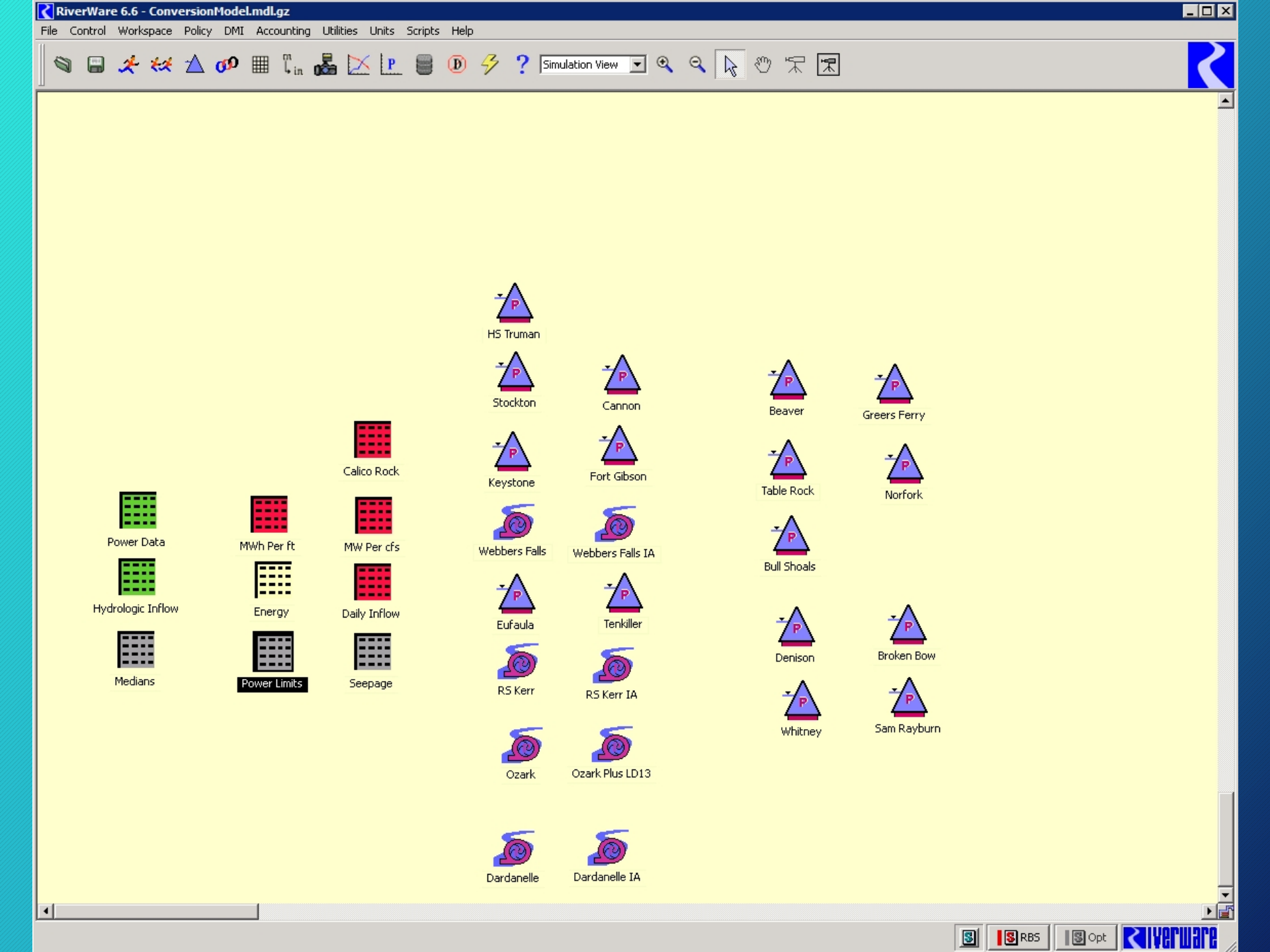
- Collect system and project conditions data, assess forecasts of hydrologic conditions, conduct resource analysis simulations
- Coordinate unit outages, transmission outages, and other maintenance work in order to maximize unit availability
- Coordinate with competing uses needs (navigation, water quality, water supply, fish and wildlife, recreation, etc.), ensuring minimal impact to hydropower operations:
  - Special operations requests
  - Endangered species operations
  - Negotiated voluntary operations for other project purposes
- Adhere to regulatory requirements, negotiate informal modifications and request formal deviations when needed
- Balance projects' energy-in-storage to maintain capacity, distribute hydrological risk, and spread potential low-pool impact evenly
- Determine replacement power purchase needs

Data Collection and Report Generation Automization

- We collect data from multiple COE websites, USGS, NOAA, SCADA, and from email (including pdf forms).
- Each day we produce a variety of reports that detail the status of the system and past and planned generation.
    a. Plant History
    b. Generation Report
    c. Current Operation Report (outflow restrictions ,special ops , outages ect.)
    d. Four Day Forecast of Inflow
    e. Planned Generation
    f. Historic Inflow Report (percent of median)
    g. Monday Morning Report



Automize (Scheduling software that runs Python and JPython scripts at times ranging from every minute to once per month)


RiverWare 6.6 - ConversionModel.mdl.gz
File Control Workspace Policy DMI Accounting Utilities Units Scripts Help
Simulation View
HS Truman
Stockton
Cannon
Beaver
Greers Ferry
Keystone
Fort Gibson
Table Rock
Norfork
Webbers Falls
Webbers Falls IA
Bull Shoals
Eufaula
Tenkiller
Denison
Broken Bow
RS Kerr
RS Kerr IA
Whitney
Sam Rayburn
Ozark
Ozark Plus LD13
Dardanelle
Dardanelle IA
Calico Rock
Power Data
MWh Per ft
MW Per cfs
Hydrologic Inflow
Energy
Daily Inflow
Medians
Power Limits
Seepage
RBS
Opt
riverware

Southwestern Power Administration
Division of Resources and Rates

Four Day Forecast - Inflow to Energy Computations

	Thu 01/29/15		Fri 01/30/15		Sat 01/31/15		Sun 02/01/15		EIS
	dsf	MWh	dsf	MWh	dsf	MWh	dsf	MWh	MWh/foot
Beaver	135	45	120	40	110	36	100	33	4,220
Table Rock	580	204	560	197	545	192	525	185	6,940
Bull Shoals	175	61	160	56	150	52	145	50	7,688
Norfork	700	212	680	206	660	200	650	197	3,164
Greers Ferry	120	39	105	34	90	29	80	26	4,917
Broken Bow	200	66	200	66	200	66	200	66	2,203
Keystone	900	120	700	93	1,400	186	1,400	186	1,381
Fort Gibson	700	74	600	64	500	53	500	53	989
Webbers Falls IA	300	16	300	16	300	16	300	16	
Webbers Falls	3,000	159	2,500	132	1,100	58	1,000	53	262
Tenkiller	500	127	500	127	400	101	400	101	1,528
Eufaula	1,000	154	1,000	154	1,300	200	1,500	231	7,178
RS Kerr IA	100	8	100	8	0	0	0	0	
RS Kerr	5,900	478	5,800	470	2,800	227	1,500	122	1,528
Ozark Plus LD13	600	32	600	32	500	27	500	27	
Ozark	7,000	378	6,000	324	5,000	270	3,000	162	228
Dardanelle IA	1,000	93	1,000	93	1,000	93	1,000	93	
Dardanelle	8,000	740	7,000	648	6,000	555	4,000	370	1,371
Stockton	250	40	250	40	250	40	225	36	1,912
HS Truman	2,600	209	2,400	193	2,200	177	2,000	161	2,215
Cannon	60	8	50	6	40	5	30	4	1,116
17 Project Total		3,112		2,848		2,448		2,035	
17 Project % Med	29%		28%		29%		18%		
Denison	500	84	500	84	500	84	500	84	6,005
Whitney	25	4	25	4	25	4	25	4	1,323
Sam Rayburn	6,000	761	6,000	761	5,500	697	5,000	634	7,300

Energies developed from midnight pool elevations on: 01/28/15

Temperature Forecast (°F)

	1/29/2015	1/30/2015	1/31/2015	2/1/2015
Calico Rock	--	--	--	--

PLANT GENERATION

Wednesday, January 28, 2015

Hour Ending	BEV	TRD	BSD	NFD	GFD	KEY	FGD	WFD	TKD	EUF	RSK	OZK	DAD	BBD	STD	HST	CAN	Sys Hydro	CU	Inter-chg	Area Load	DEN	WND	SRD	RDW
0100	0	0	7	38	0	0	0	0	0	0	0	20	0	0	0	0	0	65	0	196	73	0	0	26	1.7
0200	0	0	7	37	0	0	0	0	0	0	0	19	0	0	0	0	0	63	0	176	71	0	0	25	1.7
0300	0	0	7	41	0	0	0	0	0	0	0	20	0	0	0	0	0	68	0	181	69	0	0	25	1.6
0400	0	0	7	38	0	0	0	0	0	0	0	20	0	0	0	0	0	65	0	164	84	0	0	25	1.7
0500	0	0	7	39	0	0	0	1	0	0	0	20	0	0	0	0	0	67	0	174	76	0	0	25	1.8
0600	2	2	9	39	2	2	1	22	1	4	3	39	3	3	1	2	0	135	0	237	81	0	0	25	1.7
0700	110	98	99	78	88	70	48	22	40	90	102	40	96	100	50	58	0	1189	0	1299	102	0	0	25	1.7
0800	109	99	152	80	88	70	47	21	40	89	104	40	106	100	52	60	0	1257	0	1389	101	0	0	25	1.7
0900	4	2	140	11	86	0	0	22	40	0	57	40	104	97	51	0	0	654	0	803	86	0	0	25	1.8
1000	0	0	82	0	2	0	0	0	0	0	0	39	1	0	2	0	0	126	0	276	84	0	0	25	1.7
1100	0	0	26	0	0	0	0	0	0	0	0	3	0	0	0	0	0	29	0	183	80	0	0	25	1.7
1200	0	0	38	0	0	0	0	0	0	0	0	39	0	0	0	0	0	77	0	226	84	0	0	25	1.7
1300	0	0	26	0	0	0	0	0	0	0	0	40	0	0	0	0	0	66	0	224	76	0	0	25	1.8
1400	0	0	24	0	0	0	0	0	0	0	0	38	0	0	3	0	0	65	0	226	73	0	0	25	1.7
1500	0	0	44	0	0	0	0	0	0	0	0	2	0	0	1	0	0	47	0	214	67	0	0	25	1.7
1600	0	0	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	0	222	73	0	0	25	1.7
1700	0	0	41	1	2	0	0	1	0	0	1	0	2	3	1	0	0	52	0	227	59	0	0	25	1.9
1800	0	0	52	79	90	0	1	22	40	3	55	40	104	98	51	2	0	637	0	790	81	0	0	26	1.7
1900	0	0	107	79	92	0	46	22	39	88	57	40	105	100	51	58	0	884	0	1041	77	0	0	25	1.9
2000	0	0	108	77	91	0	0	21	39	1	54	40	106	50	52	30	0	669	0	829	73	0	0	25	1.8
2100	0	0	44	2	0	0	0	1	0	0	2	0	36	1	0	0	0	86	0	250	70	0	0	25	1.9
2200	0	0	40	0	0	0	0	0	0	0	0	0	1	0	0	0	0	41	0	166	77	0	0	25	1.9
2300	0	0	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	0	153	64	0	0	25	1.9
2400	0	0	35	0	0	0	0	0	0	0	0	1	0	0	0	0	0	36	0	147	74	0	0	25	1.9
TOT Day	225	201	1200	639	541	142	143	155	239	275	435	540	664	552	315	210	0	6476	0	9793	1855	0	0	602	42.3
MTD	7111	22310	35869	11354	12880	1738	7605	5497	7742	6886	15866	9162	35447	11364	4003	5272	775	200881	775	291510	57150	248	0	8255	1288.5
Off Peak	2	2	115	232	2	2	1	23	1	4	3	139	3	3	1	2	0	535	0	1428	592	0	0	201	14
On Peak	223	199	1085	407	539	140	142	132	238	271	432	401	661	549	314	208	0	5941	0	8365	1263	0	0	401	28.3

PROJECTED LOADING SCHEDULE — Wednesday, May 14, 2014 — CALICO ROCK TEMP: 64

	BBD	DEN	KEY	FGD	WFD	TKD	EUF	R3K	OZK	DAD	BEV	TRD	BSD	NFD	GFD	STD	HST	CAN
0100	100	0	0	0	0	20	0	0	0	35	0	25	7	0	0	0	0	0
0200	100	0	0	0	0	20	0	0	0	35	0	25	7	0	0	0	0	0
0300	100	0	0	0	0	20	0	0	0	35	0	25	7	0	0	0	0	0
0400	100	0	0	0	0	20	0	0	0	35	0	25	7	0	48	0	0	0
0500	100	0	0	0	0	20	0	0	0	70	0	25	7	0	48	0	0	0
0600	100	0	0	0	0	20	30	0	0	35	0	25	7	0	48	0	0	0
0700	100	0	0	0	0	20	60	0	0	105	0	25	7	0	48	0	0	0
0800	100	0	0	0	0	20	90	0	0	105	0	25	7	0	48	0	0	0
0900	100	0	0	0	0	20	0	0	0	35	0	25	7	0	48	0	0	0
1000	100	0	0	0	0	20	0	0	0	35	0	25	7	0	48	0	0	0
1100	100	0	0	0	0	20	0	0	0	35	0	25	7	0	48	0	0	0
1200	100	0	0	0	0	20	0	0	0	35	0	25	7	0	48	0	0	0
1300	100	0	0	0	0	20	0	0	0	35	0	25	7	0	48	0	0	0
1400	100	0	0	0	0	20	0	0	0	70	0	25	7	0	48	0	0	30
1500	100	0	35	0	0	20	0	0	0	70	0	25	40	0	48	0	0	60
1600	100	0	35	0	0	20	0	0	0	70	0	25	40	0	48	0	0	60
1700	100	0	35	0	0	20	0	0	0	70	0	25	7	0	48	0	0	60
1800	100	0	35	0	0	20	30	0	0	105	0	25	7	0	48	0	30	60
1900	100	0	0	0	0	20	60	0	0	140	0	25	7	0	48	0	30	60
2000	100	0	0	0	0	20	60	0	0	140	0	25	7	0	48	0	30	60
2100	100	0	0	0	0	20	90	0	0	140	29	25	7	40	48	0	90	60
2200	100	0	0	0	0	20	60	0	0	140	0	25	7	0	48	0	60	60
2300	100	0	0	0	0	20	0	0	0	105	0	25	7	0	48	0	0	30
2400	100	0	0	0	0	20	0	0	0	35	0	25	7	0	48	0	0	0
	2400	0	140	0	0	480	480	0	0	1715	29	600	234	40	1008	0	240	540
	MIN	SCH	MIN	EST	EST	MIN	MIN	EST	UNAV	EST	MIN	EST	EST	MIN	TGT	UNAV	MIN	TGT
	2		2, 5			2	2				2	2	1, 2, 6	1, 2	3		2, 4	3
	2400		140			480	480				29	34	80	40	1008		240	540
	MIN		MIN			MIN	MIN				MIN	MIN	MIN	MIN	TGT		MIN	TGT
													1352	410				
													MAX	MAX				

GENERATION NOTES:

CHECK MEMO PAGE FOR SUPPLEMENTAL PRIORITY

REGULATING PRIORITY LIST: TRD,BSD,GFD,BEV,EUF,DAD,NFD,Purch

PLT PRIORITY LIST: 1. Run-of-River 2. BBD,TKD 3. EUF,CAN,KEY,GFD,HST,FGD,BEV,TRD 4. BSD,NFD 5. STD

WATER SHEET ASSUMPTIONS: Regulate with Table Rock, next follow priority above; Reserves the same

Current Outages: FGD4(5/16/14), WFD1(7/31/14), TKD2(8/8/14), OZK1(8/30/15), OZK2(5/28/14), OZK3(11/30/14), OZK4(5/16/14), OZK5(8/28/14), BSD4(8/28/14), BSD5(5/15/14), BSD6(5/15/14), BSD7(5/15/14), BSD8(5/15/14), GFD2(5/15/14), STD1(7/3/14), HST8(12/18/14)

1 - Maximums for Flood Pool or Downstream Req'mt: BSD (1352 MWh), NFD (410 MWh)

2 - Minimums for Flood Pool or Downstream Req'mt: BBD (2400 MWh), KEY (140 MWh), TKD (480 MWh), EUF (480 MWh), BEV (29 MWh), TRD (34 MWh), BSD (80 MWh), NFD (40 MWh), HST (240 MWh)

3 - Targets for Flood Pool or Downstream Req'mt: GFD (1008 MWh), CAN (540 MWh)

4 - HS Truman - Weekday Rule: only peak 120 MW (4 units) over the minimum MW (# units) run in the previous 24 hours

5 - Keystone - Generate Minimum of 35 MW HE 1500 (5/14/14) - HE 1800 (5/14/14) for ODWC striper sampling directly below Keystone Dam Contact: Eric Brennan 918-504-2212

6 - Bull Shoals - Generate 7 MW for Minimum Flow Release each hour that BSD is not regulating or needed to meet loads (7 MW is not deducted from SWPA storage). TGT,MIN, or MAX is IN ADDITION to minimum flow generation. Call Tulsa Resources w/ Qs

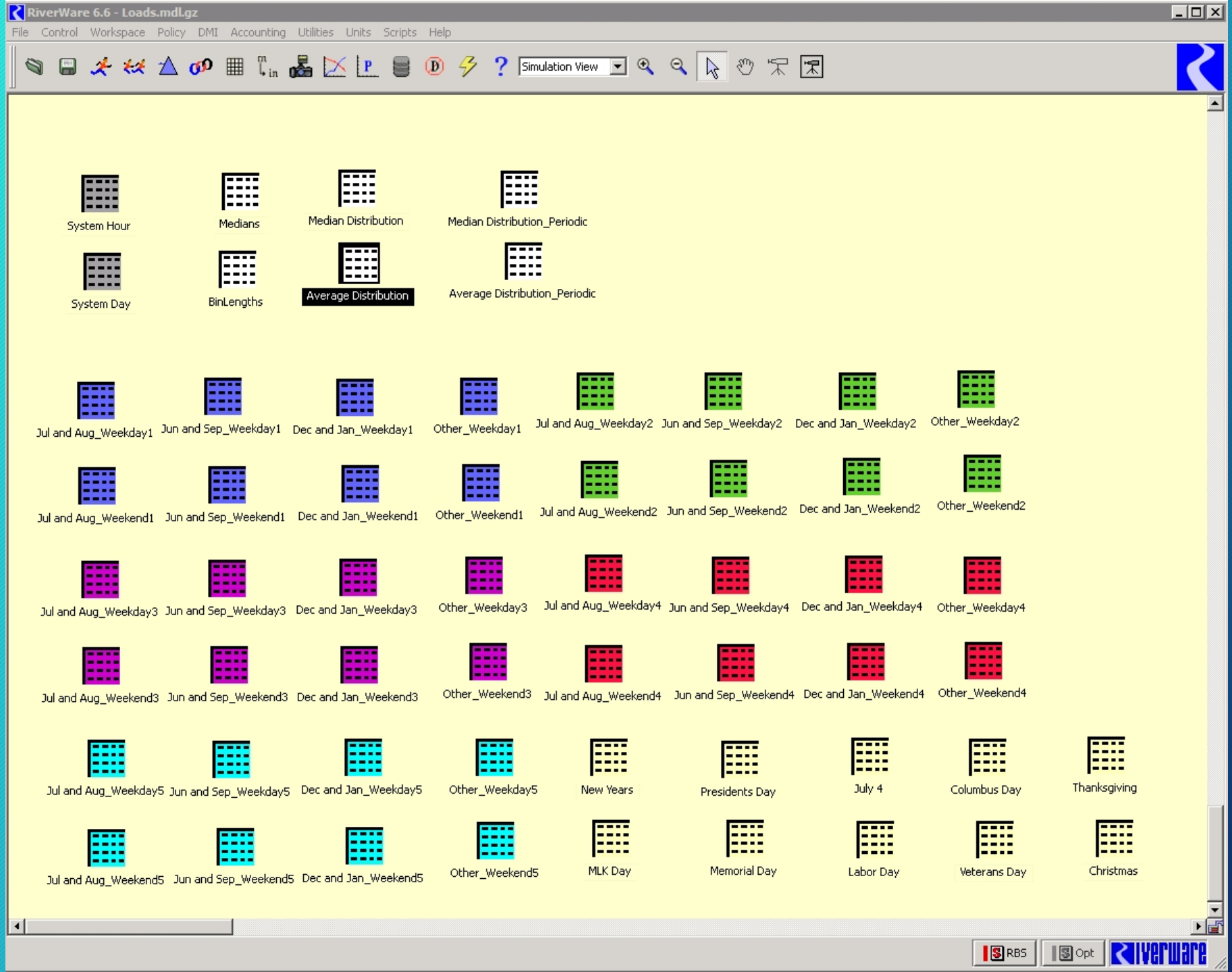
Plant KEY: Yellow Special Op | Blue Outage | Green Special Op & Outage Or Recommend Max Gen | Red Plant Unavailable

Longer Term Resource Planning Weekly, Monthly, Multi-Year

- Currently using a custom model (ironically named PRSM) that runs on a monthly timestep
- Model does not fully incorporate flood control operations, voltage regulation requirements, at best estimates minimum flows, and is difficult to use for evaluating changes in operation policy.
- Additionally it is fairly cumbersome to use and produce reports from (1980's technology)
- Solution take advantage of Flood Control Riverware models developed by John Daylor and Mary Ann Duke (Tulsa District COE) and Jan Jones (Little Rock District COE) to produce a daily timestep model of our entire system.
- Needed to develop a method for predicting historical and future electrical loads.

Electrical Loads

- Predicting our electrical load is hard to do with great confidence, but good modeling historical or future conditions is dependent upon reasonable predictions of load.
- The only firm information we know is that loads tend to be higher during very hot and very cold periods and that seasonally they change.
- To develop a reasonable daily/hourly electrical load for historical analysis and to help predict electrical load for future operations, a heuristic, non parametric procedure was developed utilizing Riverware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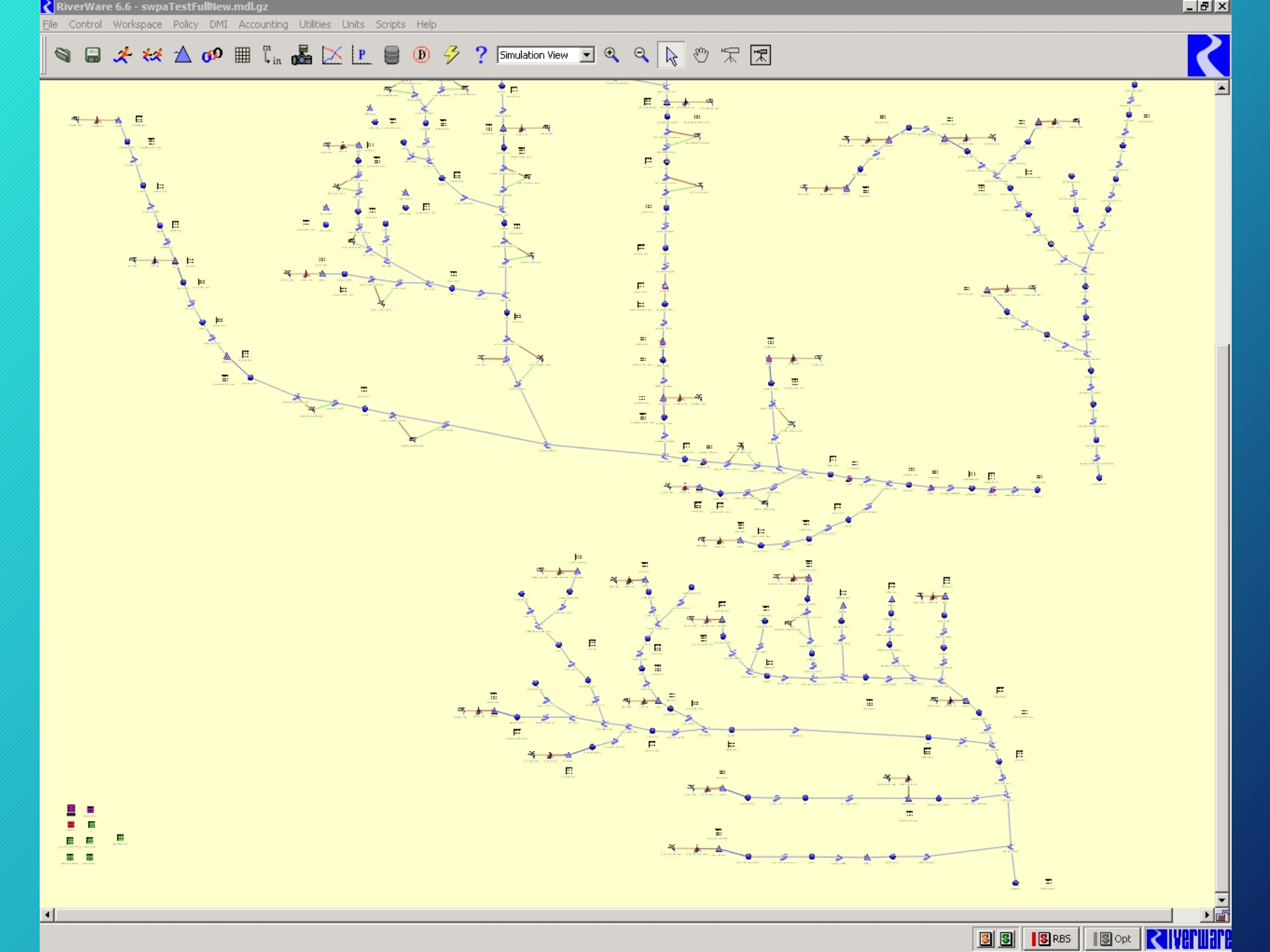
File Control Workspace Policy DMI Accounting Utilities Units Scripts Help
Simulation View
System Hour
Medians
Median Distribution
Median Distribution_Periodic
System Day
BinLengths
Average Distribution
Average Distribution_Periodic
Jul and Aug_Weekday1
Jun and Sep_Weekday1
Dec and Jan_Weekday1
Other_Weekday1
Jul and Aug_Weekday2
Jun and Sep_Weekday2
Dec and Jan_Weekday2
Other_Weekday2
Jul and Aug_Weekend1
Jun and Sep_Weekend1
Dec and Jan_Weekend1
Other_Weekend1
Jul and Aug_Weekend2
Jun and Sep_Weekend2
Dec and Jan_Weekend2
Other_Weekend2
Jul and Aug_Weekday3
Jun and Sep_Weekday3
Dec and Jan_Weekday3
Other_Weekday3
Jul and Aug_Weekday4
Jun and Sep_Weekday4
Dec and Jan_Weekday4
Other_Weekday4
Jul and Aug_Weekend3
Jun and Sep_Weekend3
Dec and Jan_Weekend3
Other_Weekend3
Jul and Aug_Weekend4
Jun and Sep_Weekend4
Dec and Jan_Weekend4
Other_Weekend4
Jul and Aug_Weekday5
Jun and Sep_Weekday5
Dec and Jan_Weekday5
Other_Weekday5
New Years
Presidents Day
July 4
Columbus Day
Thanksgiving
Jul and Aug_Weekend5
Jun and Sep_Weekend5
Dec and Jan_Weekend5
Other_Weekend5
MLK Day
Memorial Day
Labor Day
Veterans Day
Christmas
RBS
Opt
RiverWare

SWPA Planning Model

- Added two additional flood control basins in order to fully incorporate all of the reservoirs we operate in our integrated system (Osage and Salt River Basins)
- Modified the existing COE models
  a. Changed how Firm Power is used
  b. Added inline power plants for ROR projects
  c. Added calculation of minimum flows according to temperature
  d. Set electrical loads based upon temperature (instead of table)
  e. Added accounting for keeping track of minimum flow pools
- Modified Riverware methods
  a. Added new Inline Power Plant Method
  b. Modified Riverware so that electrical load could be input via rule
  c. Found multiple bugs in Phase Balancing Flood Control Method

SWPA Planning Model

- The resulting daily timestep model has 5 separate flood control basins that include:
  a. 35 storage reservoirs
  b. 17 level power reservoirs
  c. 4 inline power plants
  d. Utilization of accounting to track water utilization of various water users at 5 reservoirs
  e. Utilization of Hypothetical Simulation to adjust power production at inline power plants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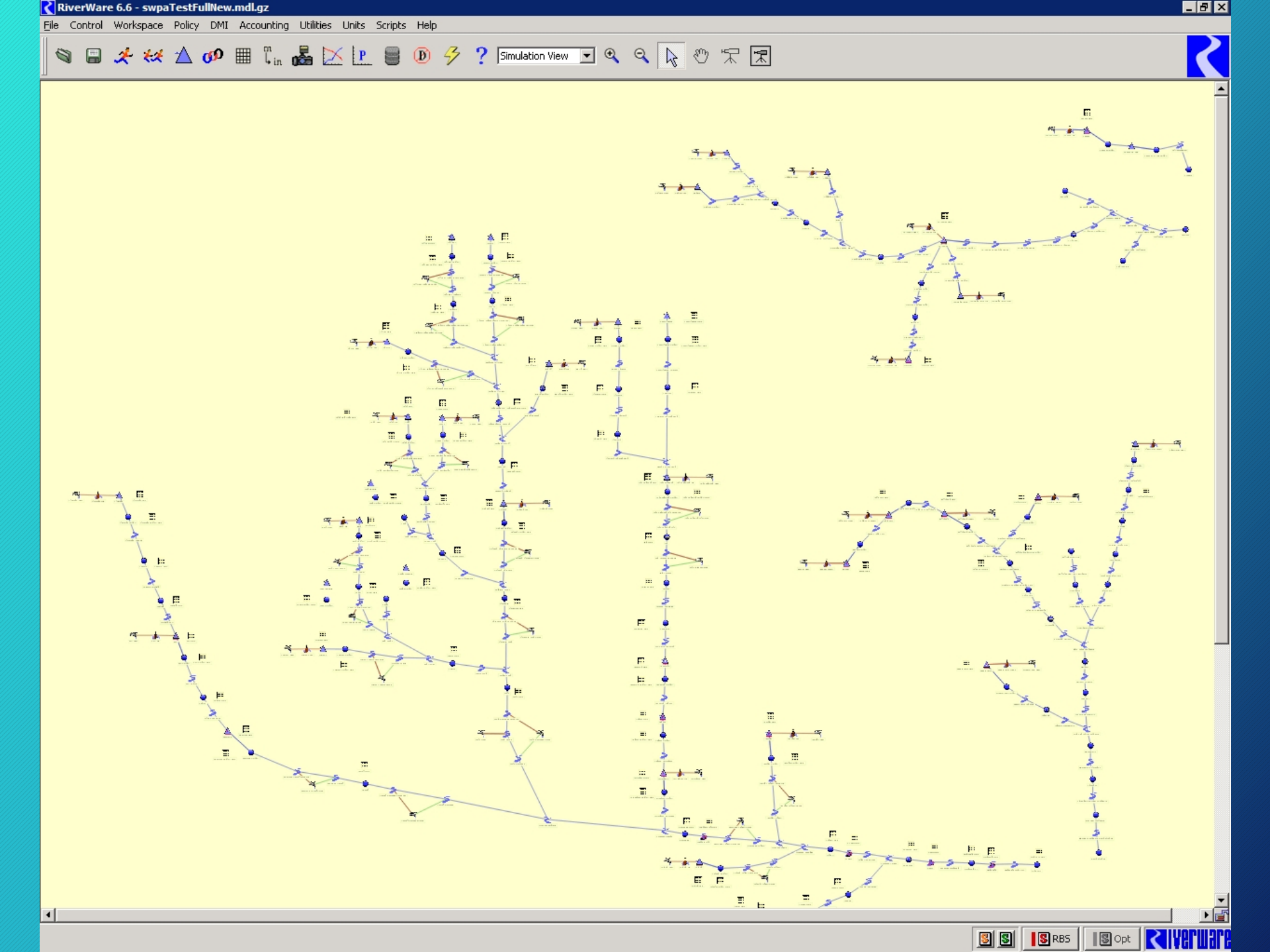
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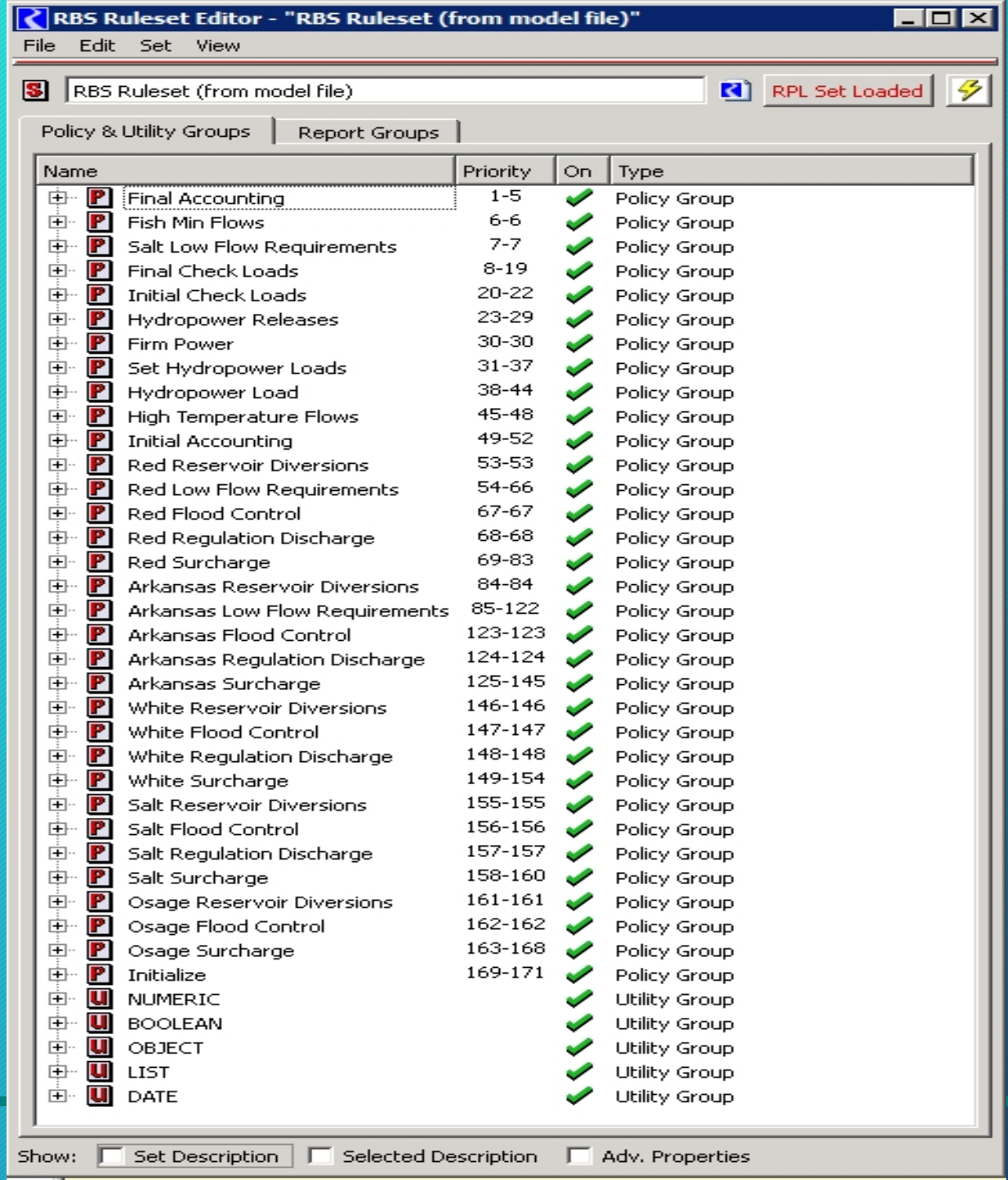
RBS Ruleset Editor - "RBS Ruleset (from model file)"
File
Edit
Set
View
RBS Ruleset (from model file)
RPL Set Loaded
Policy & Utility Groups
Report Groups
Name
Priority
On
Type
Final Accounting 1-5 Policy Group
Fish Min Flows 6-6 Policy Group
Salt Low Flow Requirements 7-7 Policy Group
Final Check Loads 8-19 Policy Group
Initial Check Loads 20-22 Policy Group
Hydropower Releases 23-29 Policy Group
Firm Power 30-30 Policy Group
Set Hydropower Loads 31-37 Policy Group
Hydropower Load 38-44 Policy Group
High Temperature Flows 45-48 Policy Group
Initial Accounting 49-52 Policy Group
Red Reservoir Diversions 53-53 Policy Group
Red Low Flow Requirements 54-66 Policy Group
Red Flood Control 67-67 Policy Group
Red Regulation Discharge 68-68 Policy Group
Red Surcharge 69-83 Policy Group
Arkansas Reservoir Diversions 84-84 Policy Group
Arkansas Low Flow Requirements 85-122 Policy Group
Arkansas Flood Control 123-123 Policy Group
Arkansas Regulation Discharge 124-124 Policy Group
Arkansas Surcharge 125-145 Policy Group
White Reservoir Diversions 146-146 Policy Group
White Flood Control 147-147 Policy Group
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Salt Flood Control 156-156 Policy Group
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Salt Surcharge 158-160 Policy Group
Osage Reservoir Diversions 161-161 Policy Group
Osage Flood Control 162-162 Policy Group
Osage Surcharge 163-168 Policy Group
Initialize 169-171 Policy Group
NUMERIC Utility Group
BOOLEAN Utility Group
OBJECT Utility Group
LIST Utility Group
DATE Utility Group
Show:
Set Description
Selected Description
Adv. Properties

Where to from here?

- Finish extending Osage Basin hydrology back to 1940 and extend all basins hydrology to 2014
- Convert from historical time horizon planning to operation model (weekly and monthly time horizon)
- Further investigate Optimization for setting loads, helping with power purchase decisions and daily operation plan development.

Questions?