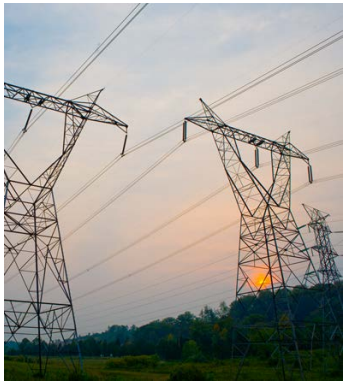
River Management Overview & RiverWare Integration

Melissa Lindquist & Gabriel Miller

What is TVA?

A power company
and so much more…

TVA's Mission of Service



Energy

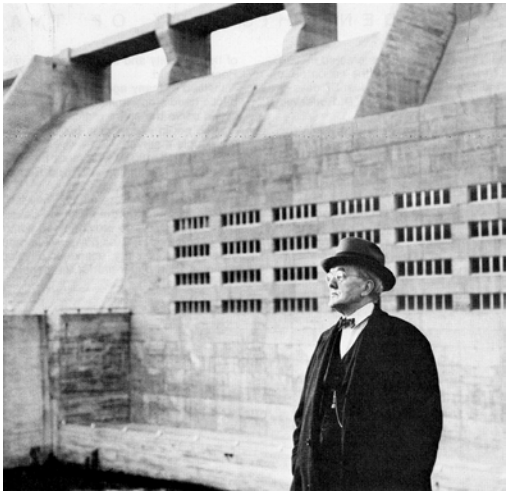
Environment

Economic Development

Integrated Resource Management

River system assigned multipurpose role through TVA Act in 1933

(section 9a) …to regulate the stream flow primarily for the purposes of promoting navigation and controlling floods. So far as may be consistent with such purposes, ...for the generation of electric energy...



“Father of TVA,” Senator George Norris

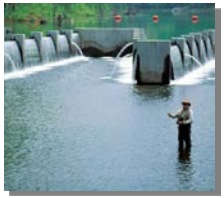
Integrated Tennessee River System
Provides Multiple Benefits

Navigation

Flood -Damage Reduction

Power Generation

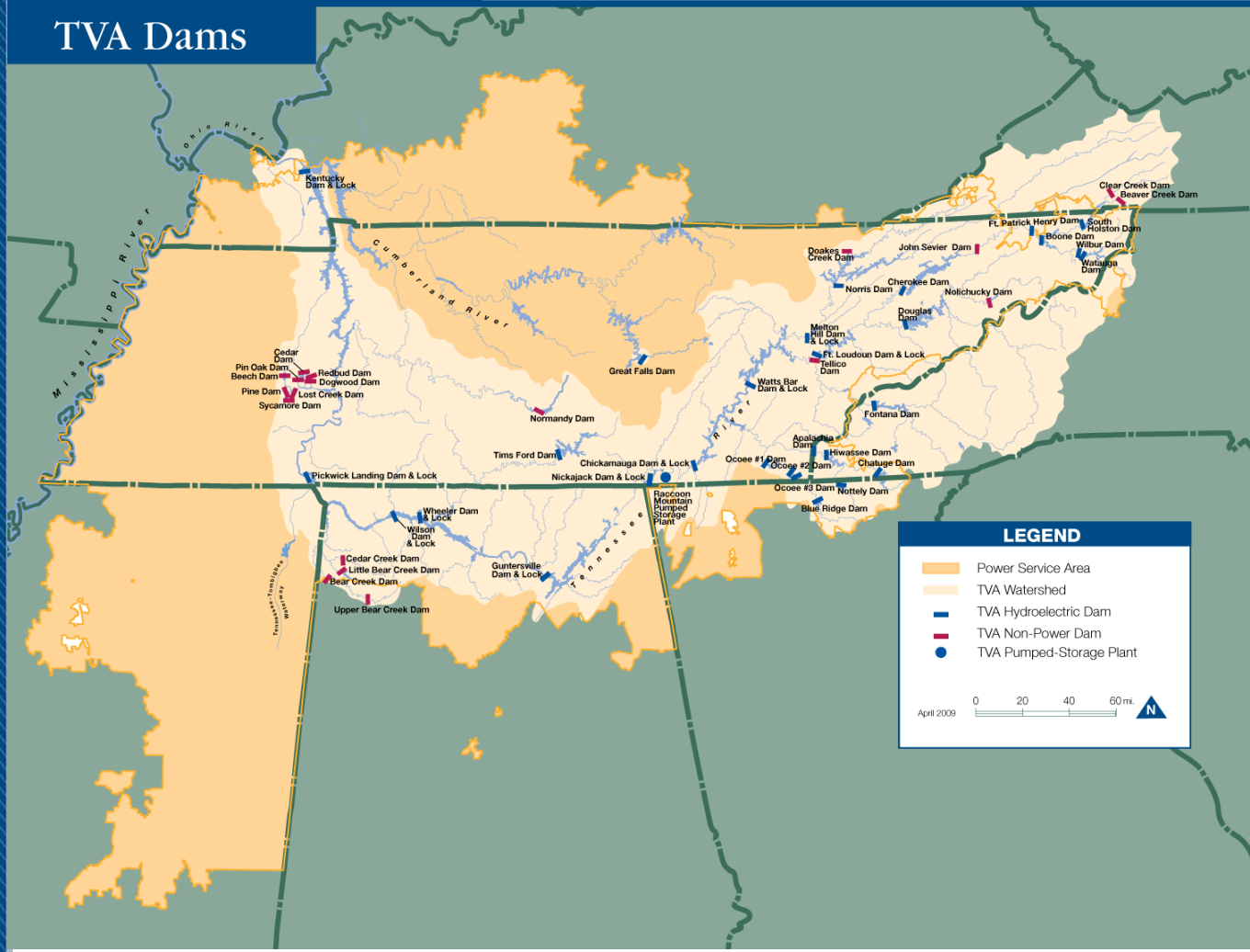
Water Supply



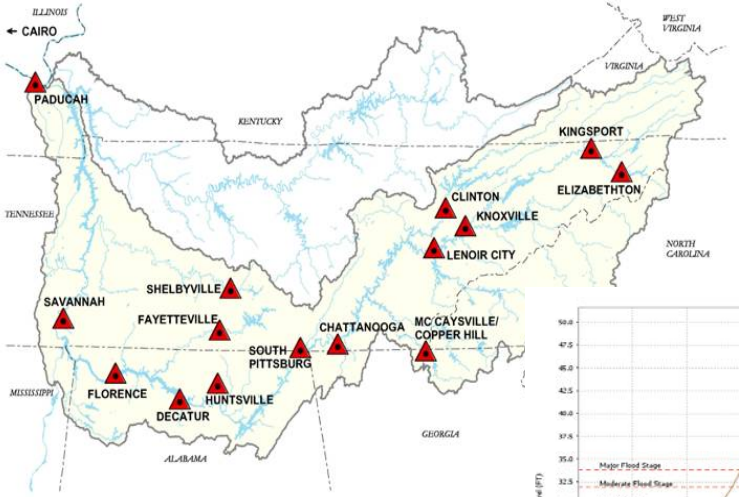
Water Quality

Recreation

TVA Dams

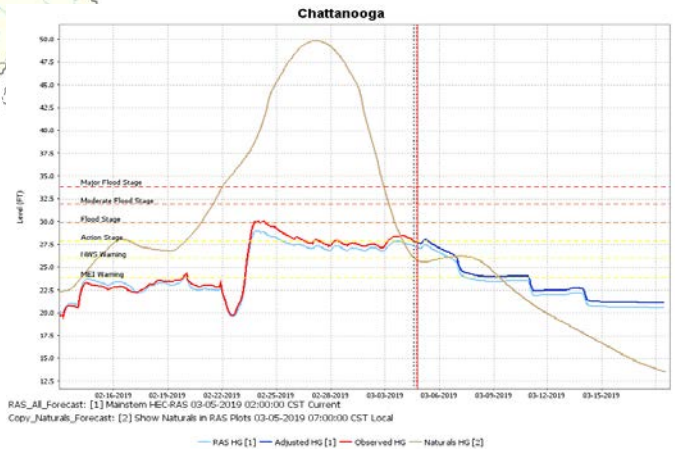

Ohio River
Mississippi River
Cumberland River
Tennessee River
Tennessee-Tombigbee Waterway
Kentucky Dam & Lock
Cedar Dam
Pin Oak Dam
Beech Dam
Redbud Dam
Dogwood Dam
Pine Dam
Lost Creek Dam
Sycamore Dam
Great Falls Dam
Normandy Dam
Tims Ford Dam
Chickamauga Dam & Lock
Nickajack Dam & Lock
Pickwick Landing Dam & Lock
Wheeler Dam & Lock
Wilson Dam & Lock
Cedar Creek Dam
Little Bear Creek Dam
Bear Creek Dam
Upper Bear Creek Dam
Guntersville Dam & Lock
Raccoon Mountain Pumped Storage Plant
Doakes Creek Dam
Norris Dam
John Sevier Dam
Ft. Patrick Henry Dams
South Holston Dam
Boone Dam
Wilbur Dam
Watauga Dam
Clear Creek Dam
Beaver Creek Dam
Cherokee Dam
Nolichucky Dam
Douglas Dam
Melton Hill Dam & Lock
Ft. Loudoun Dam & Lock
Tellico Dam
Watts Bar Dam & Lock
Fontana Dam
Apalachia Dam
Hiwassee Dam
Chatuge Dam
Ocoee #1 Dam
Ocoee #2 Dam
Ocoee #3 Dam
Nottely Dam
Blue Ridge Dam
LEGEND
Power Service Area
TVA Watershed
TVA Hydroelectric Dam
TVA Non-Power Dam
TVA Pumped-Storage Plant
April 2009
0 20 40 60 mi.
N

Flood Damage Reduction

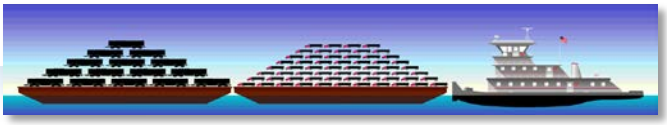


- $280 million damages averted annually
- $8.6 billion averted since 1936

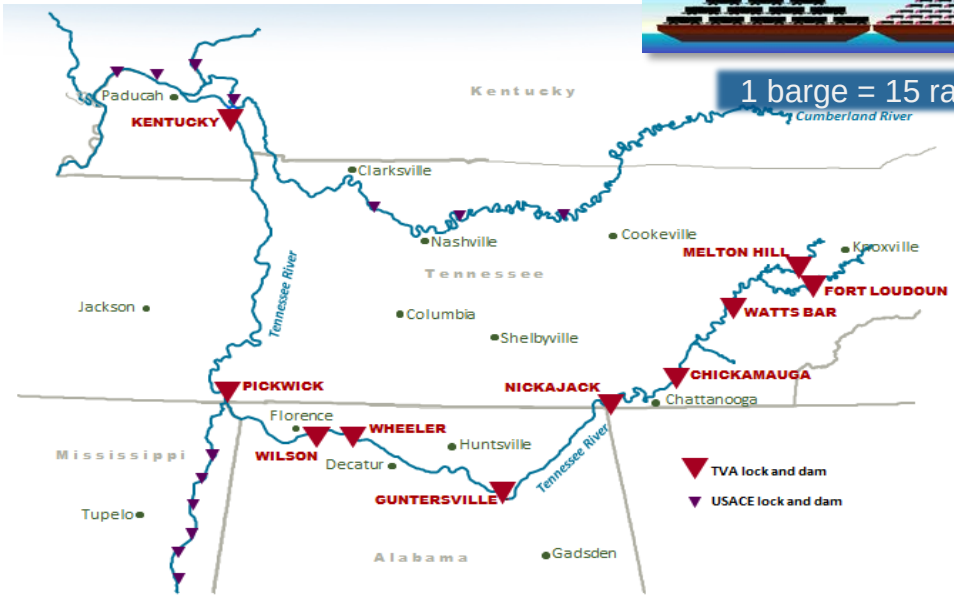
- $17 million averted annually on the Ohio and Mississippi Rivers through coordination with the USACE



Navigation



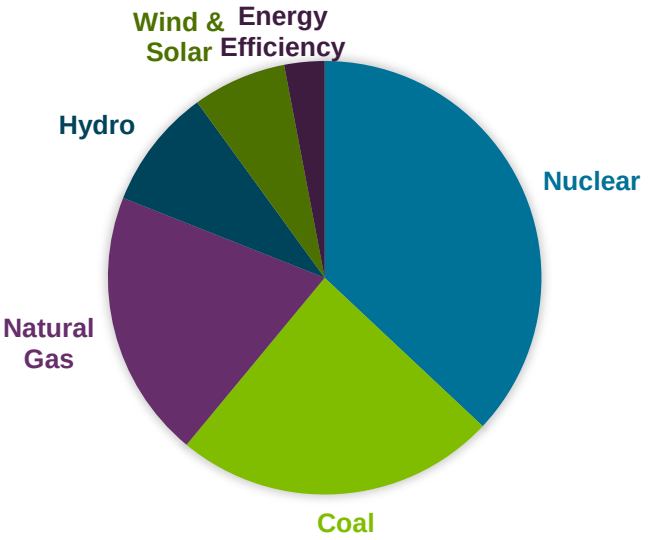
1 barge = 15 railcars = 60 trucks

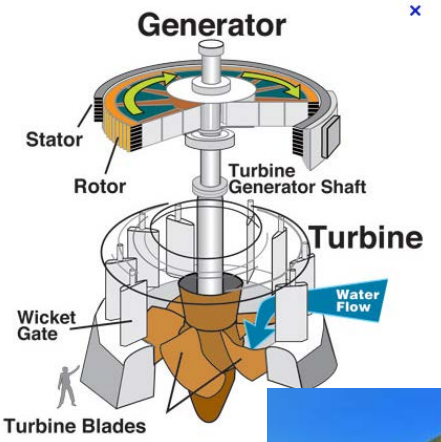


- 800 miles of commercially navigable waterways
- ~ $1 billion/year in shipper savings

Hydropower

- 3,538 MW Conv. generating capacity (109 Units)
- 1,653 MW Pump-storage capacity (4 units)
- ~ 10% of TVA's energy portfolio
- Peaking power demand
- Used to displace more expensive fuels





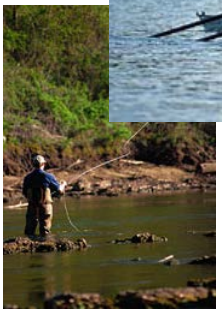
Water Supply and Quality

- Temperature and Dissolved Oxygen monitoring
- Adaptive Management for T&E species
- Minimum flow for downstream habitat
- Oxygen starved water behind the impoundment is “aerated” before being released
- Thermal compliance at TVA fossil and nuclear sites

- 700 Water Intakes
- Process water for industry, thermal-electric cooling, municipal, irrigation
- Drinking water for nearly 5 million people
- Provide minimum depths for intakes
- Manage inter-basin transfers

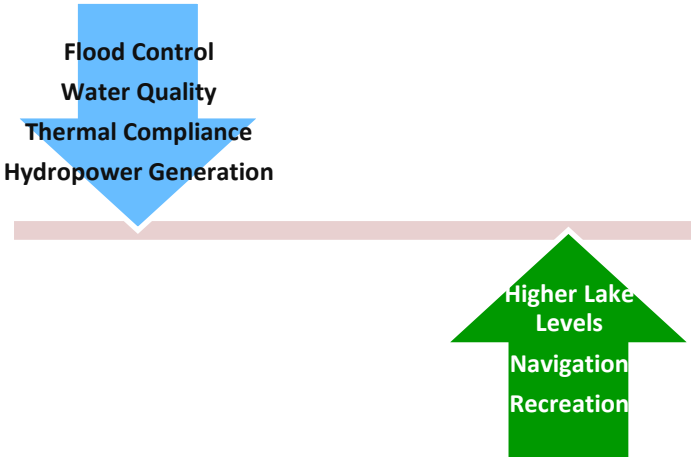
Recreation

- 230 Commercial Marinas
- 260 Campgrounds
- Drawdown restricted June 1 – Labor to provide higher summer lake levels
- Numerous tailwater releases to support trout fishing, whitewater rafting and drift-boating
- Economic Boost
- Stakeholder Involvement
- Special flows and elevations to support community events



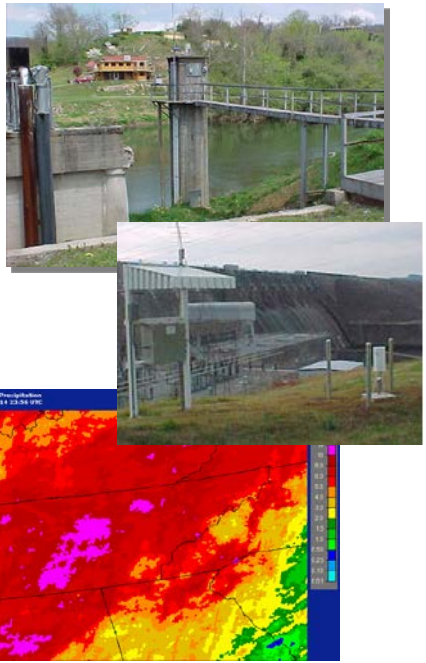
Challenges

- Balancing the competing demands on the system and the overall value to the public
- Understanding of the trade-offs associated with various scenarios
- Example: Can you keep my reservoir higher, longer?



Forecasting & Decision Support

- 200+ Rain Gages
- 130+ Stream Gages
- Data Management (FEWS)
- Inflow and Runoff Modeling (SAC-SMA)
- Reservoir Storage Routing and Simulation (Riverware)
- Hydraulic Modeling (HEC-RAS)
- Hydropower Optimization (Riverware)
- Information Dissemination (Varies)



TVA's Forecasting Process

- 24/7/365 Operation
- Constant system monitoring
- 2-4 forecasts daily
- Hydropower schedule produced twice daily

1 Collect and verify data

2 Storage inventory and QPF selection

3 Reservoir inflow forecasting

4 River routing through Pickwick

5 Kentucky/ Barkley routing

6 Hourly optimization model

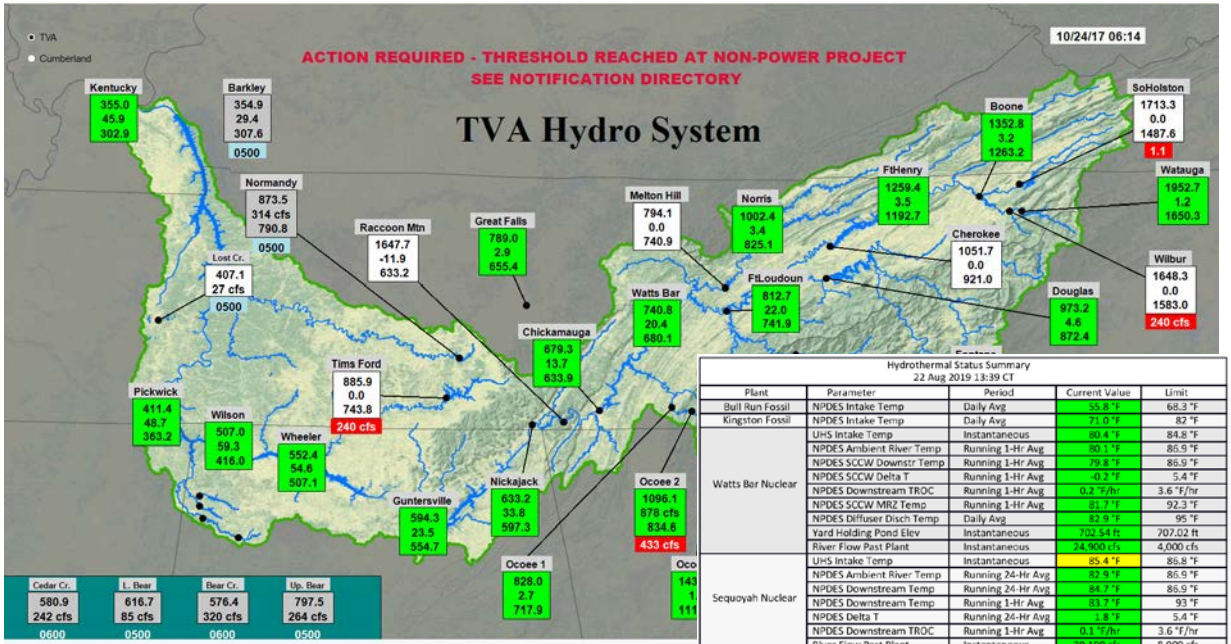
7 Schedule approval by RFC and power schedulers

8 Hydraulic models for intermediate locations

9 Information dissemination

10 Monitor system

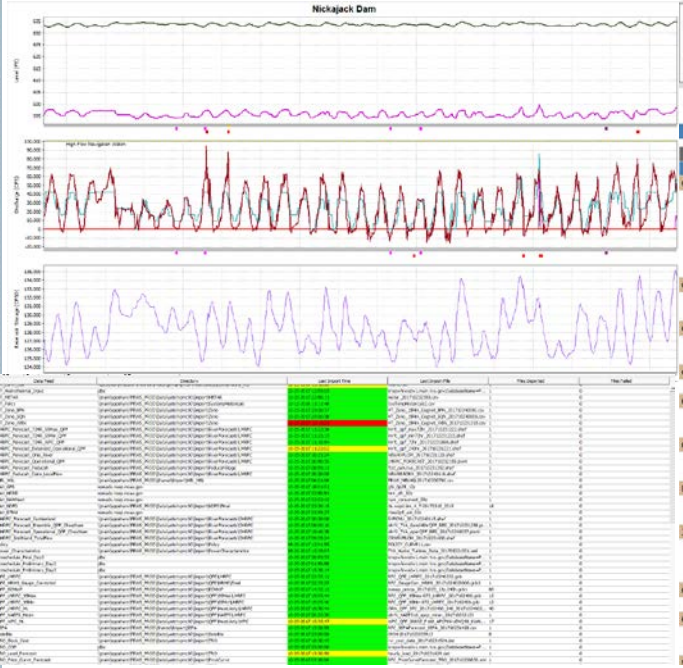
Realtime Monitoring



Hydrothermal Status Summary
22 Aug 2019 13:39 CT

Plant	Parameter	Period	Current Value	Limit
Bull Run Fossil	NPDES Intake Temp	Daily Avg	55.8 °F	68.3 °F
Kingston Fossil	NPDES Intake Temp	Daily Avg	71.0 °F	82 °F
Watts Bar Nuclear	UHS Intake Temp	Instantaneous	80.4 °F	84.8 °F
	NPDES Ambient River Temp	Running 1-Hr Avg	80.1 °F	86.9 °F
	NPDES SCCW Downstr Temp	Running 1-Hr Avg	79.8 °F	86.9 °F
	NPDES SCCW Delta T	Running 1-Hr Avg	-0.2 °F	5.4 °F
	NPDES Downstream TROC	Running 1-Hr Avg	0.2 °F/hr	3.6 °F/hr
	NPDES SCCW MRZ Temp	Running 1-Hr Avg	81.7 °F	92.3 °F
	NPDES Diffuser Disch Temp	Daily Avg	82.9 °F	95 °F
	Yard Holding Pond Elev	Instantaneous	702.54 ft	707.02 ft
	River Flow Past Plant	Instantaneous	24,900 cfs	4,000 cfs
Sequoyah Nuclear	UHS Intake Temp	Instantaneous	85.4 °F	86.8 °F
	NPDES Ambient River Temp	Running 24-Hr Avg	82.9 °F	86.9 °F
	NPDES Downstream Temp	Running 24-Hr Avg	84.7 °F	86.9 °F
	NPDES Downstream Temp	Running 1-Hr Avg	83.7 °F	93 °F
	NPDES Delta T	Running 24-Hr Avg	1.8 °F	5.4 °F
	NPDES Downstream TROC	Running 1-Hr Avg	0.1 °F/hr	3.6 °F/hr
	River Flow Past Plant	Instantaneous	39,100 cfs	8,000 cfs
Browns Ferry Nuclear	UHS Intake Temp	Instantaneous	87.5 °F	92.5 °F
	NPDES Ambient River Temp	Running 24-Hr Avg	87.4 °F	90 °F
	NPDES Downstream Temp	Running 24-Hr Avg	89.4 °F	90 °F
	NPDES Downstream Temp	Running 1-Hr Avg	89.0 °F	93 °F
	NPDES Delta T	Running 24-Hr Avg	2.0 °F	10 °F
	River Flow Past Plant	Instantaneous	32,900 cfs	10,000 cfs
Gallatin Fossil	NPDES Intake Temp	Daily Avg	74.7 °F	76 °F
Cumberland Fossil	NPDES Intake Temp	Daily Avg	82.8 °F	86.9 °F
Paradise Fossil	NPDES Intake Temp	Daily Avg	71.6 °F	89 °F

Data Collection and Validation



StartDate 10/22/2017 StartHour 24

EndDate 10/23/2017 EndHour 24

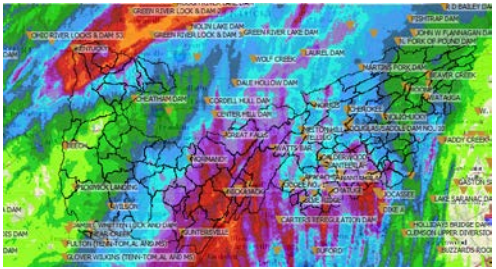
1 of 2 100% Find | Next

Questionable Hourly Water Record Data [10/23/2017 - 10/24/2017] Central Time

Reservoir / Location	Parameter	Quality / Date	Occurrences / Hour / Value
Calderwood Dam			
	Power, Total, MW	Doubtful:Original	2
	Date	Hour	Value
	2017-10-23	13	52.05
	2017-10-23	14	54.02
	Tailwater, FT	Doubtful:Original	10
	Turbine Flow, CFS	Doubtful:Original	2
Center Hill Dam			
	Power, Total, MW	Missing:Missing	3
	Spillway Flow, CFS	Missing:Missing	3
Cheatham Dam			
	Power, Total, MW	Missing:Missing	3
	Spillway Flow, CFS	Missing:Missing	3
Cheoah Dam			
	Power, Total, MW	Doubtful:Original	2
Chilhowee Dam			
	Power, Total, MW	Doubtful:Original	5
	Turbine Flow, CFS	Doubtful:Original	5
Cordell Hull Dam			
	Power, Total, MW	Missing:Missing	3
	Spillway Flow, CFS	Missing:Missing	3
Dale Hollow Dam			
	Power, Total, MW	Missing:Missing	3
	Spillway Flow, CFS	Missing:Missing	3
J Percy Priest Dam			
	Power, Total, MW	Missing:Missing	3
	Spillway Flow, CFS	Missing:Missing	3
	Tailwater, FT	Doubtful:Original	9
Ocoee No. 1 Dam			
	Tailwater, FT	Doubtful:Original	1
Old Hickory Dam			
	Power, Total, MW	Missing:Missing	3
	Spillway Flow, CFS	Missing:Missing	3
SpringHill Dam			

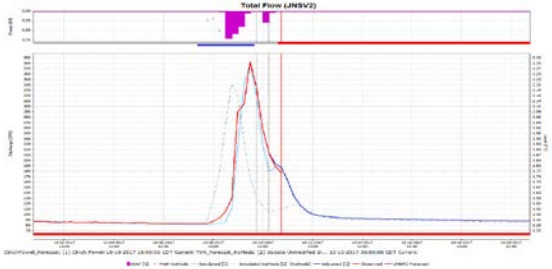
Hydrologic Inflow Models

QPE Selection

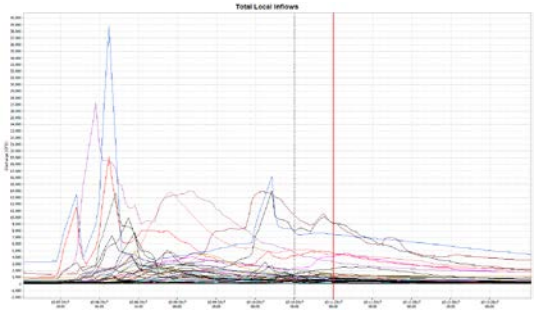


QPF Selection

Inflow Modeling

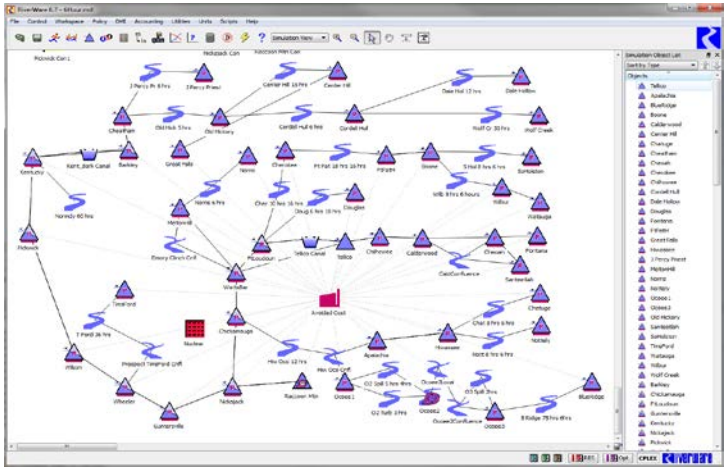


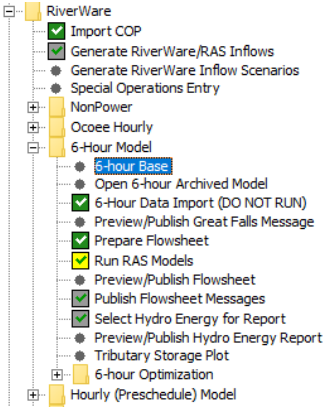
Finalize for Scheduling and Hydraulic Modeling



FEWS RiverWare Integration

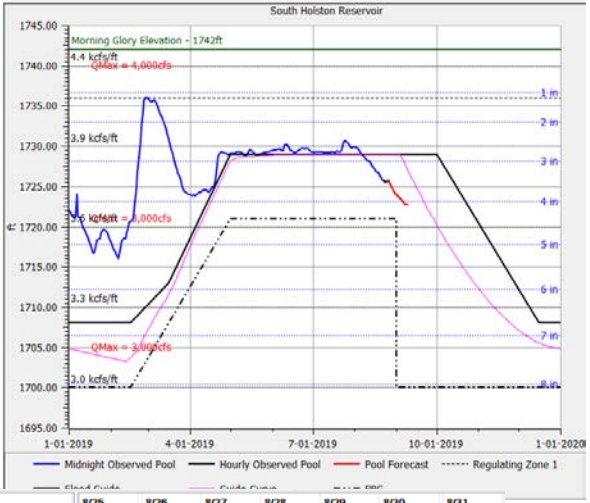
- RiverWare used with GUI and headless
- RiverWare launched using the FEWS Riverware Adapter.
- Communication between RiverWare and FEWS done using FEWS PI web service (API)





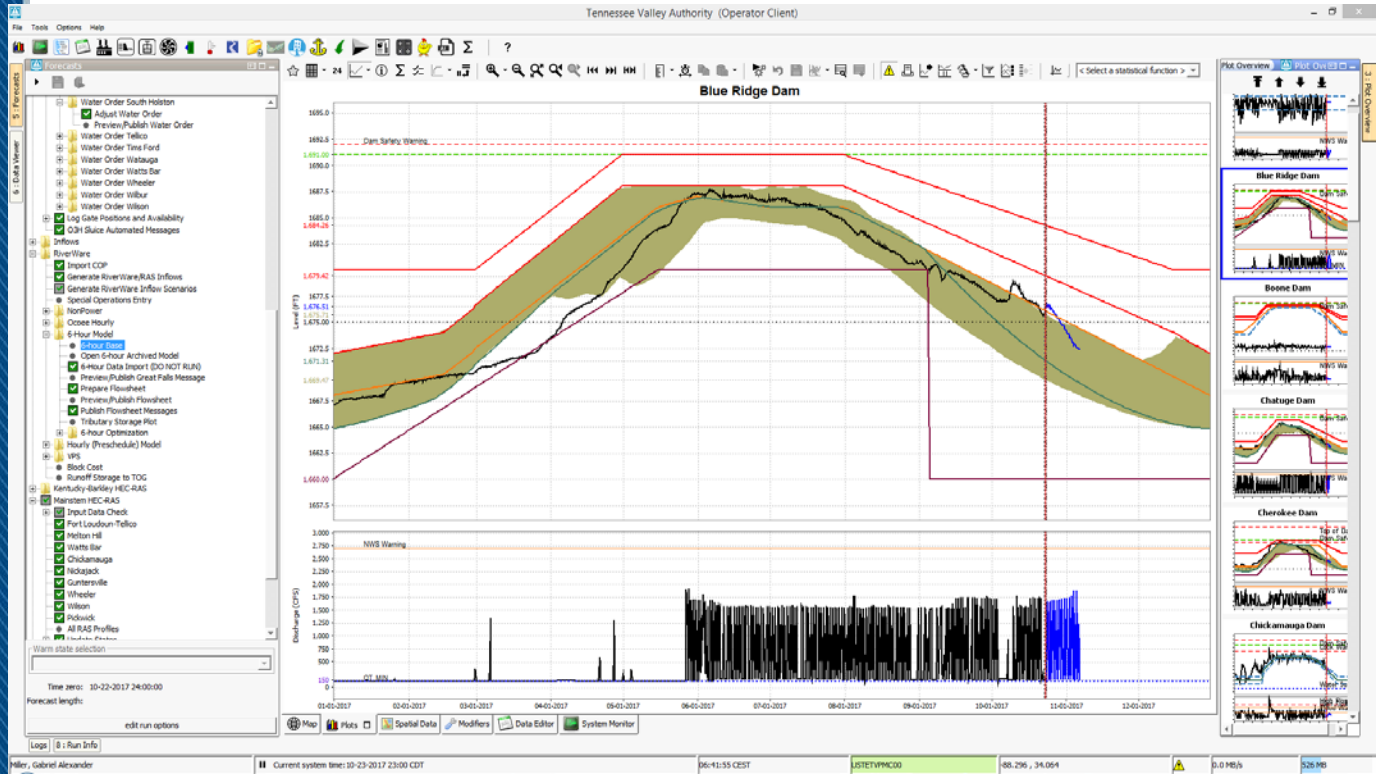
Scheduling the River

- Four RiverWare models
- 6-Hour Model
  - Model reservoirs at 6-hour time steps for 14 days
  - Simulation mode
- Preschedule Model
  - Model reservoirs at hourly time steps for 3 days (using 6-hour model volumes)
  - Optimization mode
- Ocoee Model
  - Hourly time step for scheduling flashy basin
  - Imported into 6-hour and preschedule models
- Non-Power Model
  - Hourly time step
  - Imported into 6-hour model

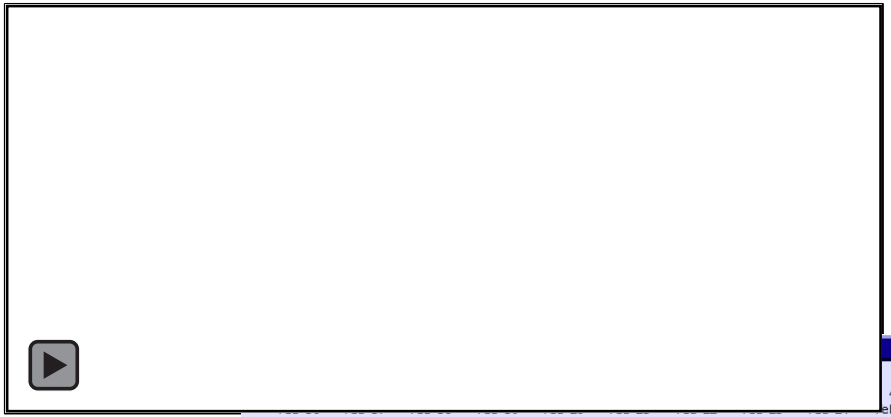


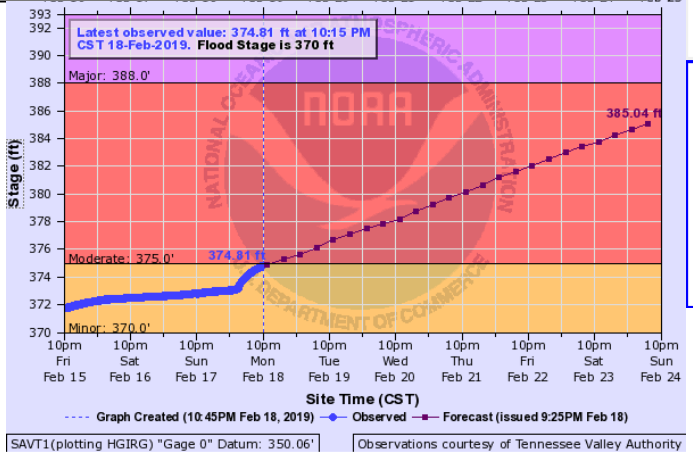
Slot Label	8/25 Sun	8/26 Mon	8/27 Tue	8/28 Wed	8/29 Thu	8/30 Fri	8/31 Sat
SOUTH HOLSTON							
Adjustment	-0.07	0.00	0.00	0.00	0.00	0.00	0.00
Total local	0.44	0.34	0.38	0.35	0.31	0.29	0.28
Total inflow		0.34	0.38	0.35	0.31	0.29	0.28
Storage	319.09	317.99	316.84	315.66	314.44	313.32	312.69
Elevation	1,725.66	1,725.36	1,725.06	1,724.74	1,724.41	1,724.10	1,723.93
6:00	1,725.57	1,725.67	1,725.39	1,725.08	1,724.76	1,724.41	1,724.11
12:00	1,725.63	1,725.59	1,725.29	1,724.98	1,724.66	1,724.36	1,724.11
18:00	1,725.63	1,725.47	1,725.18	1,724.86	1,724.53	1,724.23	1,723.99
24:00	1,725.66	1,725.36	1,725.06	1,724.74	1,724.41	1,724.10	1,723.93
Hydro capacity		44.78	44.83	44.88	44.93	44.98	46.17
Energy	70	638	680	680	680	624	408
6:00	23	23	0	0	0	24	24
12:00	23	164	200	200	200	120	24
18:00	23	246	240	240	240	240	240
24:00	0	205	240	240	240	240	120
Ave. operating head	240.95	236.41	236.12	235.80	235.47	235.17	234.96
Plant capacity fraction	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Power factor	684	433	433	433	433	433	444
Turbine discharge	0.16	1.44	1.53	1.53	1.53	1.41	0.92
Howell-Bunger discharge	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unregulated spill		0.00	0.00	0.00	0.00	0.00	0.00
Total outflow	0.17	1.44	1.53	1.53	1.53	1.41	0.92

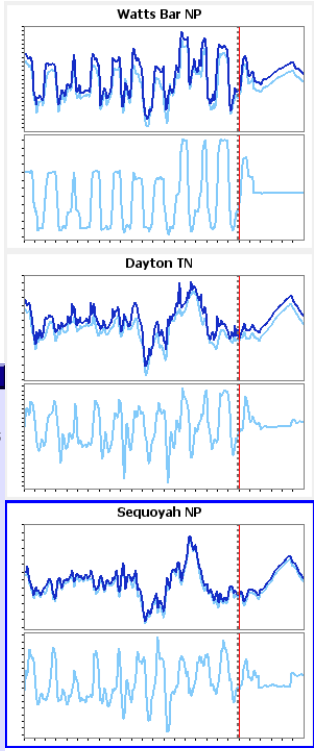
FEWS Observed and Forecast Data



Hydraulic Models

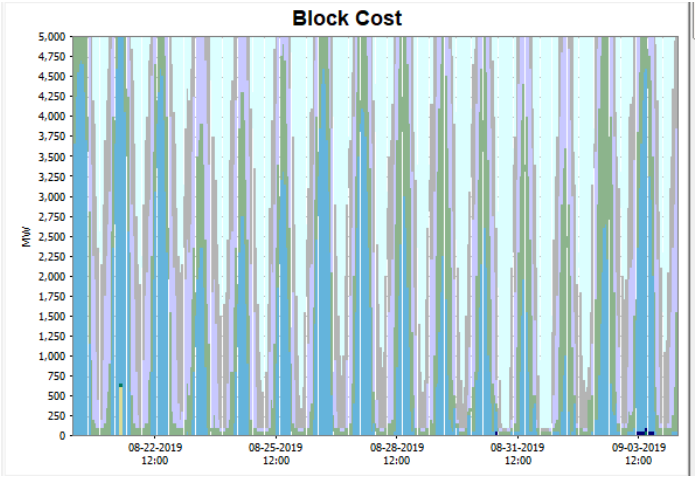


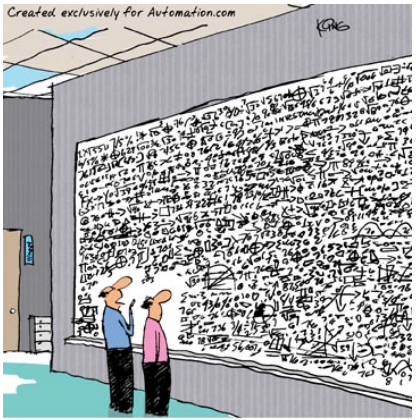




Upcoming RiverWare Project

- IT Project for Model Replacement/Improvement
  1. Get mid-term optimization model into production (two week model)
  2. Replace long-term model (weekly scheduling model)
  3. Replace block cost as signal for optimization and better integrate hydro and thermal unit commitment

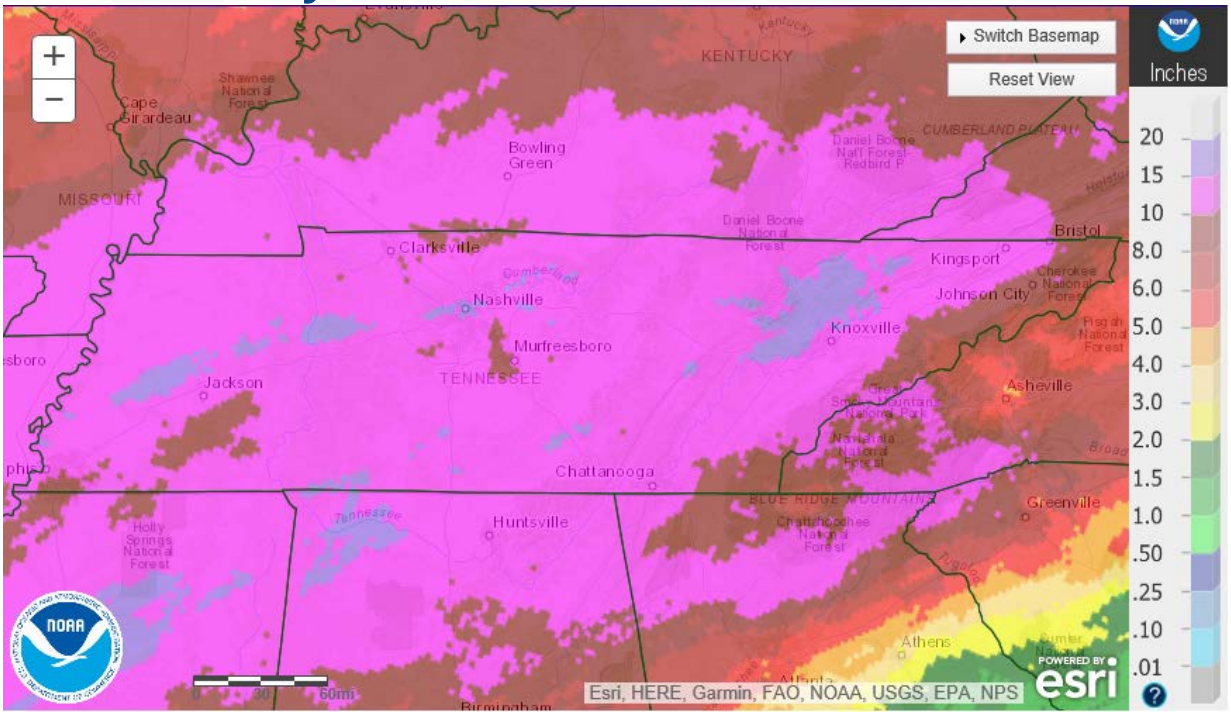




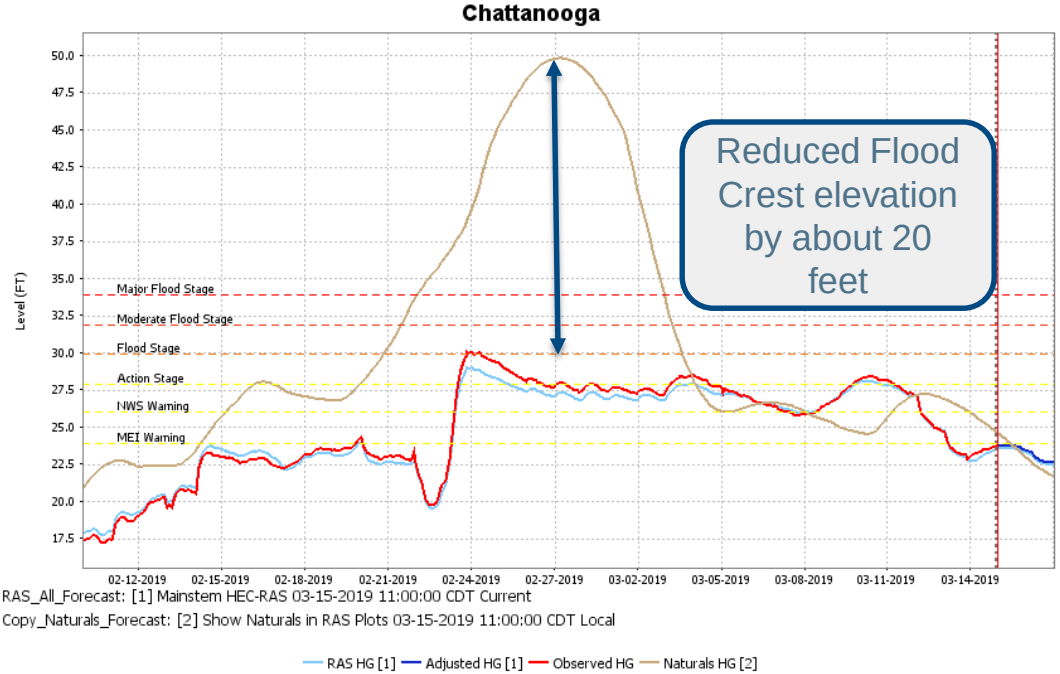
"...and that, in simple terms, is my idea on how to increase factory optimization. any questions?"

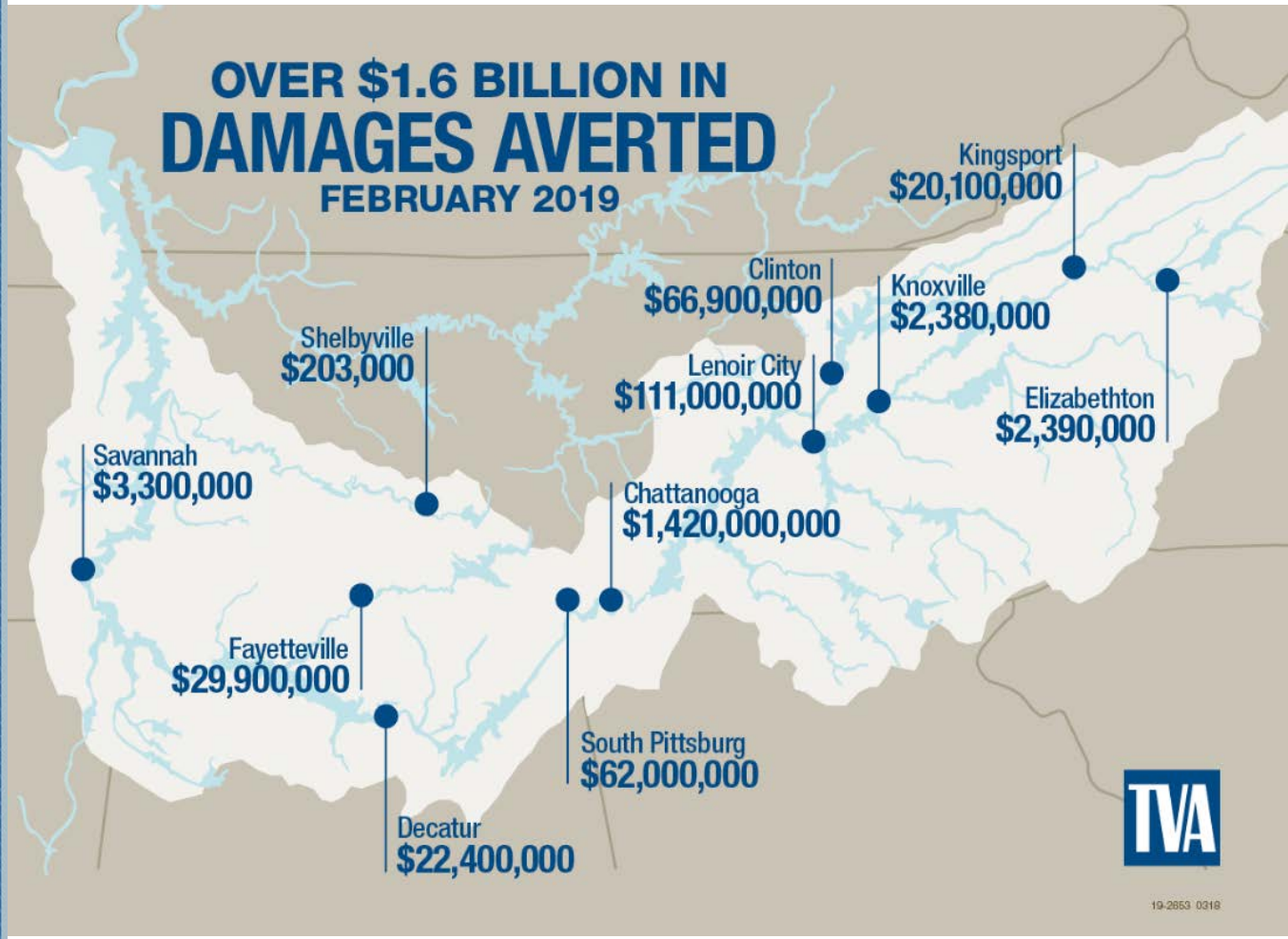
February 2019 Flood

February Rain



River Stages



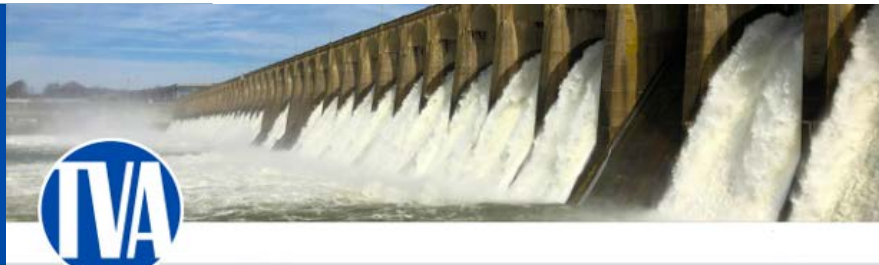

OVER $1.6 BILLION IN
DAMAGES AVERTED
FEBRUARY 2019
Kingsport
$20,100,000
Clinton
$66,900,000
Knoxville
$2,380,000
Shelbyville
$203,000
Lenoir City
$111,000,000
Elizabethton
$2,390,000
Savannah
$3,300,000
Chattanooga
$1,420,000,000
Fayetteville
$29,900,000
South Pittsburg
$62,000,000
Decatur
$22,400,000
TVA
19-2853 0318

Stakeholder Outreach

- Directly to County Emergency Management Authorities
- Conference calls with State Emergency Management
- Conference calls with Navigation Industry
- Updating National Weather Service routinely
- Updates to recreational interests, marinas, rowing venues, campgrounds, etc
- Updates to major industries near the Tennessee River
- Updates to industries in the lower Tennessee and Ohio Rivers
- Updates daily to Redstone Arsenal
- Communications social media outreach

Summary

- TVA continues it's river management mission – dating back to the TVA Act
- Operations are driven by rainfall and runoff as guided by Reservoir Operations Policy
- Integrated operation allows TVA to balance river system benefits:
  - Navigation
  - Flood-damage reduction
  - Affordable and reliable electricity
  - Improved water quality and aquatic habitat
  - Dependable water supply
  - Recreation
- RiverWare is used to balance and optimize river system benefits.



Thank You