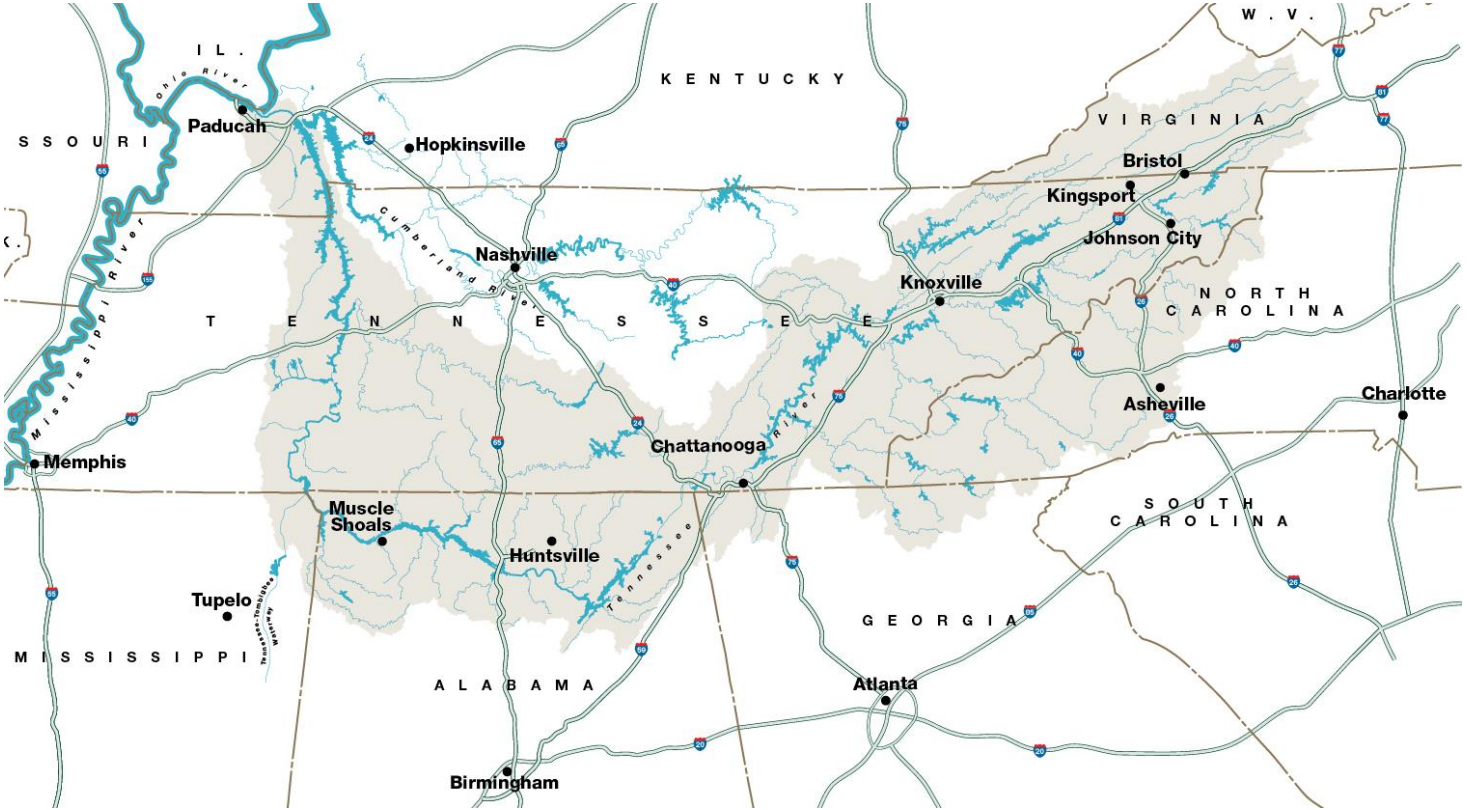
TVA Forecasting

Gabriel Miller

What is TVA?

A power company
and so much more…

Tennessee Valley Watershed



Integrated Tennessee River System

Navigation

Water Supply

Flood-Damage Reduction

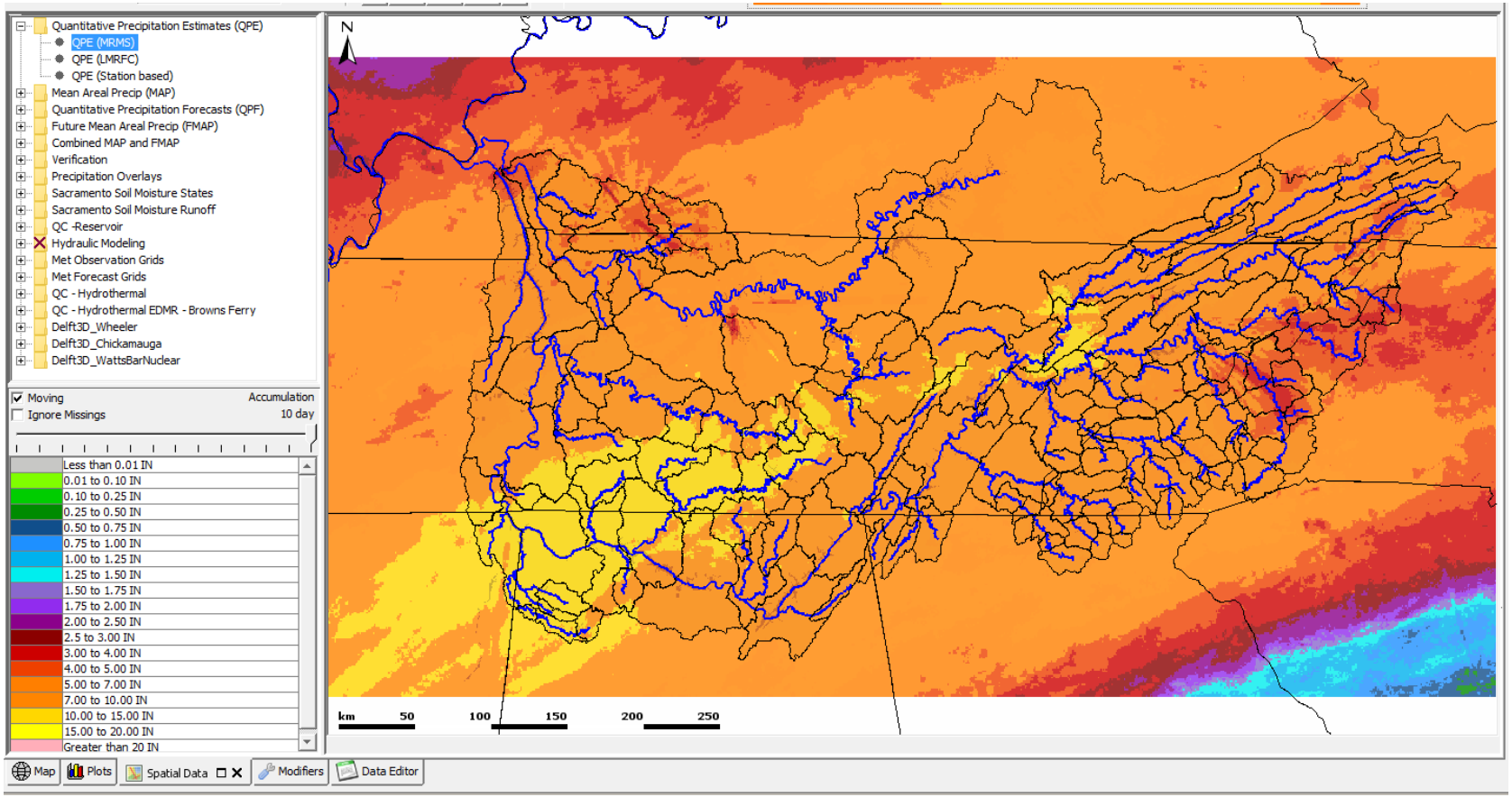
Recreation

Power Generation

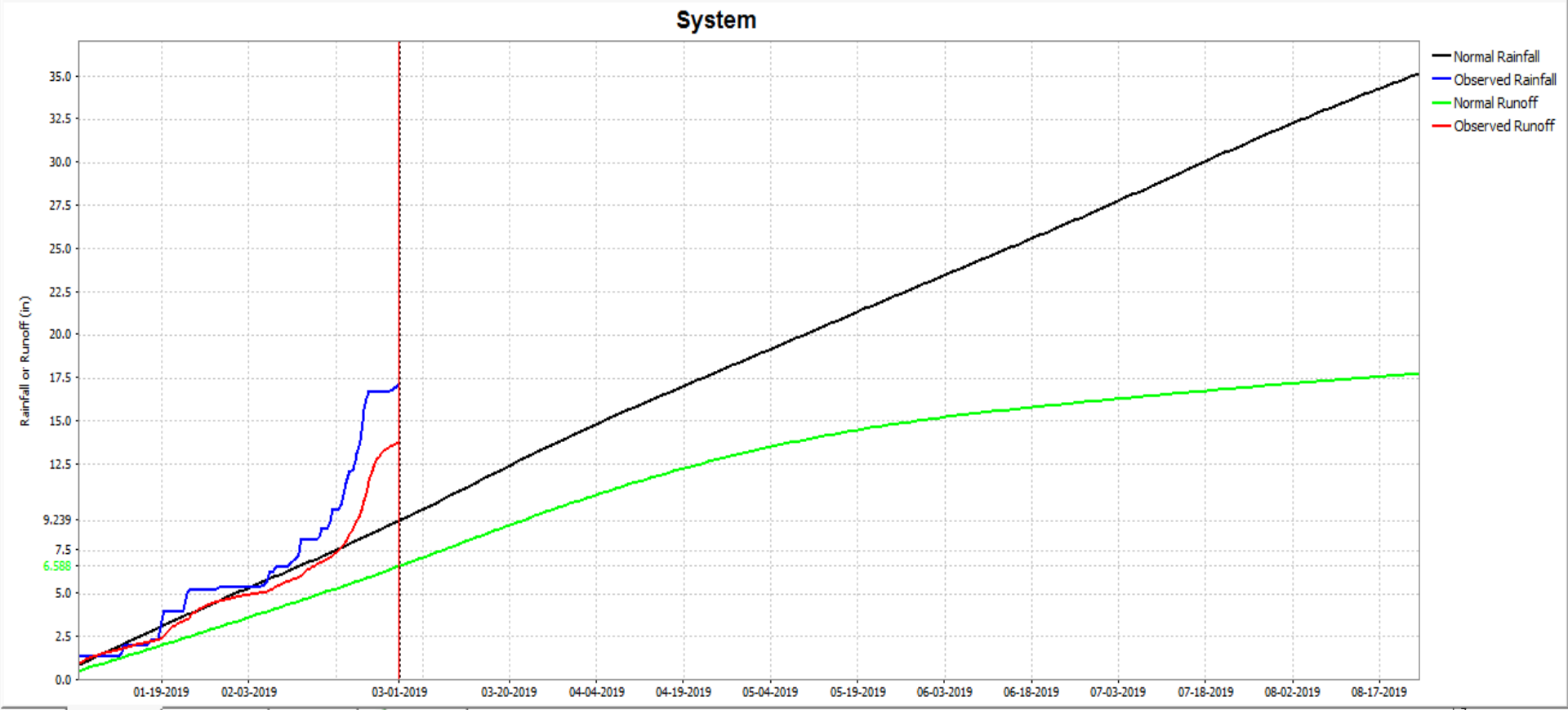
Water Quality

February 2019 Flood

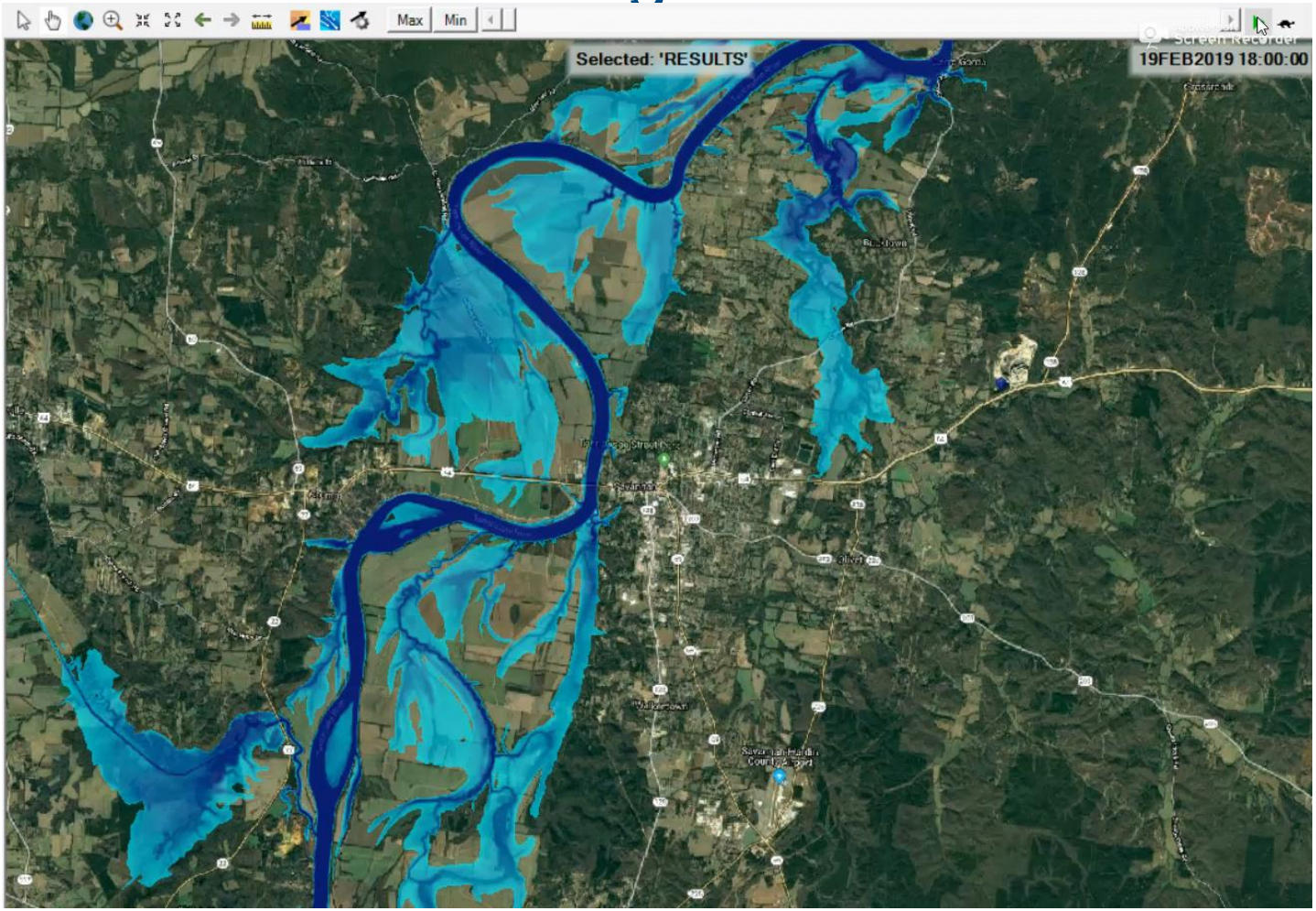
Rainfall Accumulation (10-day)



System Rainfall-runoff



Savannah Flooding

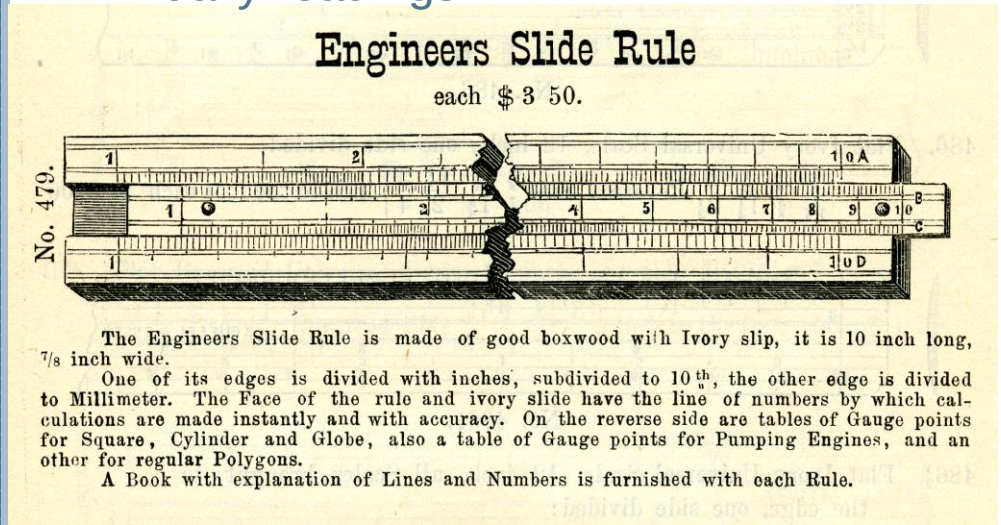


Storm Stats

- 1.6 Billion in Flood Damages Averted
- 206,000 Unique App Screen Views
- 50,000 Unique views to LakeInfo Website
- 33,000 Calls to LakeLine
- Records accumulation records:
  - Feb 2019
  - 2018
- 530,000 CFS out of Pickwick (second highest)
- Great collaboration with LMRFC

River Forecasting History

- From 1933 to 1976 all routing computations were performed by hand.
- Inflows were forecasted based on rain observed by volunteers who phoned in daily readings



Engineers Slide Rule

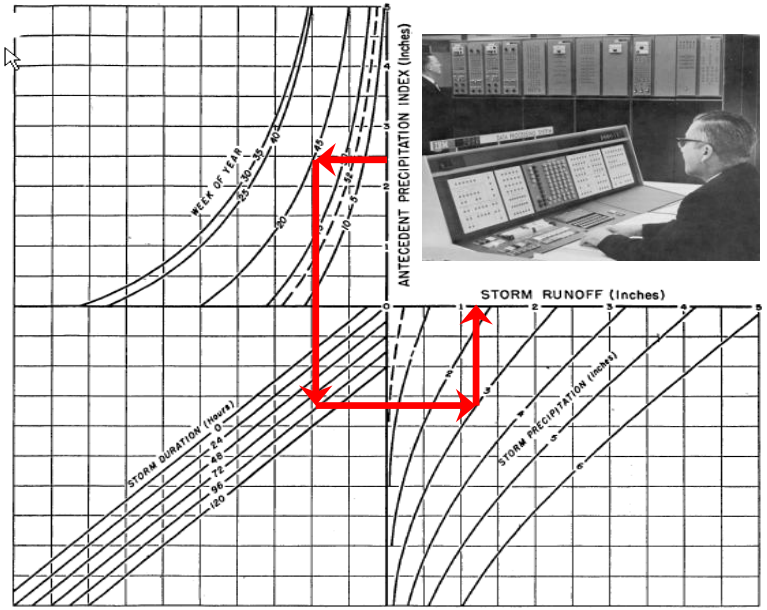
each $ 3 50.

No. 479.

The Engineers Slide Rule is made of good boxwood with Ivory slip, it is 10 inch long, 7/8 inch wide.

One of its edges is divided with inches, subdivided to 10th, the other edge is divided to Millimeter. The Face of the rule and ivory slide have the line of numbers by which calculations are made instantly and with accuracy. On the reverse side are tables of Gauge points for Square, Cylinder and Globe, also a table of Gauge points for Pumping Engines, and an other for regular Polygons.

A Book with explanation of Lines and Numbers is furnished with each Rule.



System History

Year	Hardware	Database	Modeling Techniques
1933-1975	Slide-Rule	Paper	Hand Calculations via Slide Rules
1975	IBM/CDC Mainframe	Flat Files/Tapes	Hand Calculations via Slide Rules
			Simulated Open Channel Hydraulics (SOCH)
			MacCormack Scheme
1980	HP Mini Computers		INFLOW Model
			Stochastic-Dynamic Programming (STODP)
			Kent Model
1985	PC's	ALLBASE	HydroSim (Weekly Scheduling Model V2)
1990	HP UNIX Computers	Oracle	
1995			Riverware (primitive)
2000	Solaris/Windows Computers		Hydrothermal Models (ADYN-RQUAL, BFSCH, etc..)
2005		SQL Server	
2010			HEC-RAS
			Sacramento Soil Moisture Accounting Model
			Riverware optimization techniques
2017			Delft-FEWS system

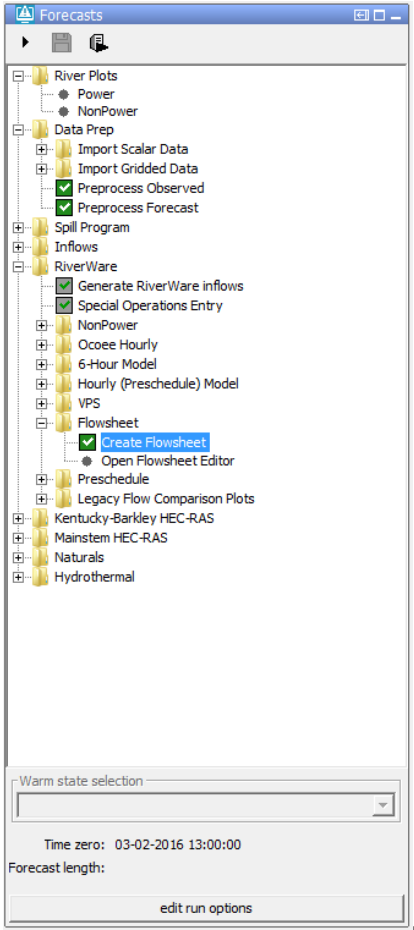
River Operations: 1978 vs 2017

Group	Staff
Director's Office	20
Flood Control	58
Geologic Services	39
River Management	24
Data Services	226
Water Systems Development	111
Mapping	132
H&H Engineers & Techs	42
IT	10
Flood Risk Analysis	22
Mathematician	18
Model Builder/Coder	34
Meteorologist	2
Total	**738**

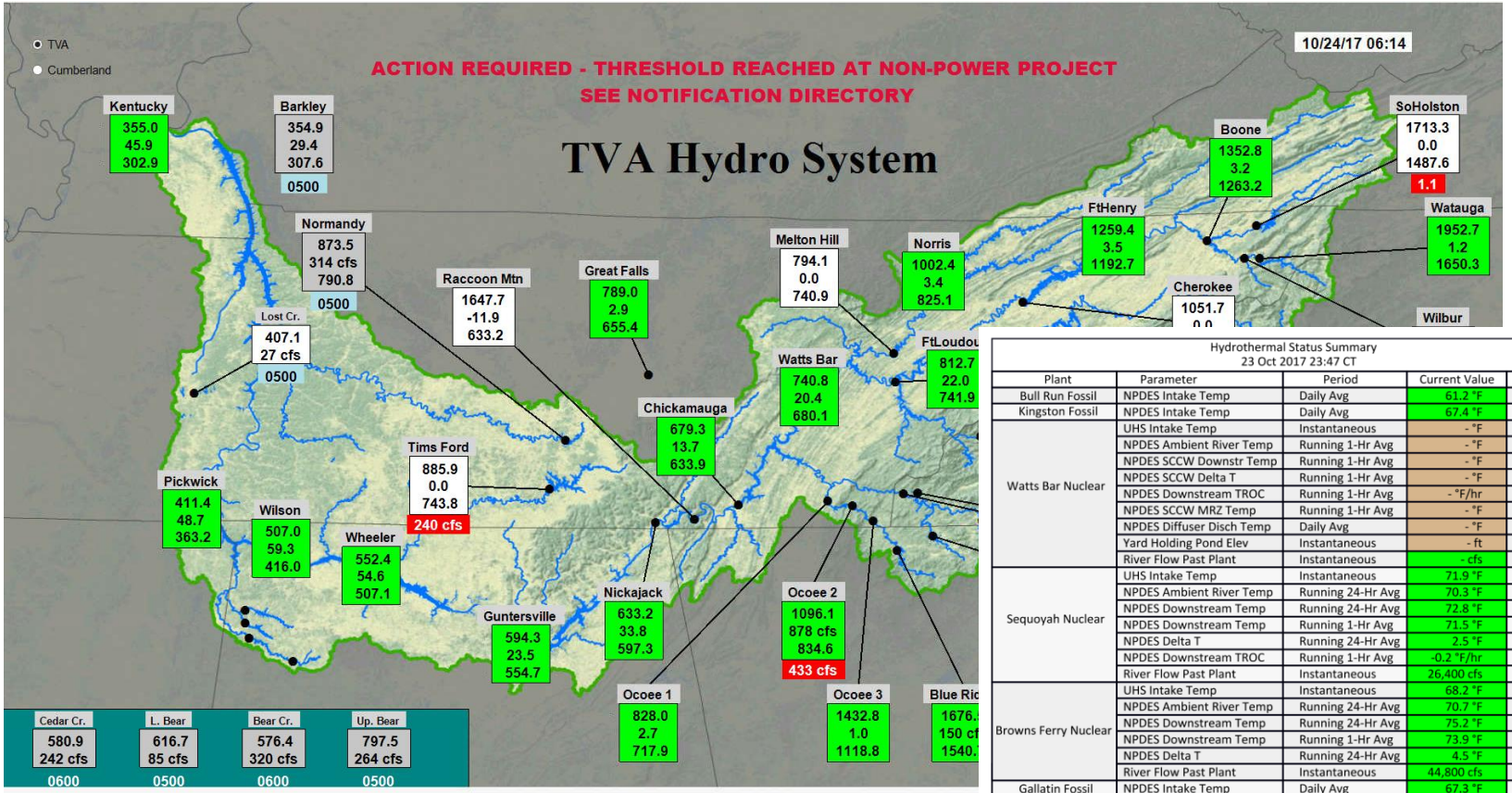
Group	Staff
RS Upper Level	6
--OE	13
--RFC	26
--Res Ops Support	53
Performance Ops Support	12
HDCC	10
Work Control	12
H&H Engineers & Techs	8
IT	3
Flood Risk Analysis	1
Model Builder/Coder	1
Total	**145**

TVA FEWS System

- Three year project
  - Converted in-house forecast system to standard models and FEWS system
  - Migration from 100+ programs to one unified platform
  - Vastly improved data visualization and reports
- Went live Feb 7th 2017



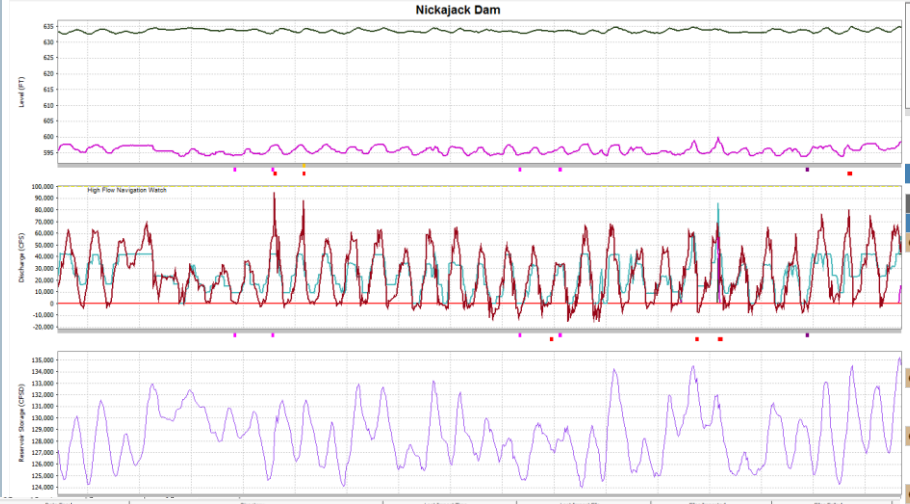
Realtime Monitoring

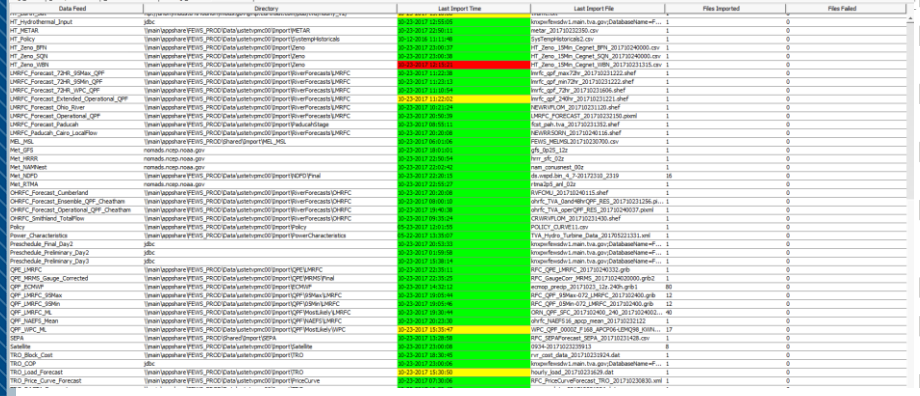


Hydrothermal Status Summary
23 Oct 2017 23:47 CT

Plant	Parameter	Period	Current Value	Limit
Bull Run Fossil	NPDES Intake Temp	Daily Avg	61.2 °F	68.3 °F
Kingston Fossil	NPDES Intake Temp	Daily Avg	67.4 °F	82 °F
Watts Bar Nuclear	UHS Intake Temp	Instantaneous	- °F	84.8 °F
	NPDES Ambient River Temp	Running 1-Hr Avg	- °F	86.9 °F
	NPDES SCCW Downstr Temp	Running 1-Hr Avg	- °F	86.9 °F
	NPDES SCCW Delta T	Running 1-Hr Avg	- °F	5.4 °F
	NPDES Downstream TROC	Running 1-Hr Avg	- °F/hr	3.6 °F/hr
	NPDES SCCW MRZ Temp	Running 1-Hr Avg	- °F	92.3 °F
	NPDES Diffuser Disch Temp	Daily Avg	- °F	95 °F
	Yard Holding Pond Elev	Instantaneous	- ft	707.02 ft
	River Flow Past Plant	Instantaneous	- cfs	4,000 cfs
Sequoyah Nuclear	UHS Intake Temp	Instantaneous	71.9 °F	86.8 °F
	NPDES Ambient River Temp	Running 24-Hr Avg	70.3 °F	86.9 °F
	NPDES Downstream Temp	Running 24-Hr Avg	72.8 °F	86.9 °F
	NPDES Downstream Temp	Running 1-Hr Avg	71.5 °F	93 °F
	NPDES Delta T	Running 24-Hr Avg	2.5 °F	5.4 °F
	NPDES Downstream TROC	Running 1-Hr Avg	-0.2 °F/hr	3.6 °F/hr
	River Flow Past Plant	Instantaneous	26,400 cfs	8,000 cfs
Browns Ferry Nuclear	UHS Intake Temp	Instantaneous	68.2 °F	92.5 °F
	NPDES Ambient River Temp	Running 24-Hr Avg	70.7 °F	90 °F
	NPDES Downstream Temp	Running 24-Hr Avg	75.2 °F	90 °F
	NPDES Downstream Temp	Running 1-Hr Avg	73.9 °F	93 °F
	NPDES Delta T	Running 24-Hr Avg	4.5 °F	10 °F
	River Flow Past Plant	Instantaneous	44,800 cfs	10,000 cfs
Gallatin Fossil	NPDES Intake Temp	Daily Avg	67.3 °F	76 °F
Cumberland Fossil	NPDES Intake Temp	Daily Avg	68.2 °F	86.9 °F
Paradise Fossil	NPDES Intake Temp	Daily Avg	62.1 °F	89 °F

Data Collection and Validation





StartDate 10/22/2017 StartHour 24

EndDate 10/23/2017 EndHour 24

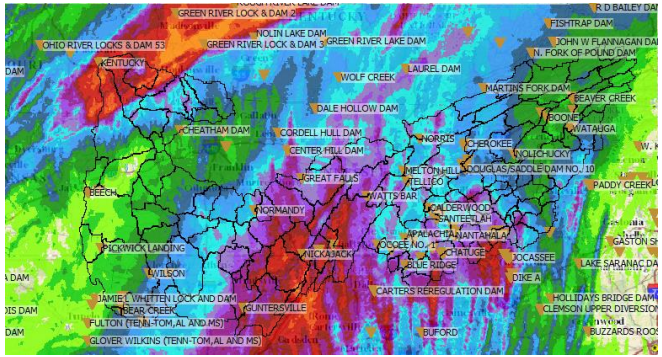
1 of 2 100% Find | Next

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

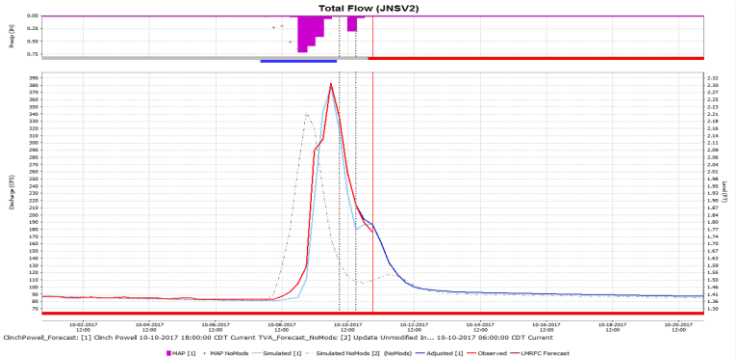
Reservoir			
Location	**Parameter**	**Quality**	**Occurrences**
Calderwood Dam			
	⊟Power, Total, MW	Doubtful:Original	2
	Date	**Hour**	**Value**
	2017-10-23	13	52.05
	2017-10-23	14	54.02
	⊞Tailwater, FT	Doubtful:Original	10
	⊞Turbine Flow, CFS	Doubtful:Original	2
Center Hill Dam			
	⊞Power, Total, MW	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
Sapteetlah Dam			

Hydrologic Models (Inflows)

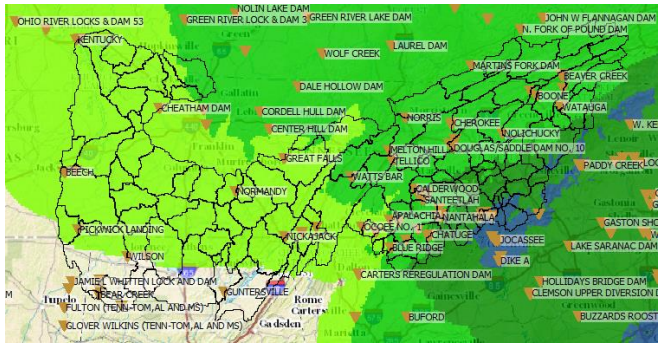
QPE Selection



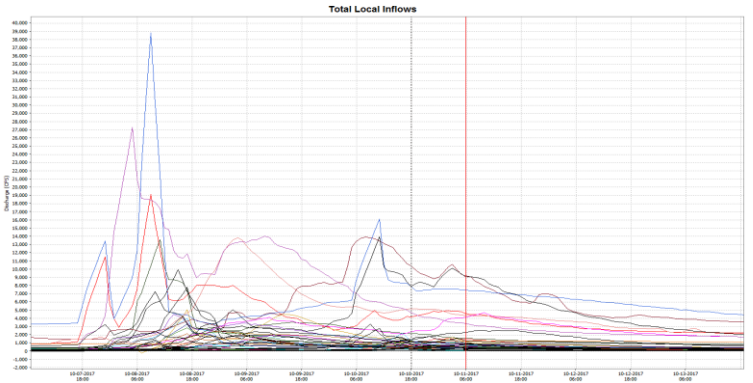
Inflow Modeling



QPF Selection

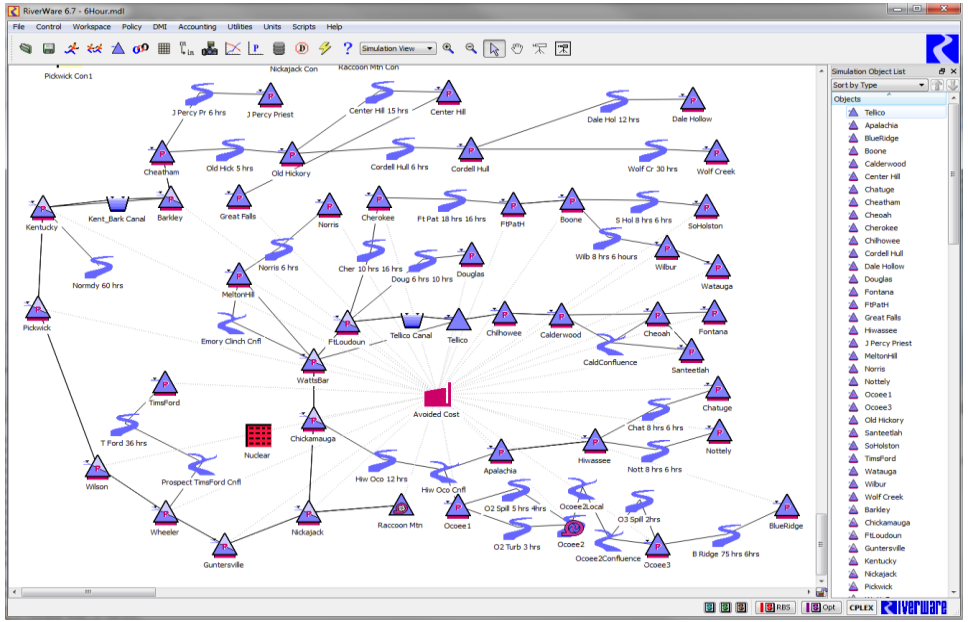


Finalize for Scheduling and Hydraulic Modeling



Scheduling the River

- Two Primary Riverware
- 6-Hour Model
  - Model reservoirs at 6-hour time steps for 14 days
  - Simulation/optimization mode
- Preschedule Model
  - Model reservoirs at hourly time steps for 3 days (using 6-hour model volumes)
  - Optimization mode



Tennessee Valley Authority (Operator Client)

File Tools Options Help

Forecasts

- Water Order South Holston
  - Adjust Water Order
  - Preview/Publish Water Order
- Water Order Tellico
- Water Order Tims Ford
- Water Order Watauga
- Water Order Watts Bar
- Water Order Wheeler
- Water Order Wilbur
- Water Order Wilson
- Log Gate Positions and Availability
- O3H Sluice Automated Messages
- Inflows
- RiverWare
  - Import COP
  - Generate RiverWare/RAS Inflows
  - Generate RiverWare Inflow Scenarios
  - Special Operations Entry
  - NonPower
  - Ocoee Hourly
  - 6-Hour Model
    - 6-hour Base
    - Open 6-hour Archived Model
    - 6-Hour Data Import (DO NOT RUN)
    - Preview/Publish Great Falls Message
    - Prepare Flowsheet
    - Preview/Publish Flowsheet
    - Publish Flowsheet Messages
    - Tributary Storage Plot
    - 6-hour Optimization
  - Hourly (Preschedule) Model
  - VPS
  - Block Cost
  - Runoff Storage to TOG
- Kentucky-Barkley HEC-RAS
- Mainstem HEC-RAS
  - Input Data Check
  - Fort Loudoun-Tellico
  - Melton Hill
  - Watts Bar
  - Chickamauga
  - Nickajack
  - Guntersville
  - Wheeler
  - Wilson
  - Pickwick
  - All RAS Profiles

Warm state selection

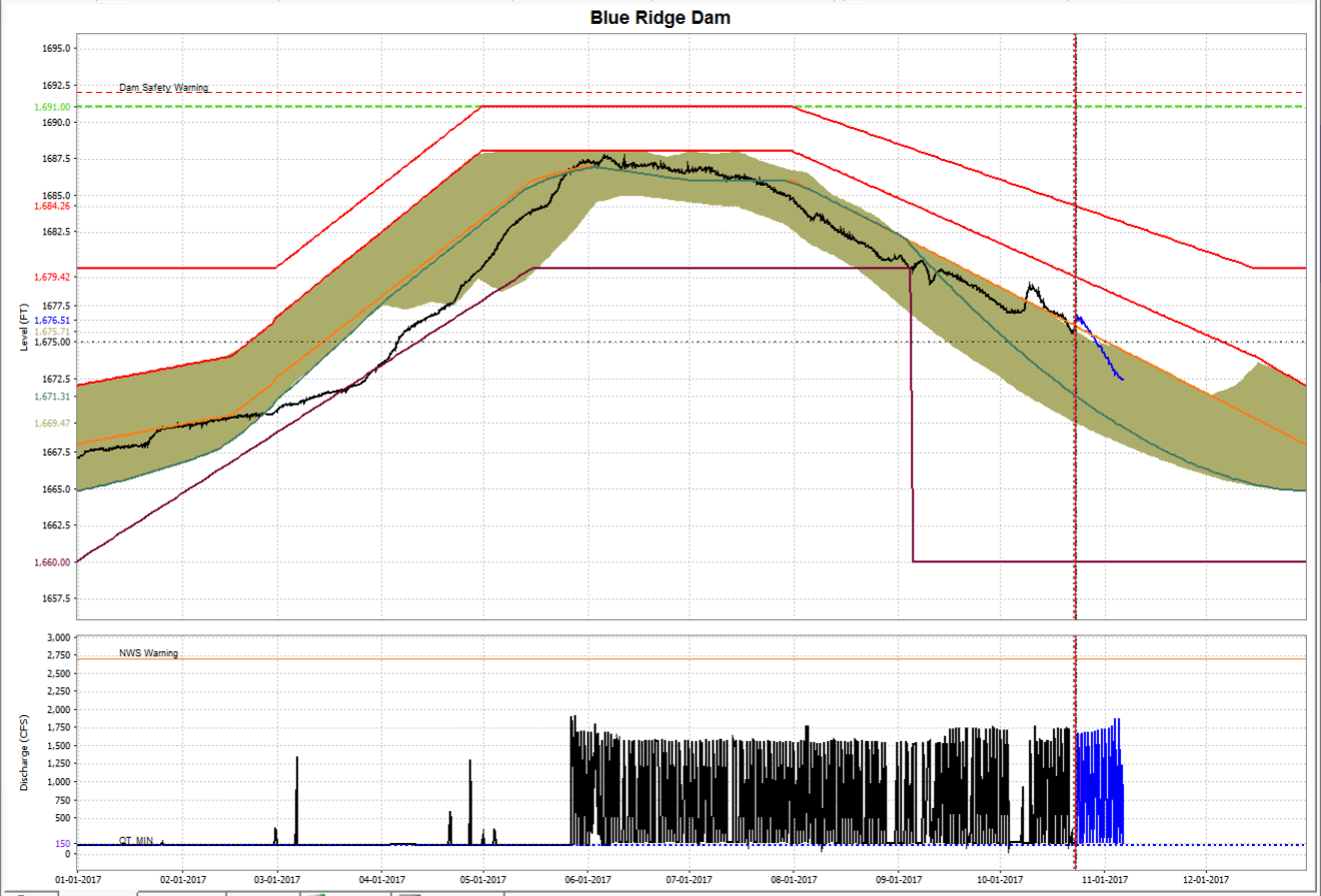
Time zero: 10-22-2017 24:00:00

Forecast length:

edit run options

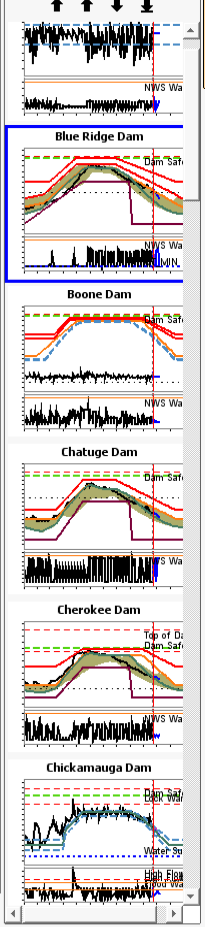
Logs | 8 : Run Info

< Select a statistical function >



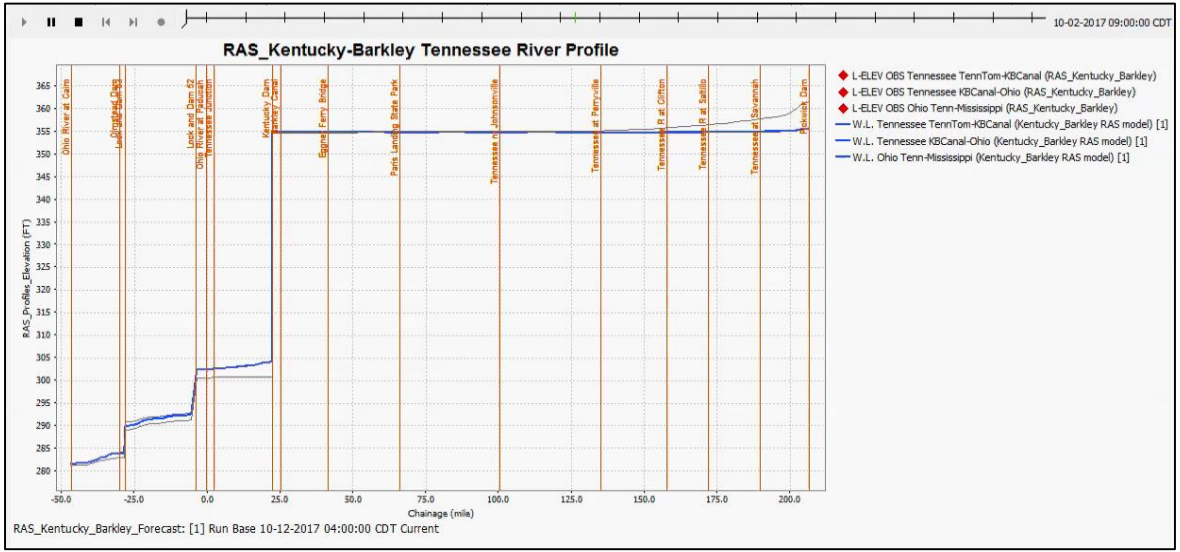
Map | Plots | Spatial Data | Modifiers | Data Editor | System Monitor

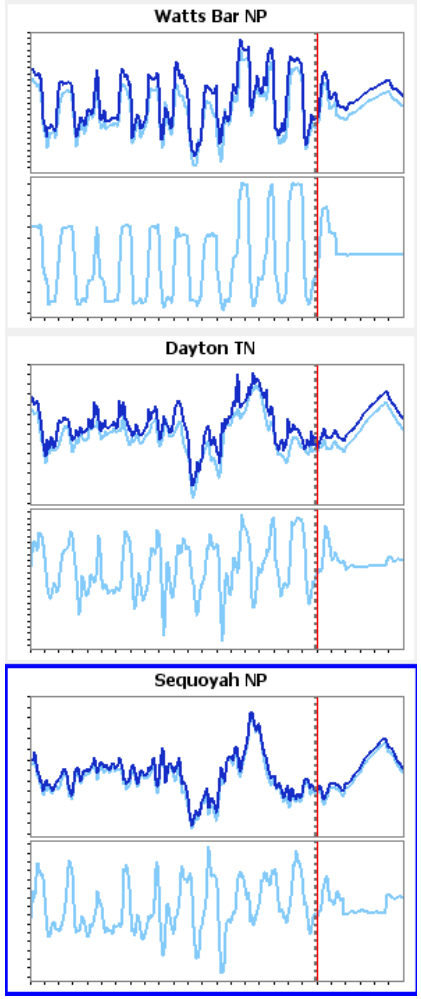
Plot Overview



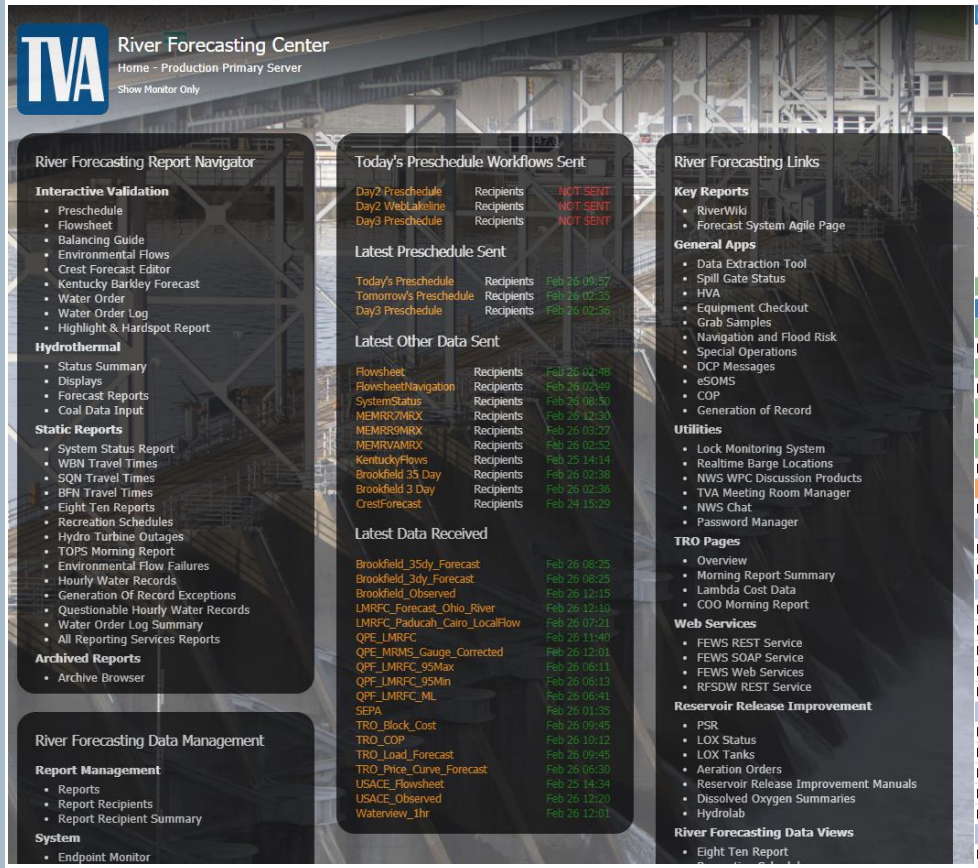
Miller, Gabriel Alexander | Current system time: 10-23-2017 23:00 CDT | 06:41:55 CEST | USTETVPMC00 | -88.296 , 34.064 | 0.0 MB/s | 526 MB

Hydraulic Models





Reporting



DAILY HYDRO REPORT | **Tuesday, February 26, 2019** | **Generated:2/26/2019 12:34 PM Central**

```
SHH: 2/6-3/3. Daily TGB oil check/cleanup. No generation 1200-1400.
BOH: UFN. Spread generation and limit ramping to stabilize TW.
BOH: 1/7-3/30. Fluctuating pool for baseline data collection.
FPH: 2/26-27. Unit Testing.  Min of 1 unit from 0700-1830 each day.
O1H: UFN. Unit 5 creep. Run 1 unit minimum.
GFH: thru 4/30. Unit restrictions for HW below 787.5'.
GFH: UFN. Minimize spill below 794.0' to avoid logs stuck in gates.
-------------------------------------------------------------------------------
WBH: UFN. Run 1 unit for 1 hour after 4 consecutive hours of zero flow.
WBH/CHH: UFN. SQN. Min 8K past plant, steady if daily Q is less than 10.5K.
GUH/WEH: UFN. BFN Min 13K hourly, min 13K daily, steady past BFN if Q<15K.


EXPECTED GATE CHANGES
Today: FPH,NOH,MHH,O3H,O1H,GFH,FLH,NJH,WEH,WLH,KYH
Tomorrow: WIH,BOH,FPH,CRH,DGH,FNH,NOH,MHH,CTH,APH,O3H,O1H,GFH,CHH,NJH,WEH,WLH,PKH,KYH

If you have any questions concerning the daily hydro report, please call River Operations at 865-632-6065.
```

TVA Statistic | TVA Project | Brookfield Project | Corps Project | Canal

Location	Tue, 02/26	Wed, 02/27	Thu, 02/28	Fri, 03/01	Sat, 03/02	Sun, 03/03	Mon, 03/04	Tue, 03/05	Detail Trend
TVA Total									
⊞Sum MWh	55,625.0	58,132.0	58,636.0	60,007.0	60,436.0	60,543.0	59,342.0	60,801.0	
TVA+(Cmb-SEPA)									
⊞Sum MWh	64,243.0	66,676.0	67,108.0	68,714.0	69,628.0	70,615.0	68,232.0	69,953.0	
Tributary Storage									
⊞End Stor	4,198.3	4,189.9	4,164.7	4,135.6	4,101.5	4,060.5	4,013.0	3,959.6	
Chatt FS Available									
⊞End %	28.3	30.5	33.3	36.4	39.3	42.1	45.2	48.1	
Chilhowee									
⊞Avg Out	12.3	16.6	16.0	16.2	15.7	15.5	15.4	15.3	
Tellico									
⊞Avg In	6.8	4.2	3.3	3.1	2.6	2.1	1.7	1.5	
⊞Avg Out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Fort Loudoun									
⊞Avg In	16.2	8.6	6.1	5.5	4.7	3.7	2.9	2.3	
⊞End El	811.7	811.2	810.8	810.4	809.9	809.1	808.7	808.8	
⊞Avg Out	77.4	77.5	77.5	77.5	77.5	77.5	70.3	63.0	
⊞End TW	748.9	748.5	748.2	747.9	747.7	747.6	745.1	744.8	
⊞Sum MWh	3,559.6	3,583.0	3,660.0	3,659.0	3,652.0	3,642.0	3,652.0	3,679.0	
Watts Bar									
⊞Avg In	7.9	5.0	4.4	3.9	3.5	2.9	2.4	2.1	
⊞End El	742.4	741.4	740.3	739.4	739.0	738.5	737.6	737.0	
⊞Avg Out	131.5	131.7	131.5	124.4	117.3	117.0	116.5	103.5	
⊞End TW	691.4	691.1	690.6	688.8	688.2	688.0	687.8	684.9	
⊞Sum MWh	4,268.5	4,248.0	4,115.0	4,100.0	4,146.0	4,105.0	4,024.0	4,046.0	
Chickamauga									
⊞Avg In	19.5	12.3	9.4	7.8	7.4	6.3	5.4	4.8	

Wiki

Main page | Discussion | Read | View source | View history | Search RiverWiki

Main page
Recent changes
Email Questions

- Checklists
  - Roles
  - Lead
  - Preschedule
  - Kentucky Barkley
  - Data Steward
- FEWS Basics
- River Forecast System
- Hydrothermal
- System Documentation
- Wiki Basics
- Tools

Welcome to the RiverWiki

The RiverWiki s a tool to help you do your job better and more easily. How many times have you thought; "now where did I put that info on the sluice elevation at N
Please use this wiki as a place to store our collective knowledge of our river system, and how to run it. The tools for collecting and organizing information are so ea
note much faster. You don't even need permissions to use this tool, because it is yours. To edit a page simply login (upper right hand corner) and then click on the

If you encounter any bugs or issues in FEWS, please enter them into our tracking system **IT Backlog**.

River Forecast System

- Data Validation
- Spill Calculator
- Precipitation Processing and Selection
- Inflow Model
- Transitional Data Retrieval
- Riverware
- Kentucky-Barkley Model
- Mainstem HEC-RAS Models
- Reports and Messaging
- Archive
- Applications and Links
- Checklists
- How to Make a Schedule Change
- Crest Forecast and Phone Bank Tools
- Daylight Savings
- Verification
- IT Backlog

Hydrothermal Modeling System

- Disclaimer

Key Data

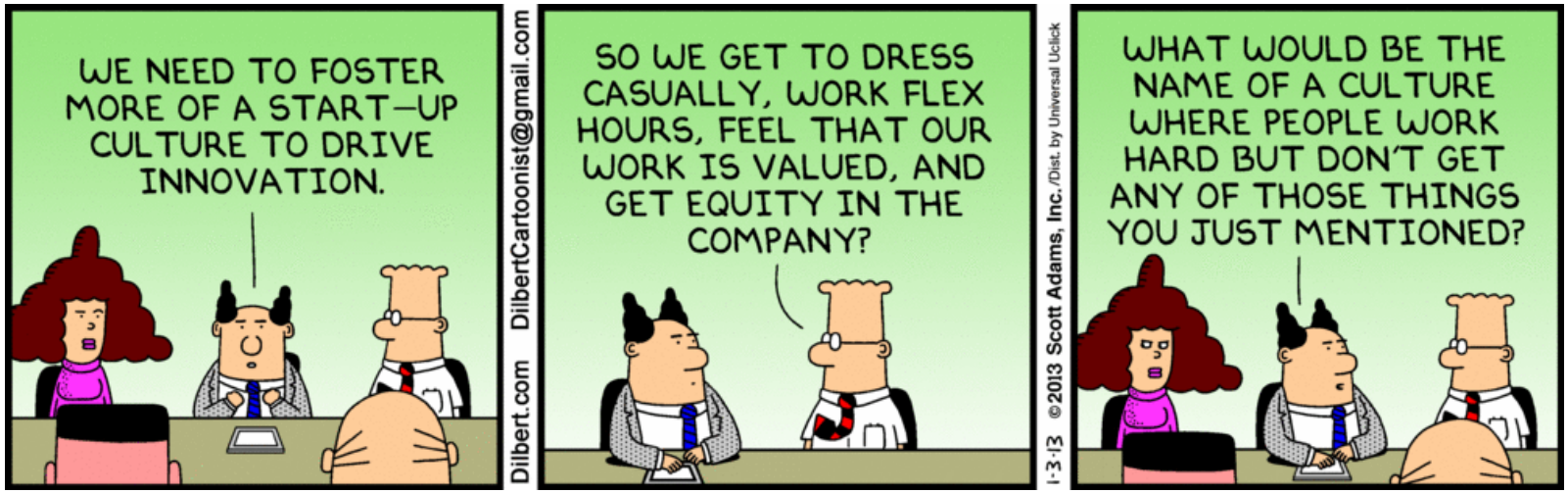
- River Data Repository
- Reservoir Operations Study (ROS)
- Support Contacts
- LakeInfo Website
- NWSChat
- Reports Manager
- Live Data
- Flood Risk and Floodplains
- Water Record Data Access
- **Water Resources Dashboard**

System Documentation

- Locations
- Parameters
- Min Flow Requirements
- System Administration
- System Diagram
- FAQ
- Daylight Savings Known Issues

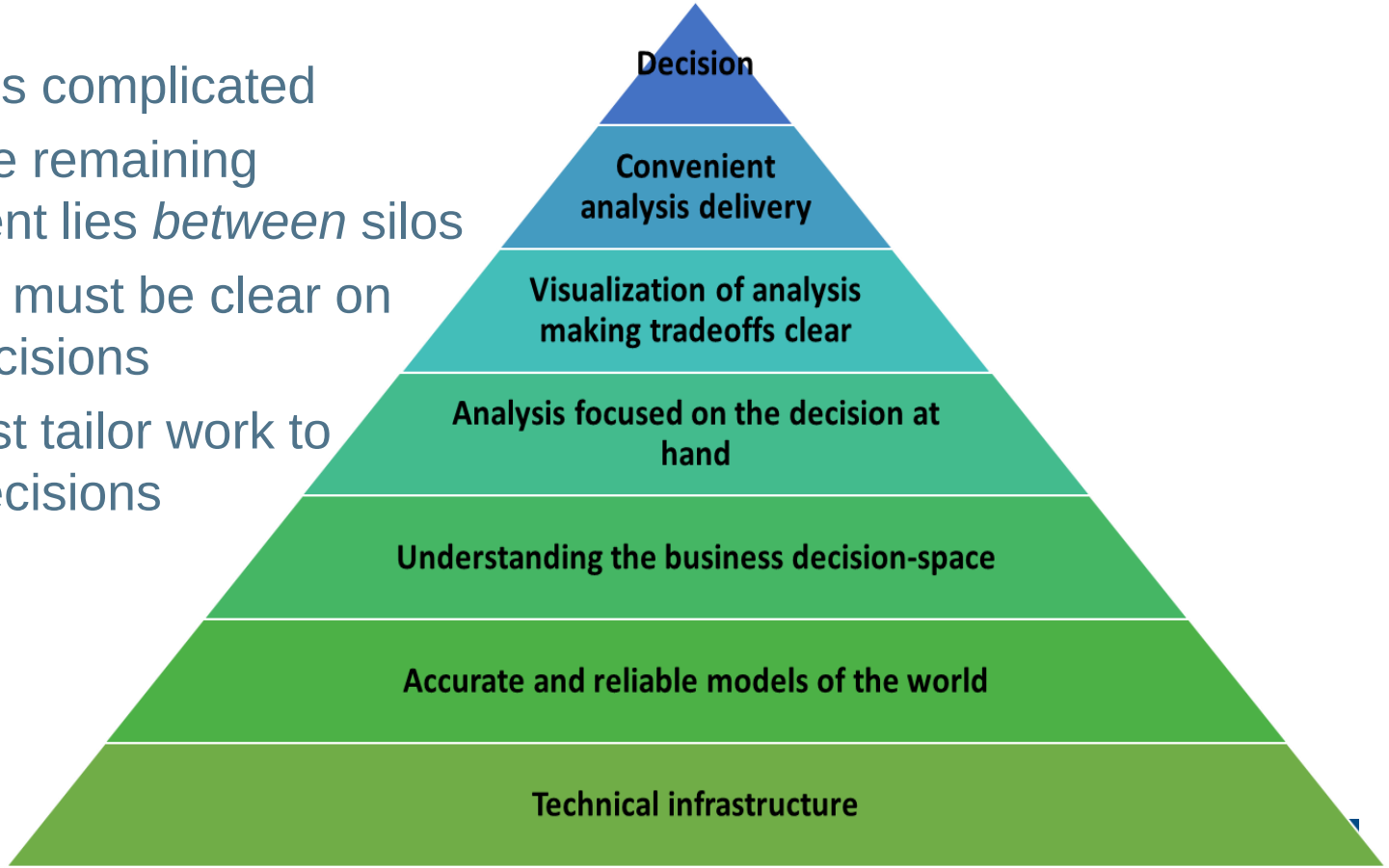
FEWS Information

What's the next innovation?

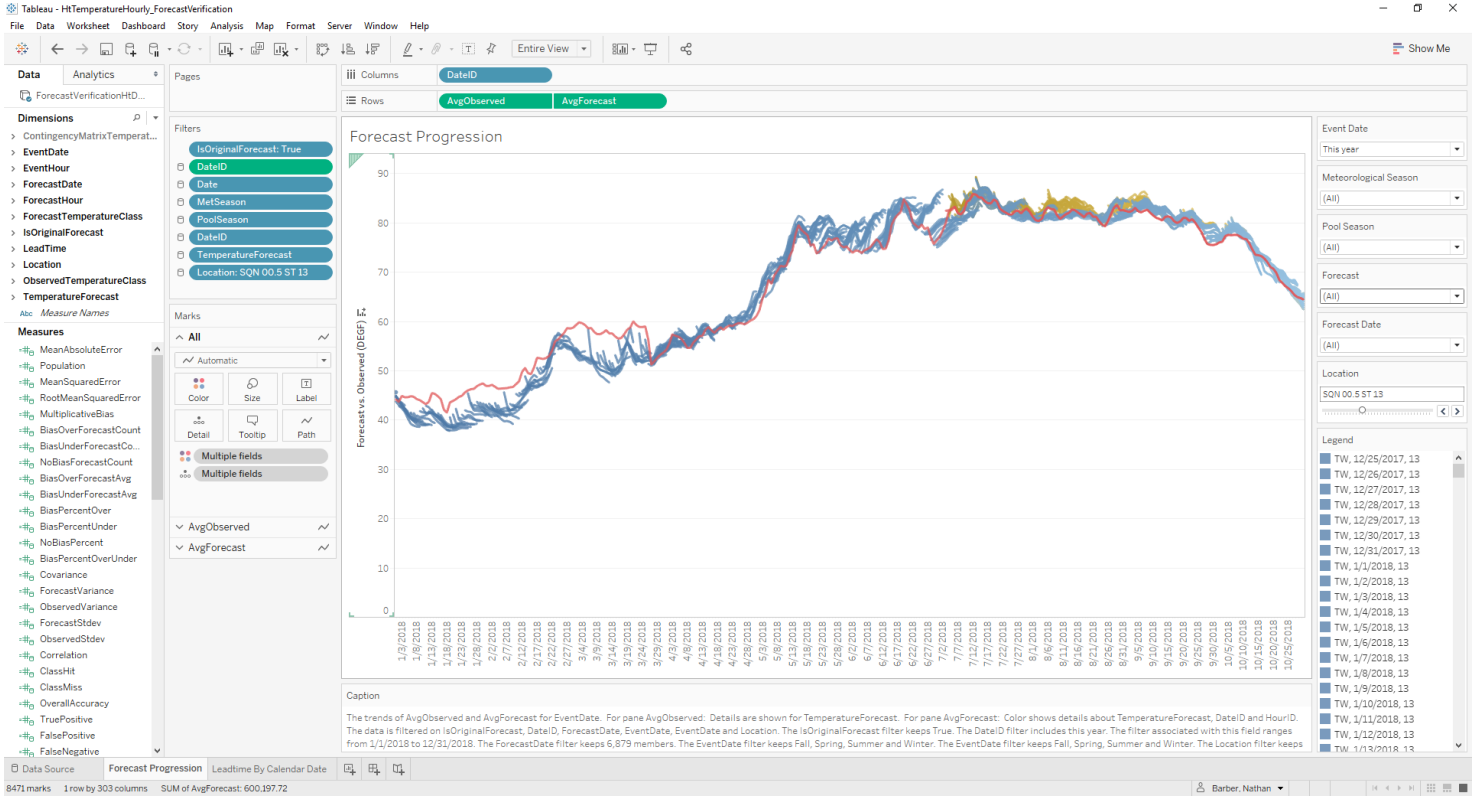


Better Decisions

- The world is complicated
- Much of the remaining improvement lies *between* silos
- Executives must be clear on framing decisions
- Teams must tailor work to improve decisions



Validate Decisions (Forecast Verification)

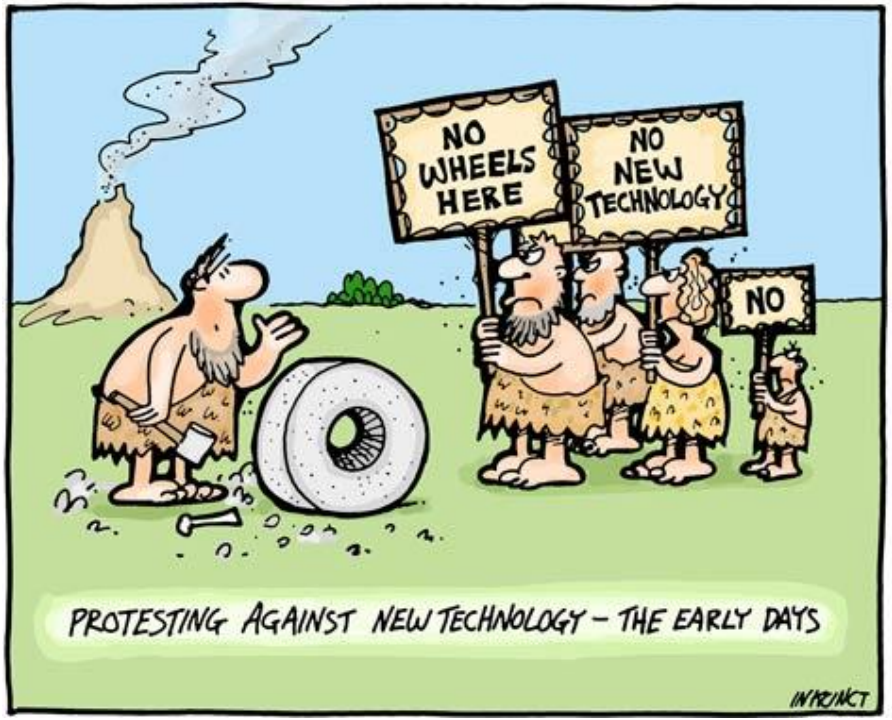


Ongoing/Upcoming Projects

- Reservoir optimization improvements
- Probabilistic Flood Hazards Analysis
  - Paleo hydrology study
- Real-time floodplain inundation mapping
- Water Supply Reliability
  - Dendrochronology study
- Better integration of hydro with our thermal units
- Lots of small improvement request
  - 140 Currently in JIRA tracking system

Future Opportunities

- Data Assimilation
- Internal Mobile App/Thin Client (In FEWS?)
- Better external data feeds/improved app
- Ensemble Inflow Forecasts
- Machine learning
- Drought in the west
- Aging infrastructure – Dam Safety



TVA