



Modeling Extreme Events at TVA with RiverWare

**RiverWare User Group Meeting
Boulder, Colorado Feb 1-2 2012**

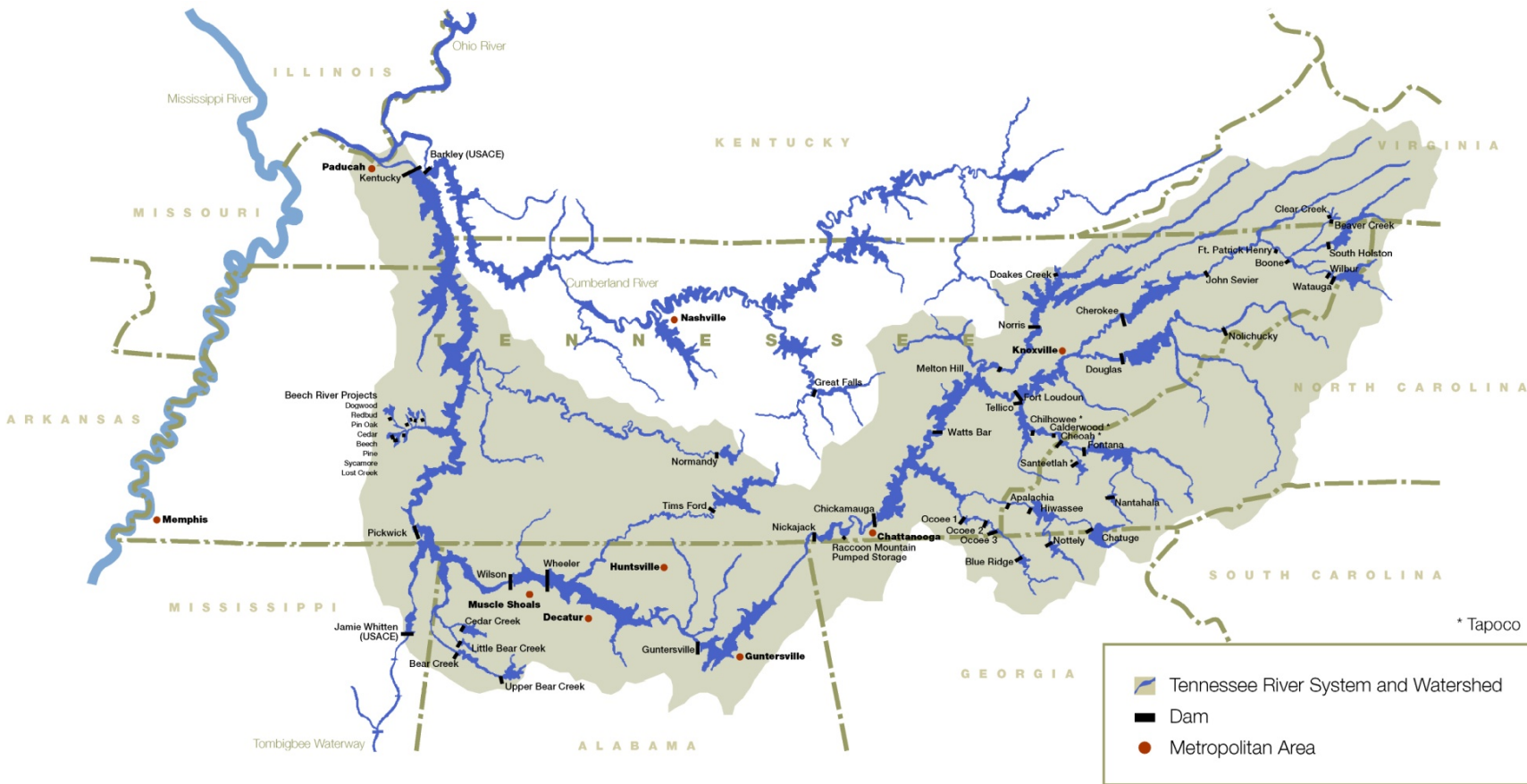


Outline

- A little TVA background
- TVA recalculation of PMF levels at 49 dams
- What is the role of RiverWare?
- What data are needed for RiverWare on TVA's main river projects?
- How well does RiverWare perform?



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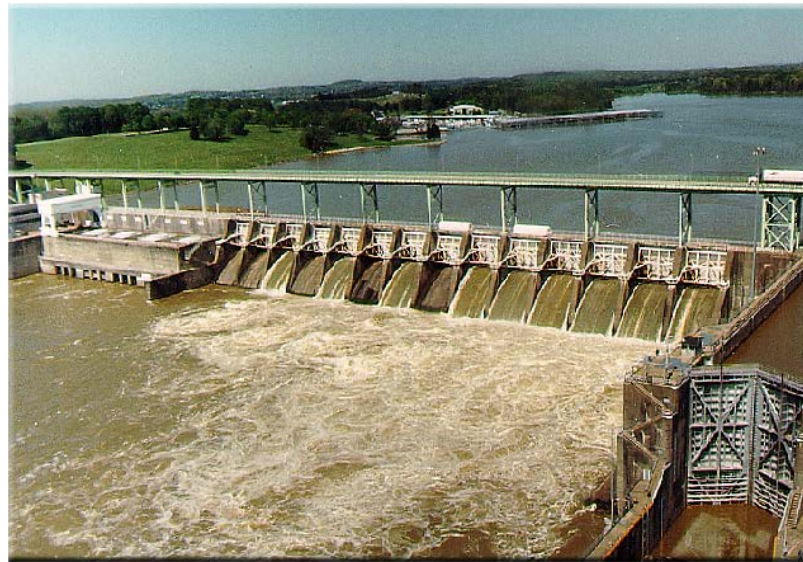


49 Projects

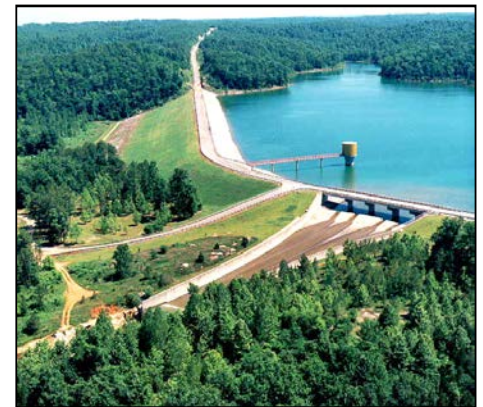


LARGE

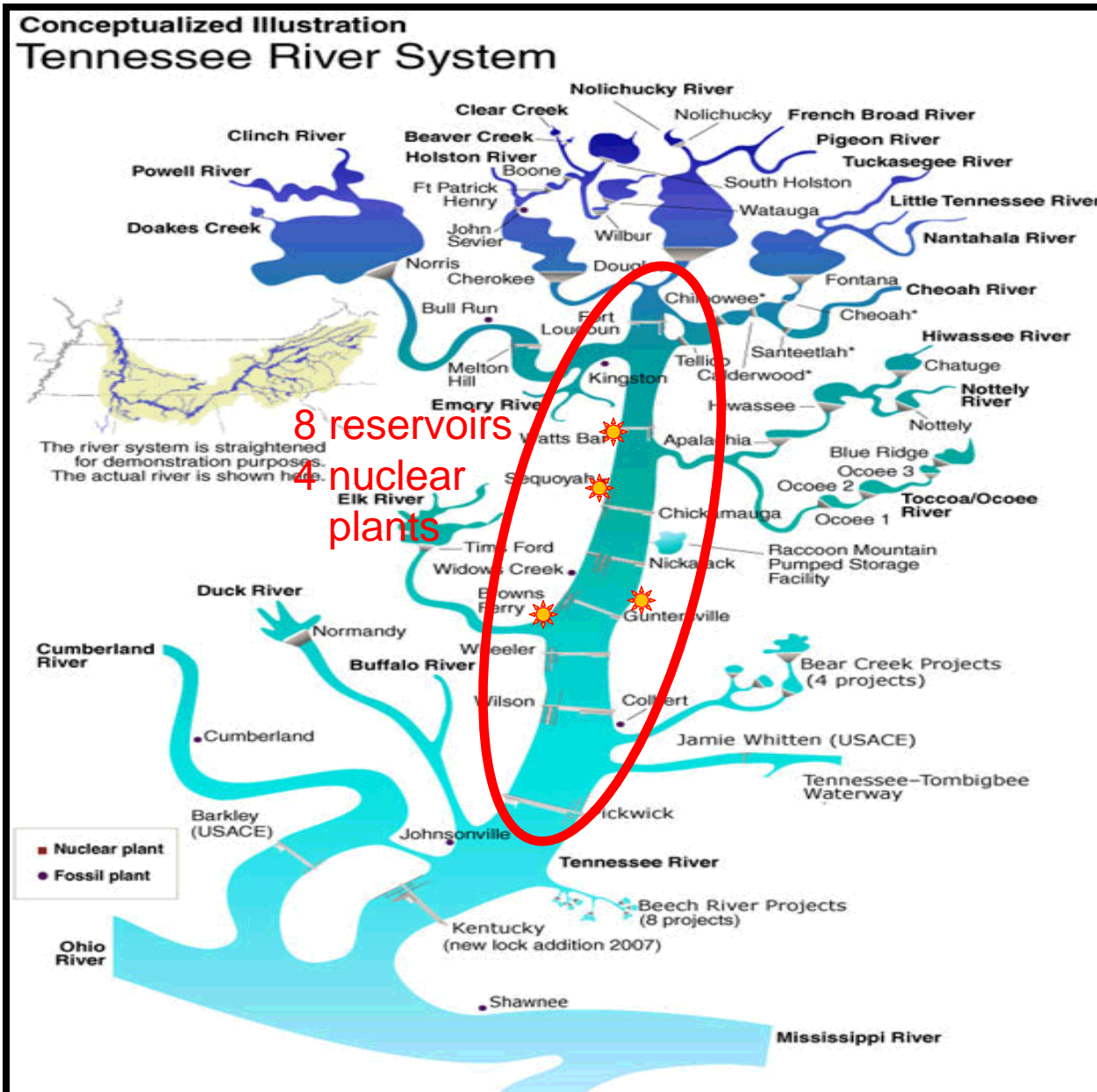
MEDIUM



Small

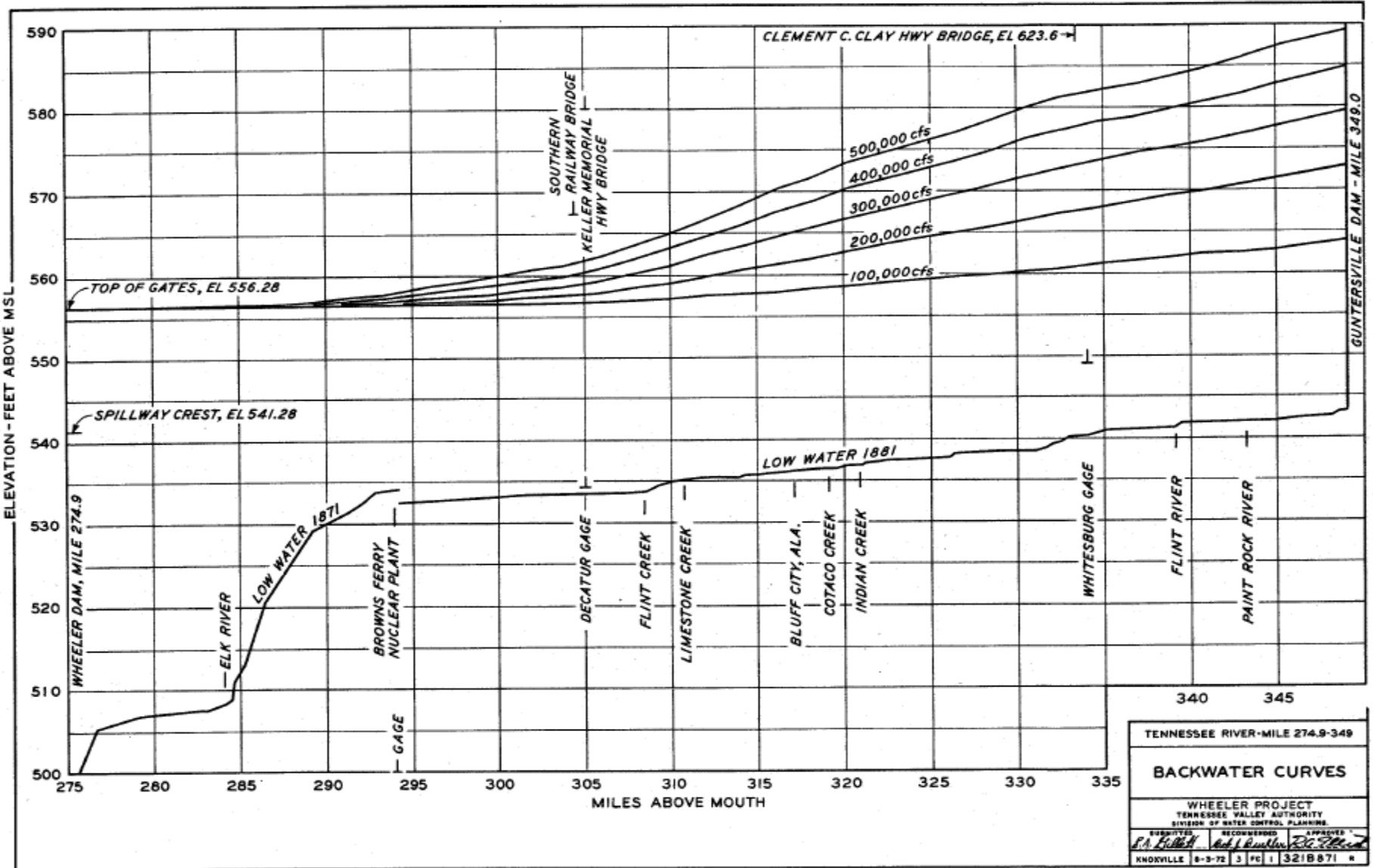


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Backwater Profile for Wheeler Reservoir



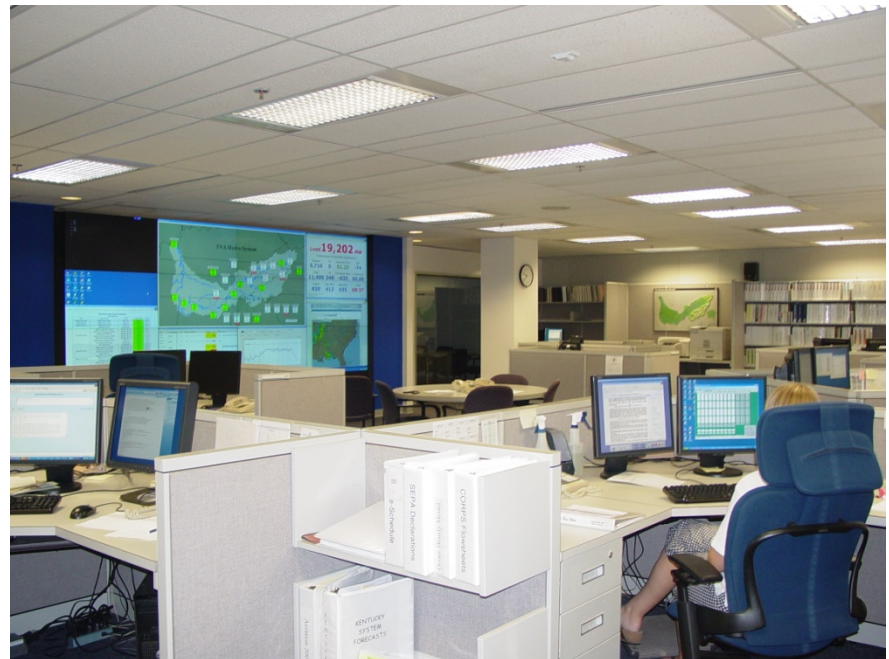
Completing reassessment of PMF at 49 projects

- Team of TVA employees and contractors performed calculations
- Initially triggered by interest in getting license to resume construction on deferred nuclear plant
- New channel geometry and historic flood calibrations for many reservoirs
- Complete reevaluation of dam rating curves (DRC's) at all projects
- Deterministic analysis, using Weather Service HMR's for design rainfall
- For main river reservoirs, used TVA's SOCH model for reservoir routing (TVA's equivalent of HEC-RAS--may convert to HEC-RAS for future studies)
- RiverWare not used directly in these studies



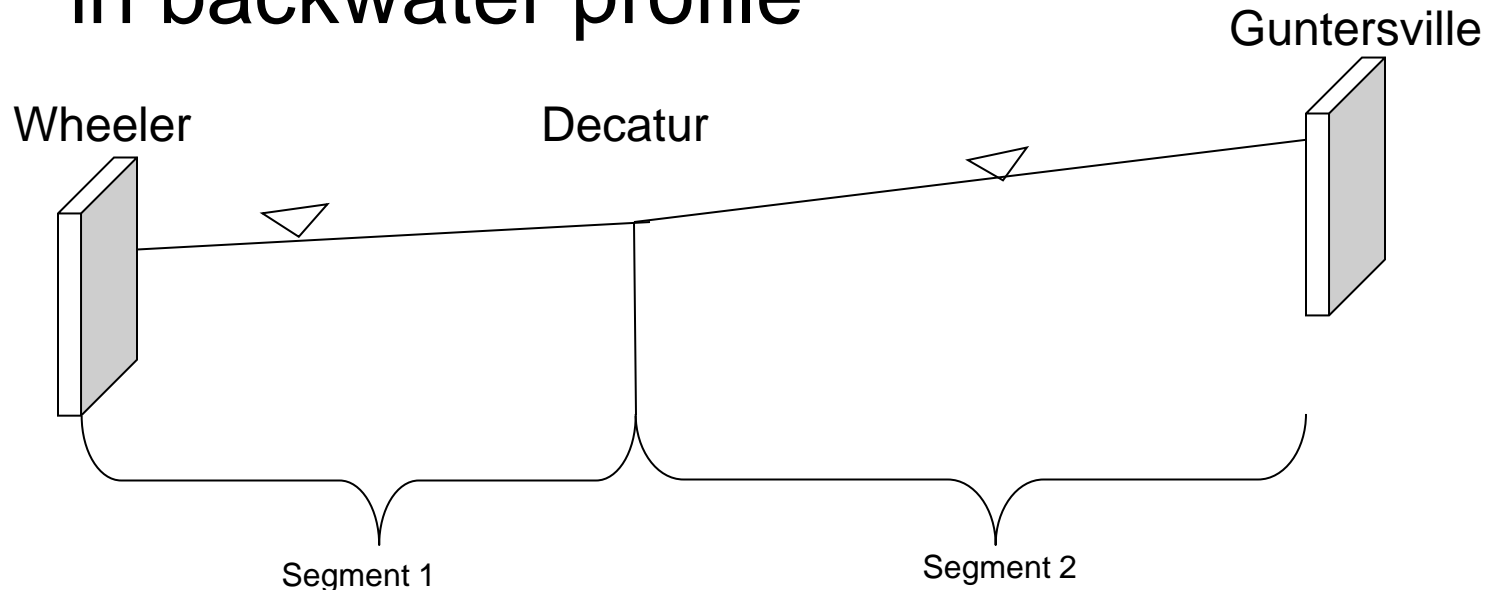
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But it is the “tool of choice” for day to day scheduling of the reservoir system and for issuing river forecasts (since 1996)



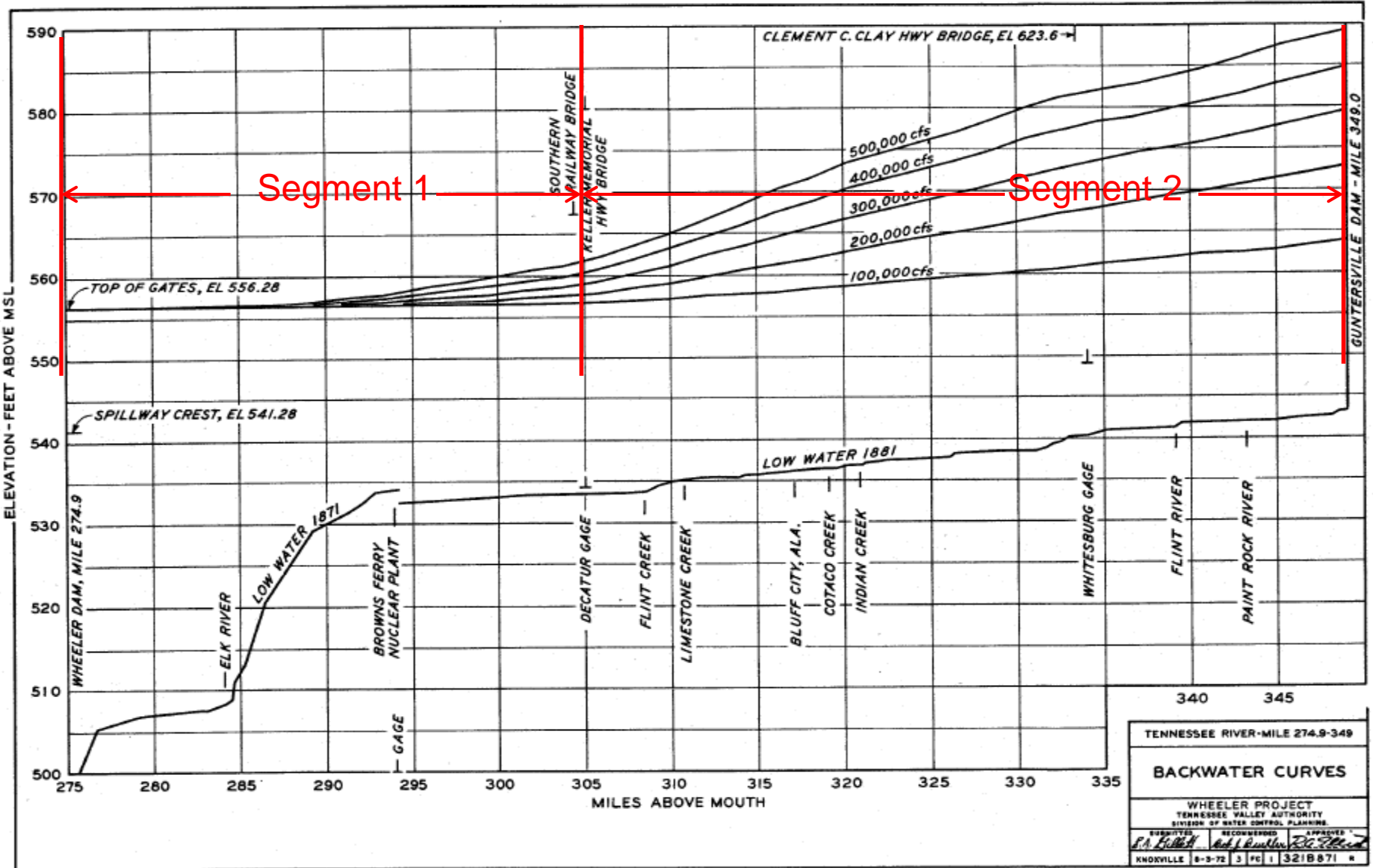
Slope storage calculations in RiverWare

- Slope storage reservoirs can be divided into segments
- The end of a segment denotes a break in backwater profile





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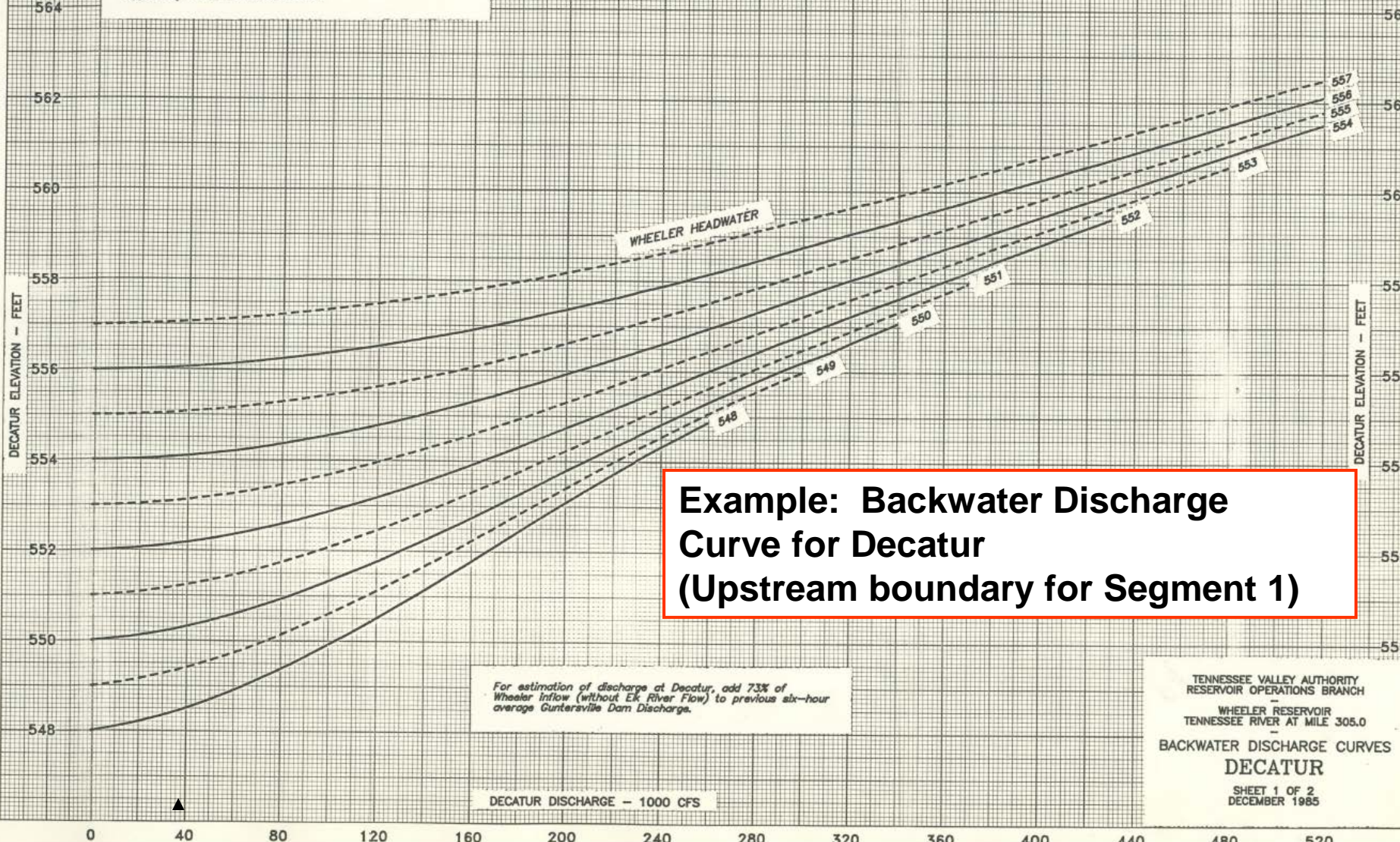


Backwater Profile for Wheeler Reservoir



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These curves were derived from steady flow simulations on the Main River Hourly Dynamic Routing Model developed by Engineering Laboratory Branch. The model was calibrated and verified for the full range of observed flows and elevations. Extension of curves to PWF levels was based on information supplied by Flood Protection Branch.



Example: Backwater Discharge Curve for Decatur (Upstream boundary for Segment 1)

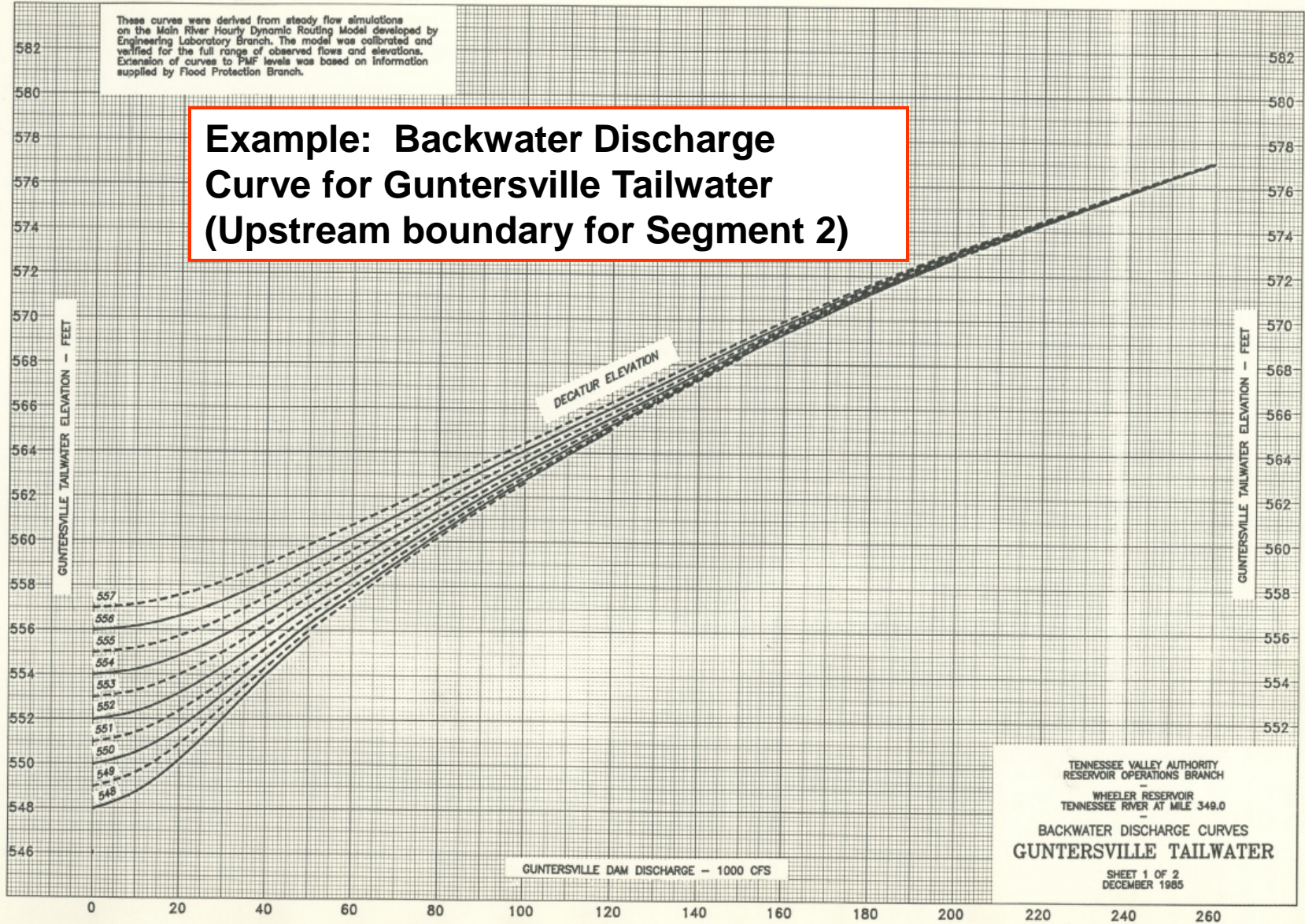
TENNESSEE VALLEY AUTHORITY
RESERVOIR OPERATIONS BRANCH
WHEELER RESERVOIR
TENNESSEE RIVER AT MILE 305.0
BACKWATER DISCHARGE CURVES
DECATUR
SHEET 1 OF 2
DECEMBER 1985



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These curves were derived from steady flow simulations on the Main River Hourly Dynamic Routing Model developed by Engineering Laboratory Branch. The model was calibrated and verified for the full range of observed flows and elevations. Extension of curves to PMF levels was based on information supplied by Flood Protection Branch.

Example: Backwater Discharge Curve for Guntersville Tailwater (Upstream boundary for Segment 2)

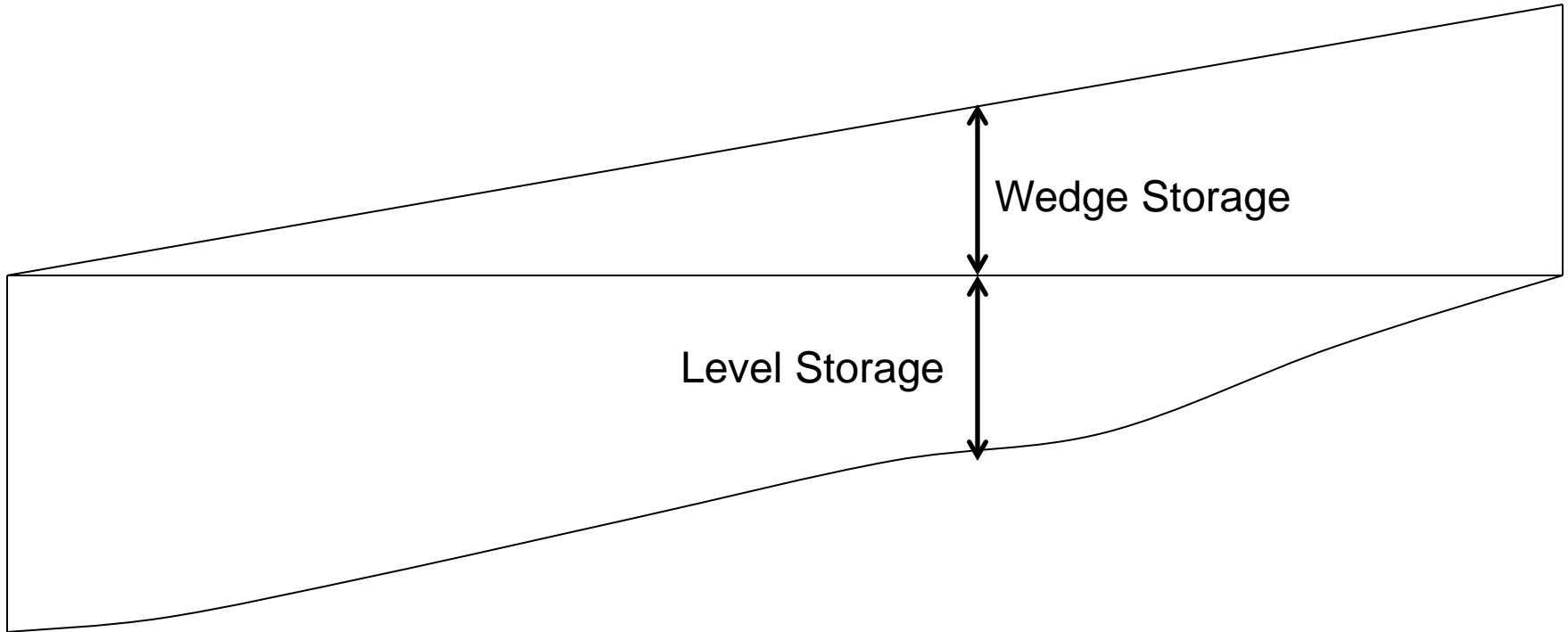


TENNESSEE VALLEY AUTHORITY
 RESERVOIR OPERATIONS BRANCH
 -
 WHEELER RESERVOIR
 TENNESSEE RIVER AT MILE 349.0
 -
 BACKWATER DISCHARGE CURVES
GUNTERSVILLE TAILWATER
 SHEET 1 OF 2
 DECEMBER 1985

Guntersville Tailwater
 30.00 TO THE INCH = 15.00 FEET
 K&E
 RECEIVED & ISSUED CO. MADE IN U.S.A.

47 1242

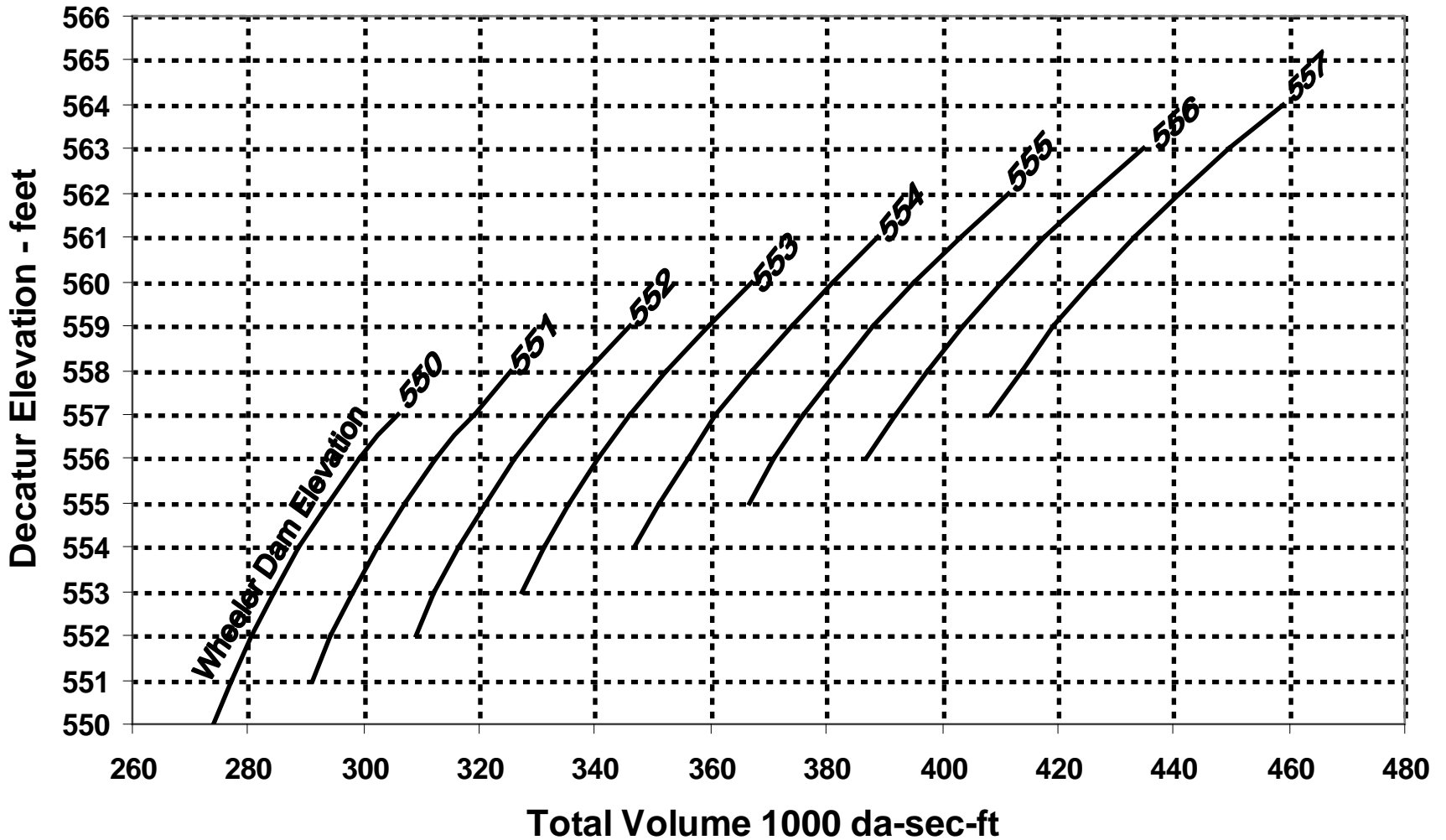
Profile Storage





Modeling Extreme Events at TVA with RiverWare

Wheeler Dam to Decatur Profile Storage





Modeling Extreme Events at TVA with RiverWare

Let's look at the relevant tables in RiverWare

Open Object - Wheeler

File Edit View Slot Account

Object Name: Wheeler

Slots Methods Accounts

Selected Method:

Category	Method
hydrologicInflowCalculationCategory	inputHydrologicInflow
hydrologicInflowCalculationCategory	SlopeStorageCalc
hydrologicInflowCalculationCategory	Segments in Reservoir
hydrologicInflowCalculationCategory	Profile Storage Table
targetSlopeStorageCategory	TargetSlopeStorageCalc
Evaporation and Precipitation	NoEvaporation
Surcharge Release Calculation	None
Flood Control Release Calculation	None
bankStorageCalculationCategory	NoBankStorage
Seepage Calculation	NoSeepage
targetOperation	NoTargetOperation
SedimentCalculation	NoSediment
Diversion from	NoDiversion

Edit Wheeler::Segments

File Edit View

Value:

Segments in Reservoir

Segment	Value
0	2.00

Edit Wheeler::Profile Storage Table

File Edit View

Value:

	Headwater 1	Backwater 1	Storage 1	Headwater 2	Backwater 2	Storage 2
	ft	ft	1000cfs-day	ft	ft	1000cfs-day
0	548.00	548.00	242.46	548.00	548.00	78
1	548.00	549.00	244.87	548.00	549.00	79
2	548.00	550.00	247.72	548.00	550.00	80
3	548.00	551.00	251.04	548.00	551.00	81
4	548.00	552.00	254.83	548.00	552.00	83
5	548.00	553.00	259.09	548.00	553.00	84
6	548.00	554.00	263.84	548.00	554.00	86

Let's look at the relevant tables in RiverWare

Open Object - Wheeler

File Edit View Slot Account

Object Name: Wheeler
Slope Power Reservoir Object

Slots Methods Accounts

24:00 August 5, 2009

Slot Name	Value	Units
Regulated Spill Capacity Fraction	NaN	decimal
Partitions per Segment		
Prof Hydro Inflow	0.00	1000 cfs
Requested Energy	NaN	MWH
Partition Profile Coef Table		
Partition Flow Parameters	39	1000 cfs
Partition BW Table		
Partition BW Elevation	NaN	ft
Requested Outflow	NaN	1000 cfs

- TVA.20090806.sim

Utilities Help

Simulation View

tsBar

amauga

Avoided Cost

Hiw Oco 12 hrs

Hiw Oco Cnfl

Apalachia

Hiwassee

O2 Spill 5 hrs

Ocoee2Local

O3 Spill

Raccoon Mtn

Ocoee1

Wheeler.Partition BW Table

File Edit Row Column View Adjust

Partition BW Table

Value: 548 ft

	Flow Param 1 1000 cfs	Headwater 1 ft	Backwater 1 ft	Flow Param 2 1000 cfs	Headwater 2 ft	Backwater 2 ft	Flow Param 3 1000 cfs	Headwater 3 ft	Backwater 3 ft	Flow 1000
0	0.00	548.00	548.00	0.00	548.00	548.00	0.00	548.00	548.00	
1	0.00	549.00	549.00	0.00	549.00	549.00	0.00	549.00	549.00	
2	0.00	550.00	550.00	0.00	550.00	550.00	0.00	550.00	550.00	
3	0.00	551.00	551.00	0.00	551.00	551.00	0.00	551.00	551.00	
4	0.00	552.00	552.00	0.00	552.00	552.00	0.00	552.00	552.00	
5	0.00	553.00	553.00	0.00	553.00	553.00	0.00	553.00	553.00	
6	0.00	554.00	554.00	0.00	554.00	554.00	0.00	554.00	554.00	
7	0.00	555.00	555.00	0.00	555.00	555.00	0.00	555.00	555.00	

Estimating Flow Parameters

Flow in the Main River reservoirs is gradually varying. However, because we use steady flow models, we use “flow parameters”. The flow parameter is the estimate of a steady flow, when the actual flow is gradually varying.

How are flow parameters computed in RiverWare?

$$P(t) = a_1 I(t) + a_2 I(t-1) + \dots + a_n I(t-n) + b_1 H(t) + b_2 H(t-1) + \dots + b_n H(t-n) + c_1 I2(t) + c_2 I2(t-1) + \dots + c_n I2(t-n) + d_2 P(t-1) + d_3 P(t-2) + \dots + d_n P(t-n) + e_1 O(t) + e_2 O(t-1) + \dots + e_n O(t-n)$$

Where...

I = Inflow from upstream dam

H = Hydrologic inflow

I2 = Inflow 2 (side inflows)

P = Flow parameter

O = Outflow



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What is a Dam Rating Curve?

A Dam Rating Curve shows the **maximum** amount of water that can be released at the dam as a function of pool elevation

A DRC will include one or more of the following components:

- Turbine discharge (regulated)
- Spillway discharge (regulated)
- Sluice (bypass) discharge (regulated)
- Emergency spillway discharge (unregulated)
- Flow over spillway deck (unregulated)
- Flow over top of raised spillway gates (unregulated)
- Flow over top of “non-overflow” portions of dam (unregulated)
- Flow over the top of lock gates and appurtenant lock structures (unregulated)
- Flow through failed portions of dams and saddle dams (unregulated)

DRC's are not static and may change throughout the storm event!



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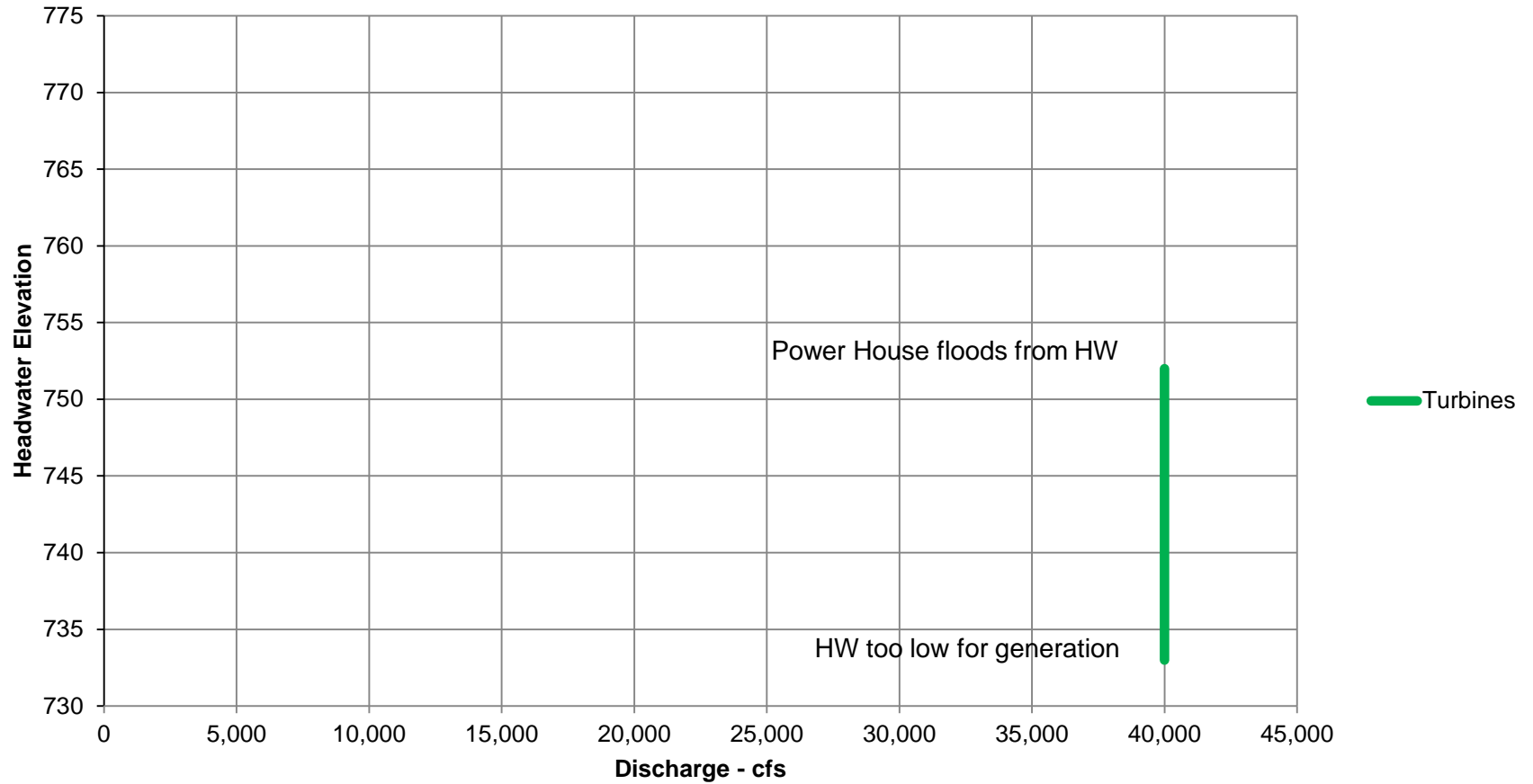
TVA uses these slots to define the DRC for a project as needed:

- Unreg Flow 3 Spill Table
- Unreg Flow 2 Spill Table
- Unregulated Spill Table
- Regulated Spill Table
- Bypass Table
- Max Turbine Q



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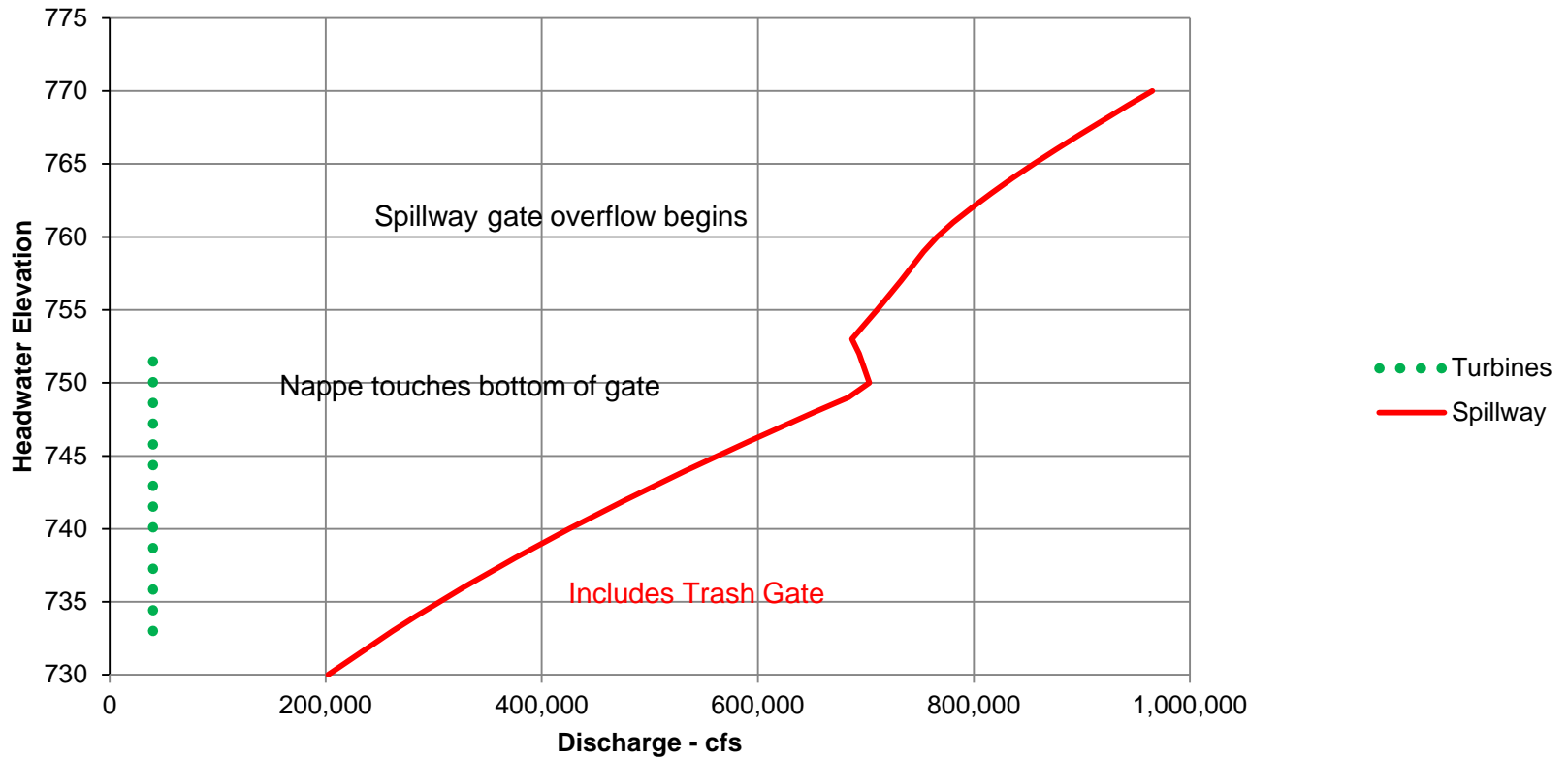
Watts Bar DRC





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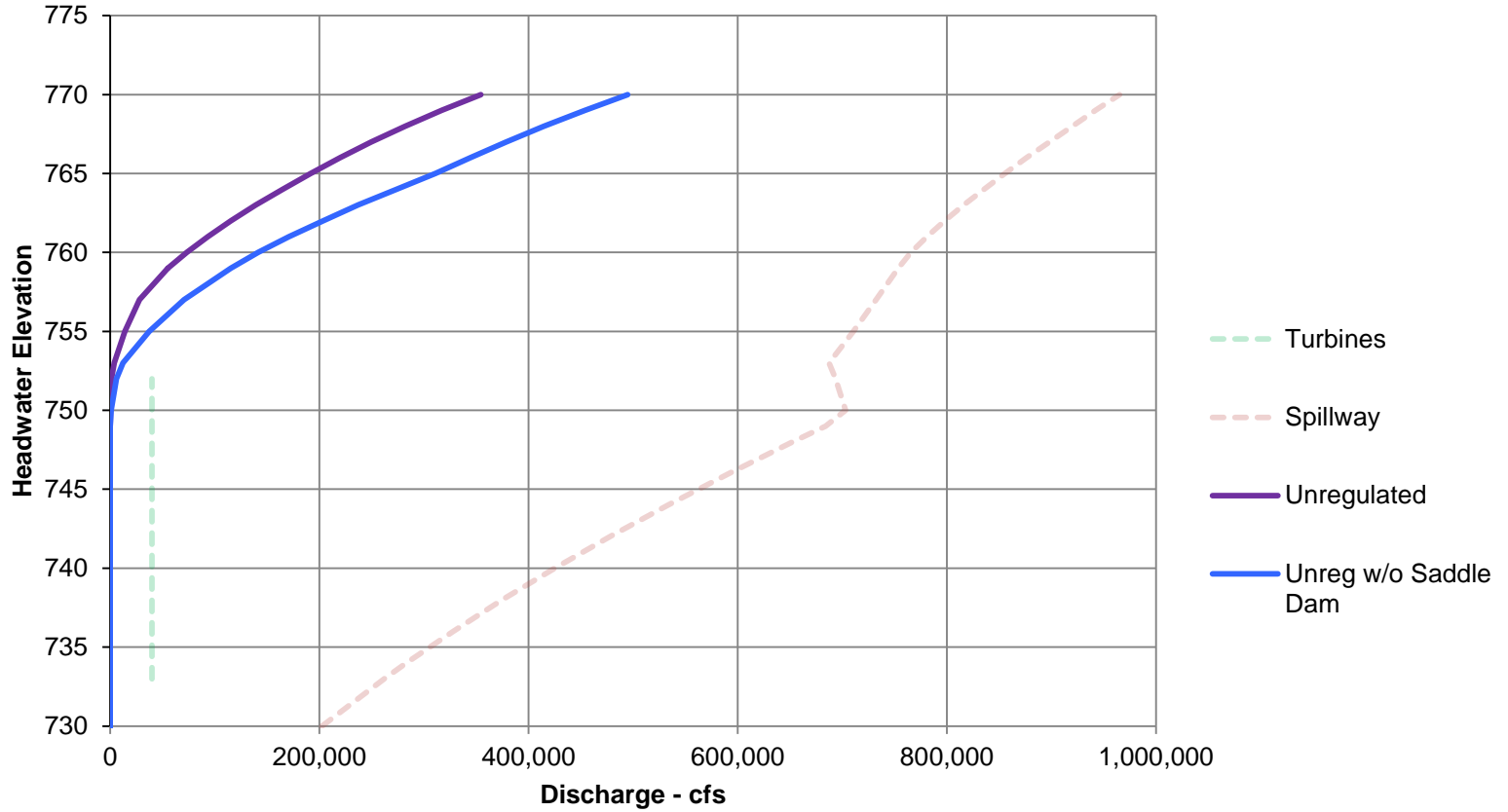
Watts Bar DRC





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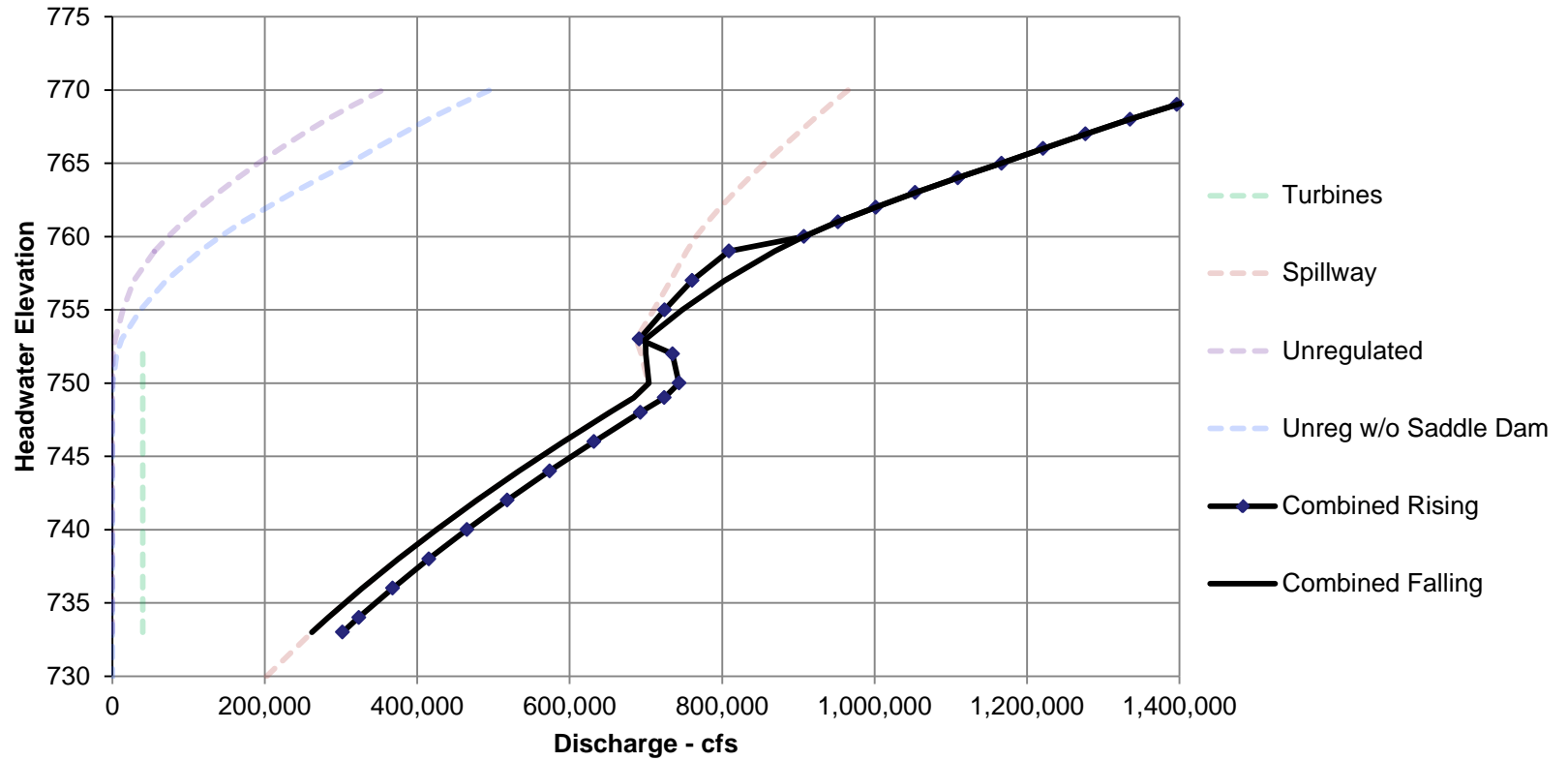
Watts Bar DRC





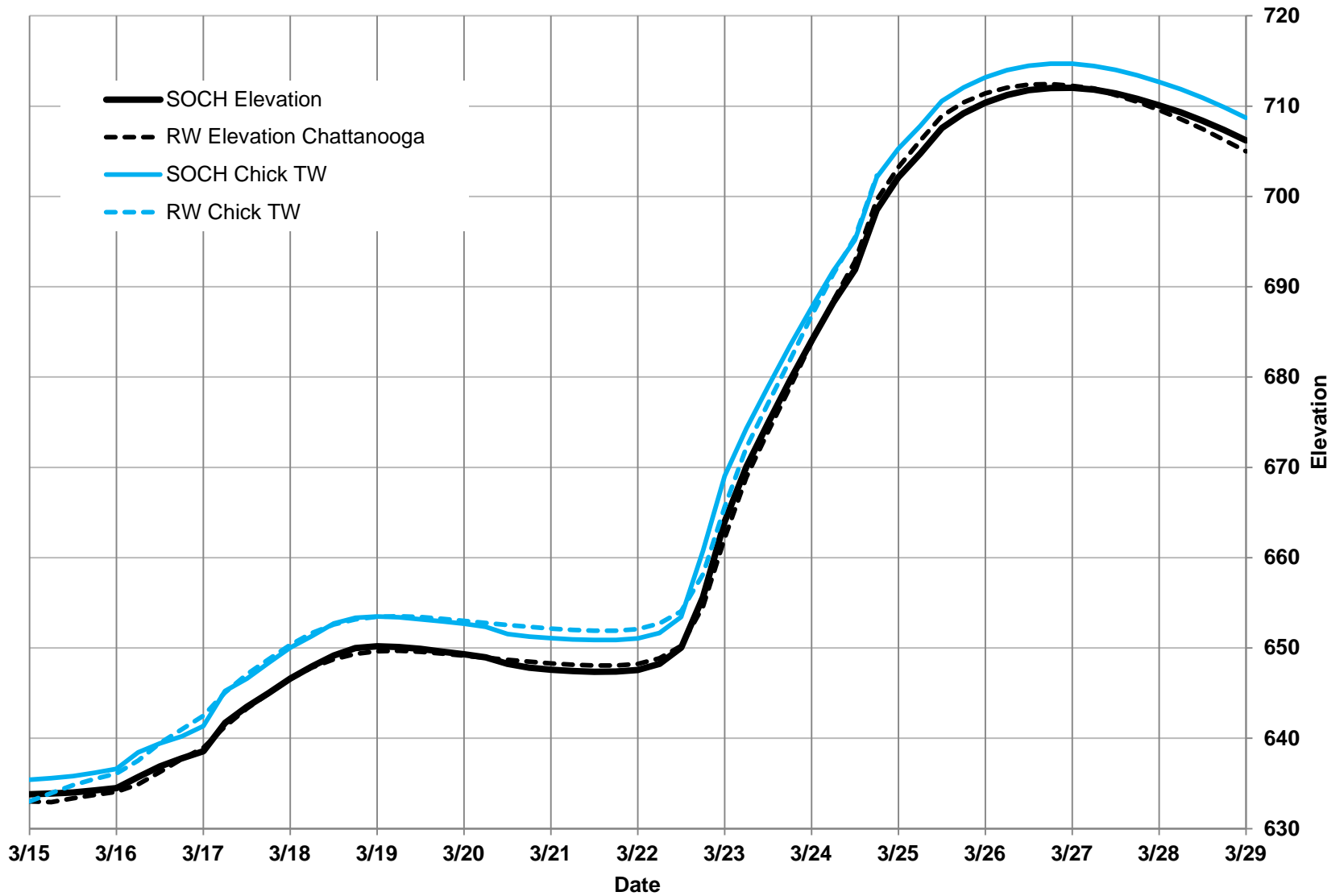
Modeling Extreme Events at TVA with RiverWare

Watts Bar DRC





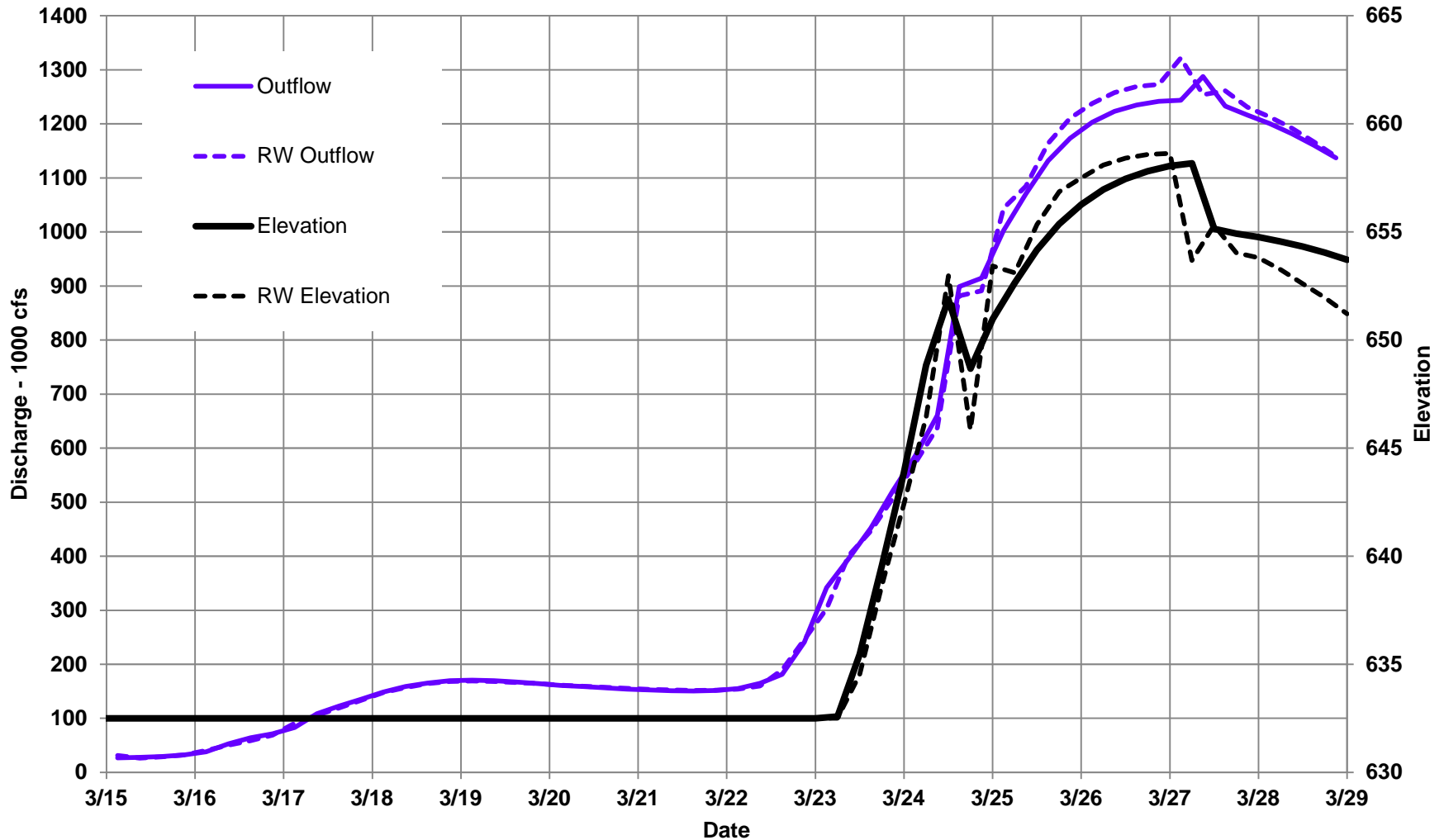
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Modeling Extreme Events at TVA with RiverWare

21400 Nickajack Reservoir





Modeling Extreme Events at TVA with RiverWare

21400 Chickamauga Reservoir Final Lock Configuration

