May 2003 Flood

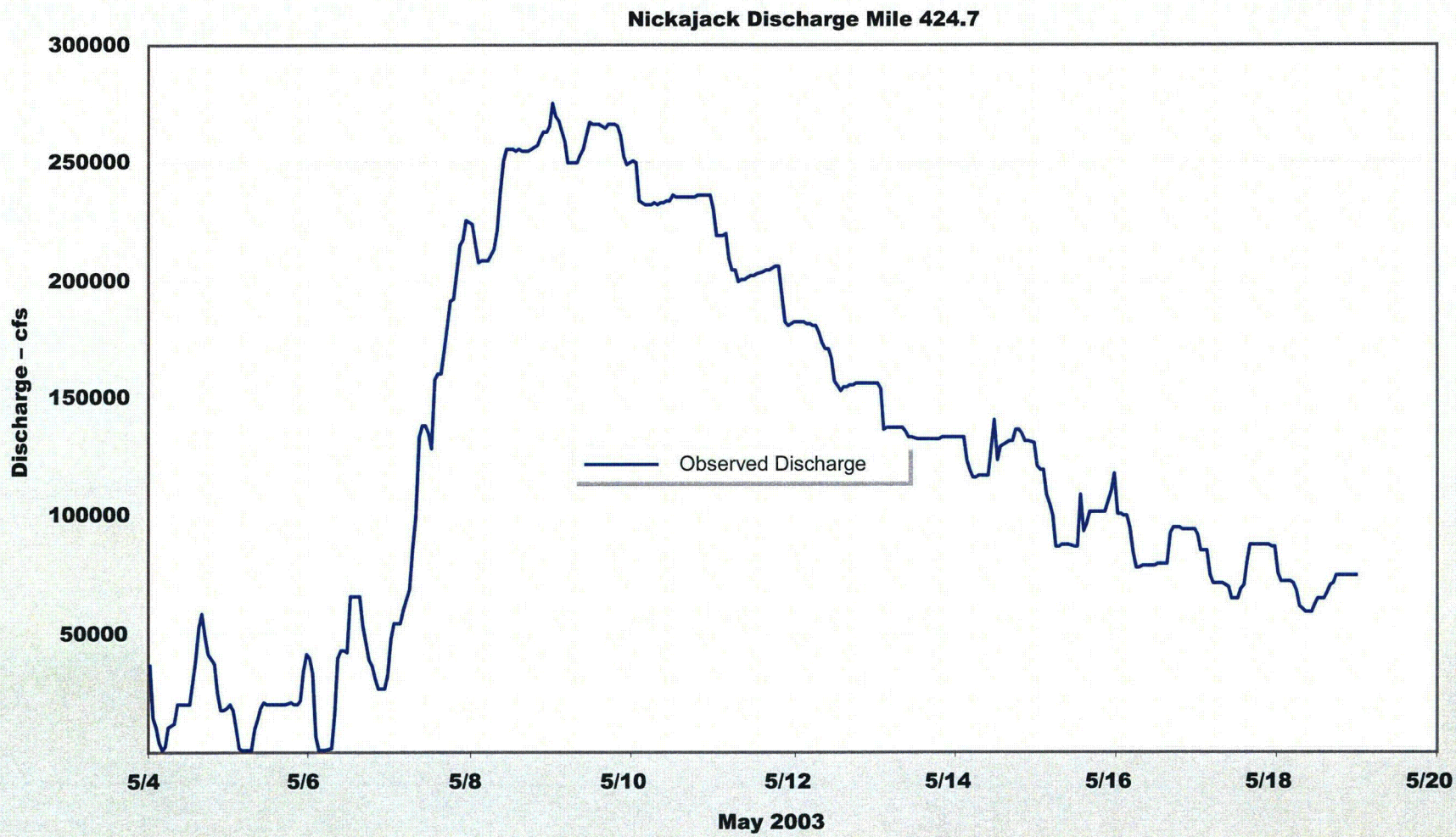
Simulations Based on Approximate Inflows

May 2003 Flood

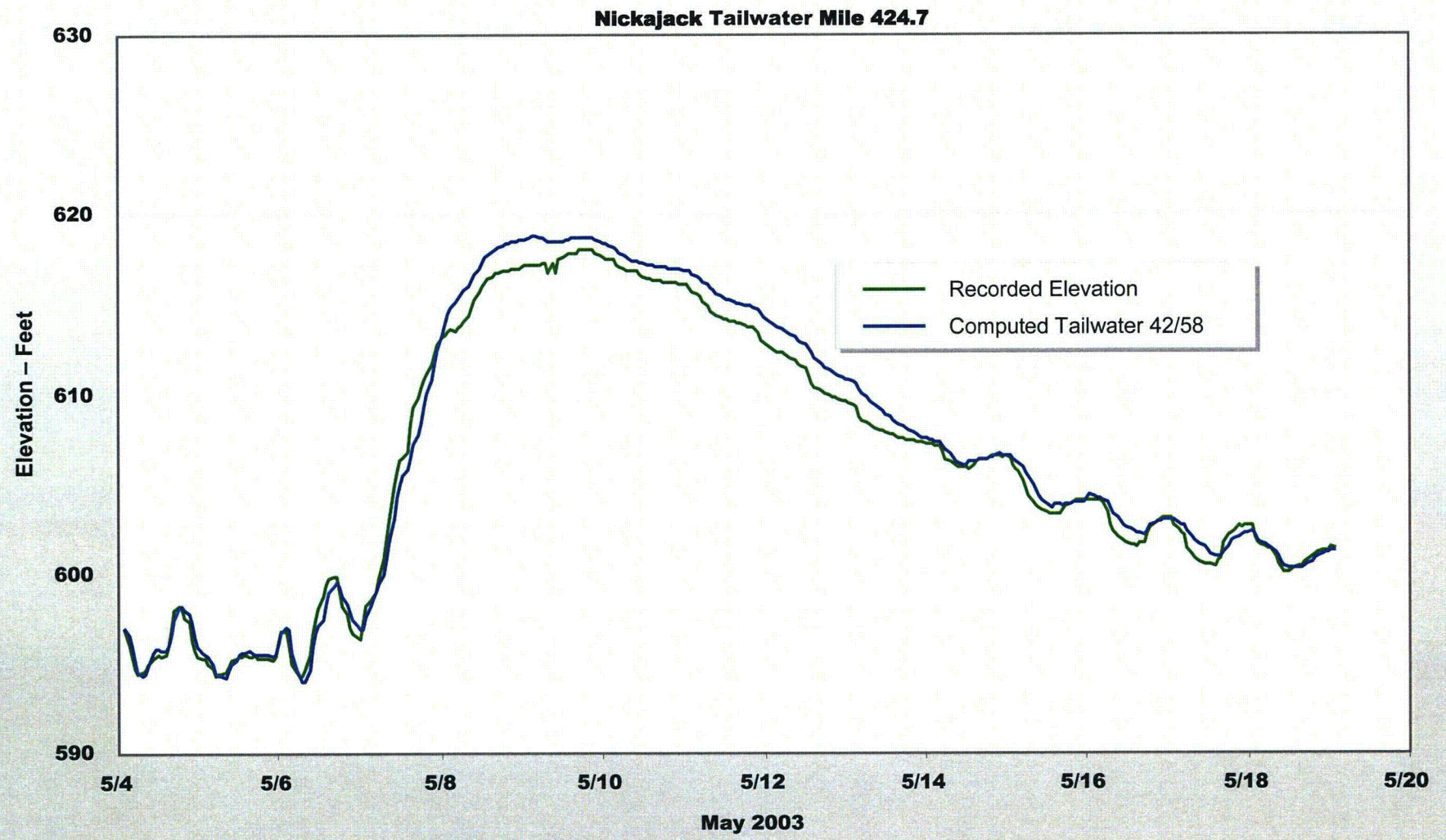
- SOCH Model Setup (updated Guntersville geometry)
  - Upstream boundary Nickajack discharge
  - Downstream boundary Guntersville headwater
  - Sequatchie River local input as local at Mile 421.7 (gaged)
  - Reservoir Local (north)– distributed Mile 424.7 to Mile 391.06 (first 16 reaches)
  - Reservoir local (south) – distributed Mile 391.06 to Mile 349 (lower 22 reaches)

[Total local based on 24-hour average subtract out — (inflow minus outflow) — APPROXIMATE]

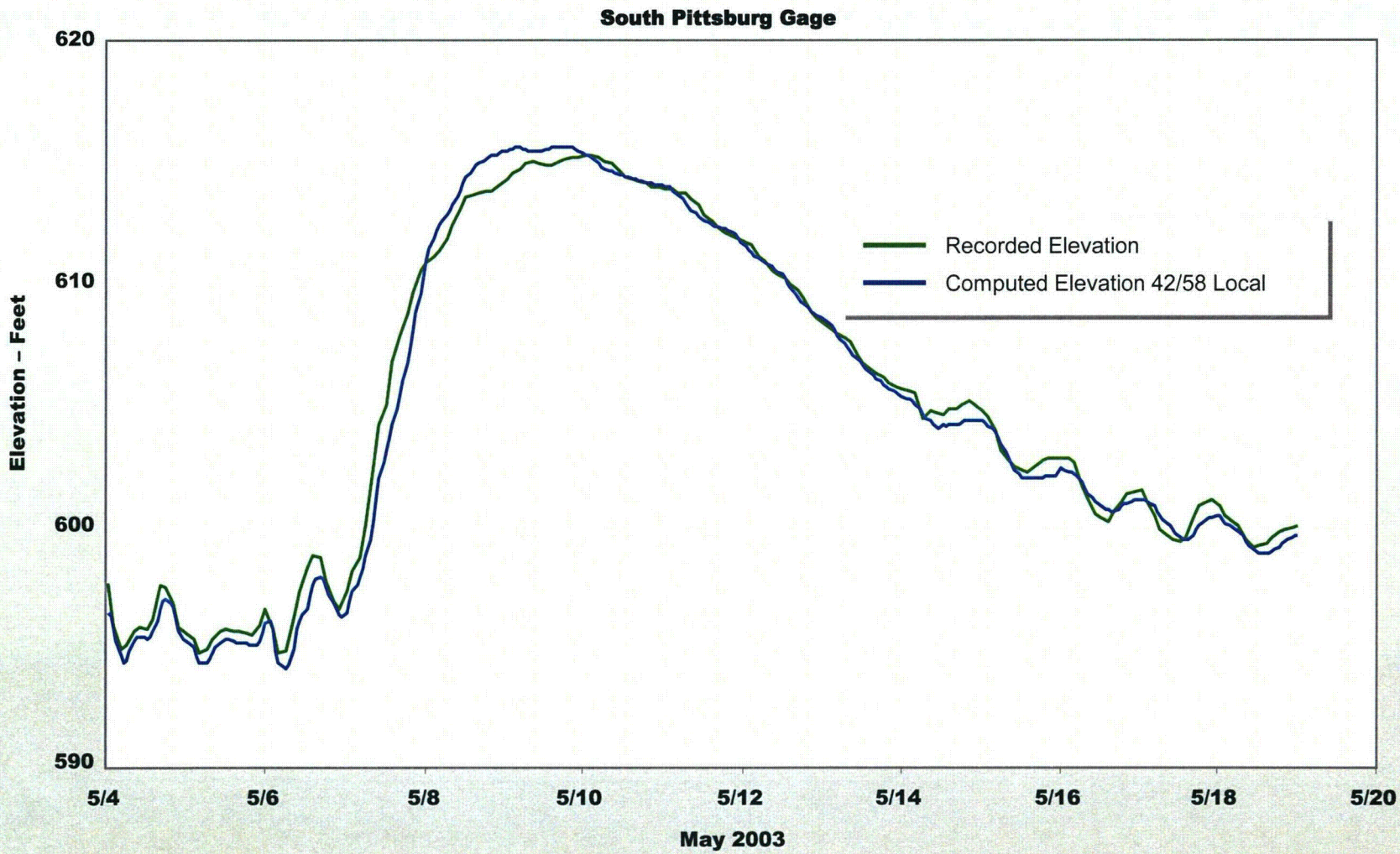
May 2003 Nickajack Discharge
(SOCH Upstream Boundary)



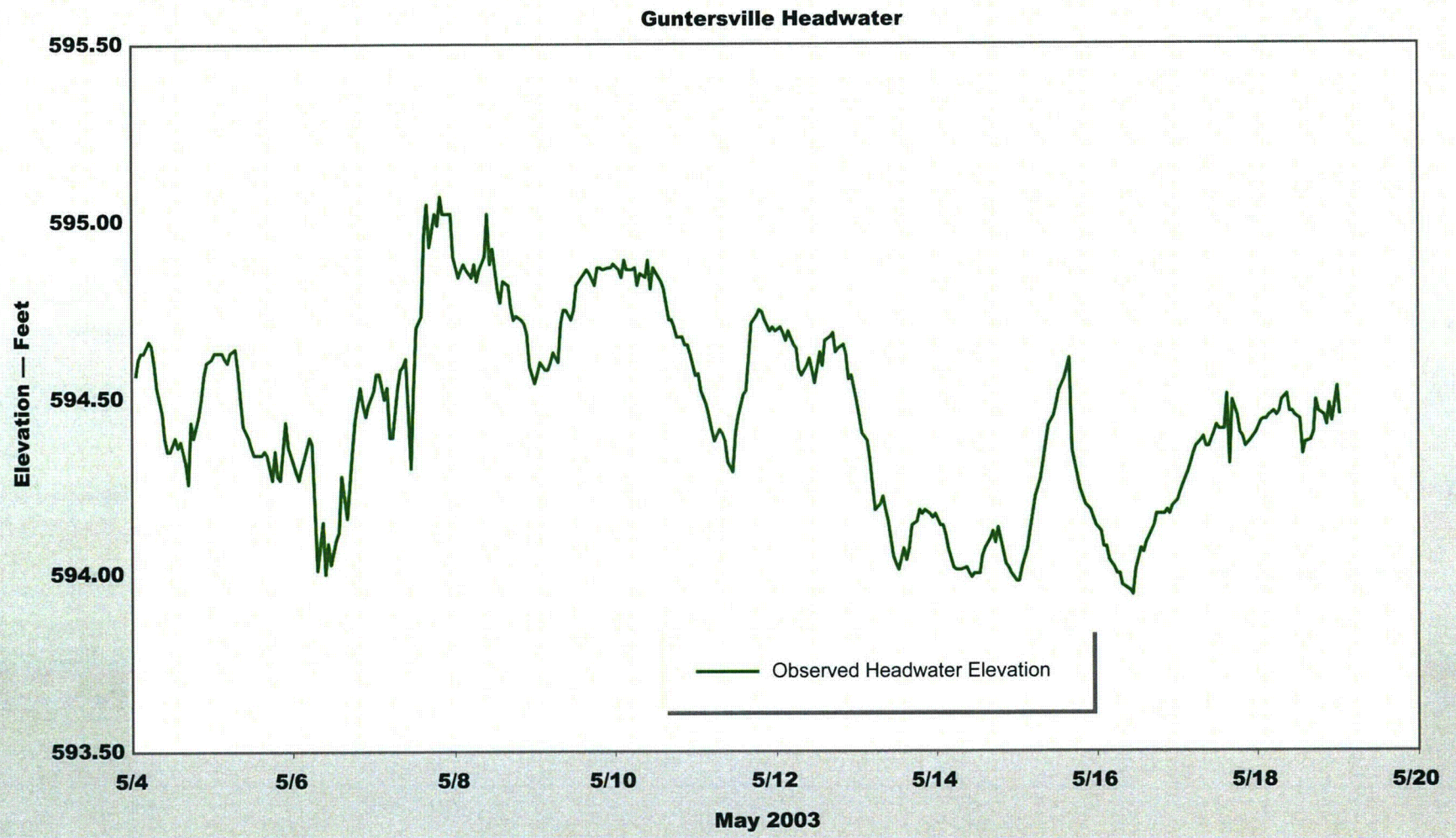
May 2003 Nickajack Tailwater



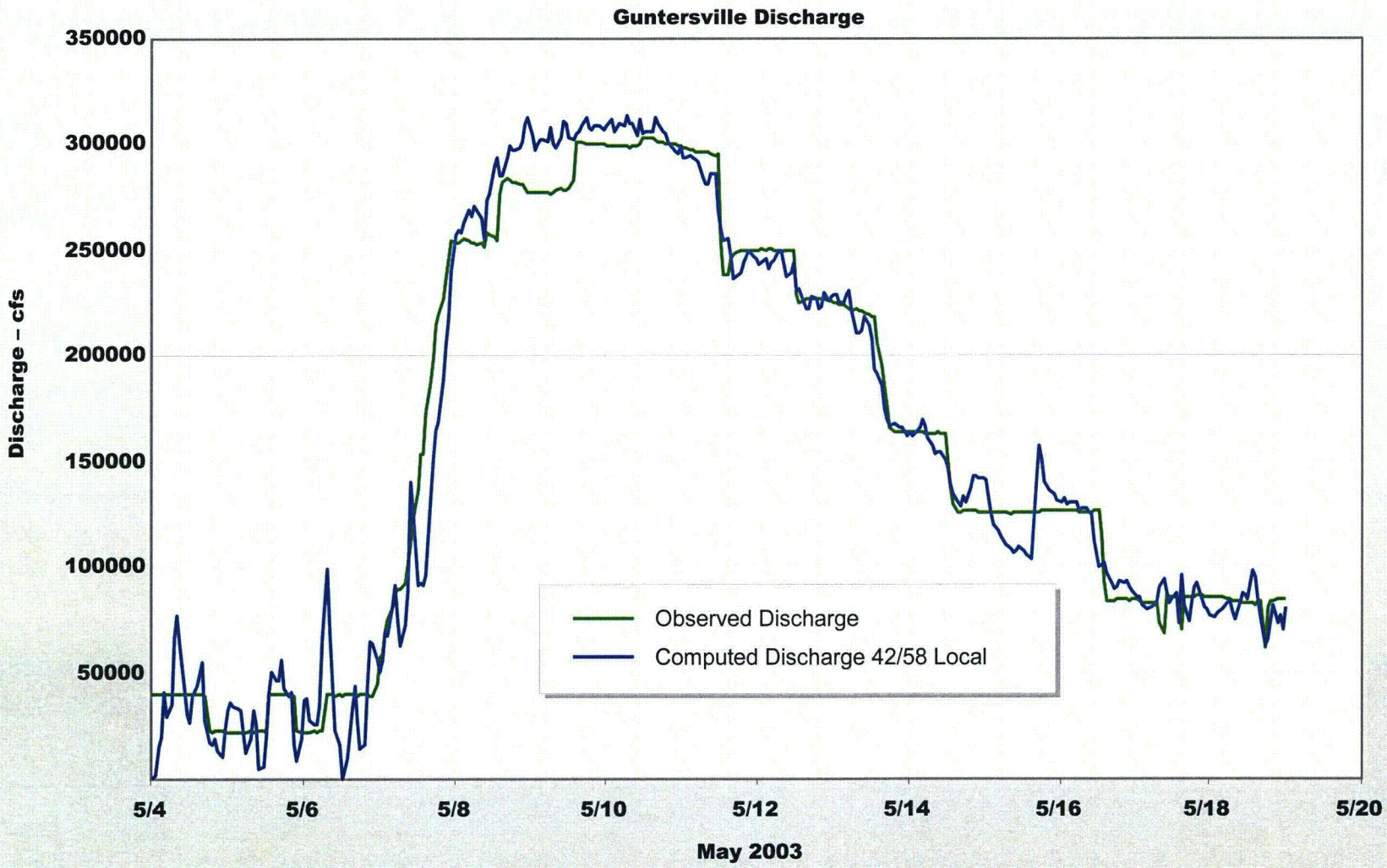
May 2003 South Pittsburg Gage



May 2003 Guntersville Headwater
(SOCH Downstream Boundary)



May 2003 Guntersville Discharge



Geometry Development Summary

- March 1973 and May 2003 events in Guntersville about the same magnitude.
- March 1973 Flood has more gage data for calibration.
- Preliminary SOCH model (updated) shows good agreement with observed events.
- Final calibration of model will provide good match with historic floods and steady flow profiles at Bellefonte.

Break Time

That's all Folks

Break Time

TVA

TVA/NRC Workshop

June 23–27, 2008

Probable Maximum Flood

Probable Maximum Flood (PMF)

The criteria set forth in ANSI/ANS-2.8-1992 were followed in determining the PMF.

PMF— The hypothetical flood (peak discharge, volume, and hydrograph shape) that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of probable maximum precipitation and other hydrologic factors favorable for maximum flood runoff such as sequential storms and snowmelts.

The PMF was determined from consideration of all potentially critical areal and seasonal variations of probable maximum precipitation (PMP) on the watershed above Bellefonte.

Probable Maximum Flood (PMF)

A PMF computation involves selection of a sequence of meteorological and hydrologic events. These include:

- Principal storm rainfall (PMP)
- Antecedent storm rainfall
- Seasonal variations of rainfall
- Time and areal distribution of rainfall
- Infiltration loss rates
- Hydrograph determination

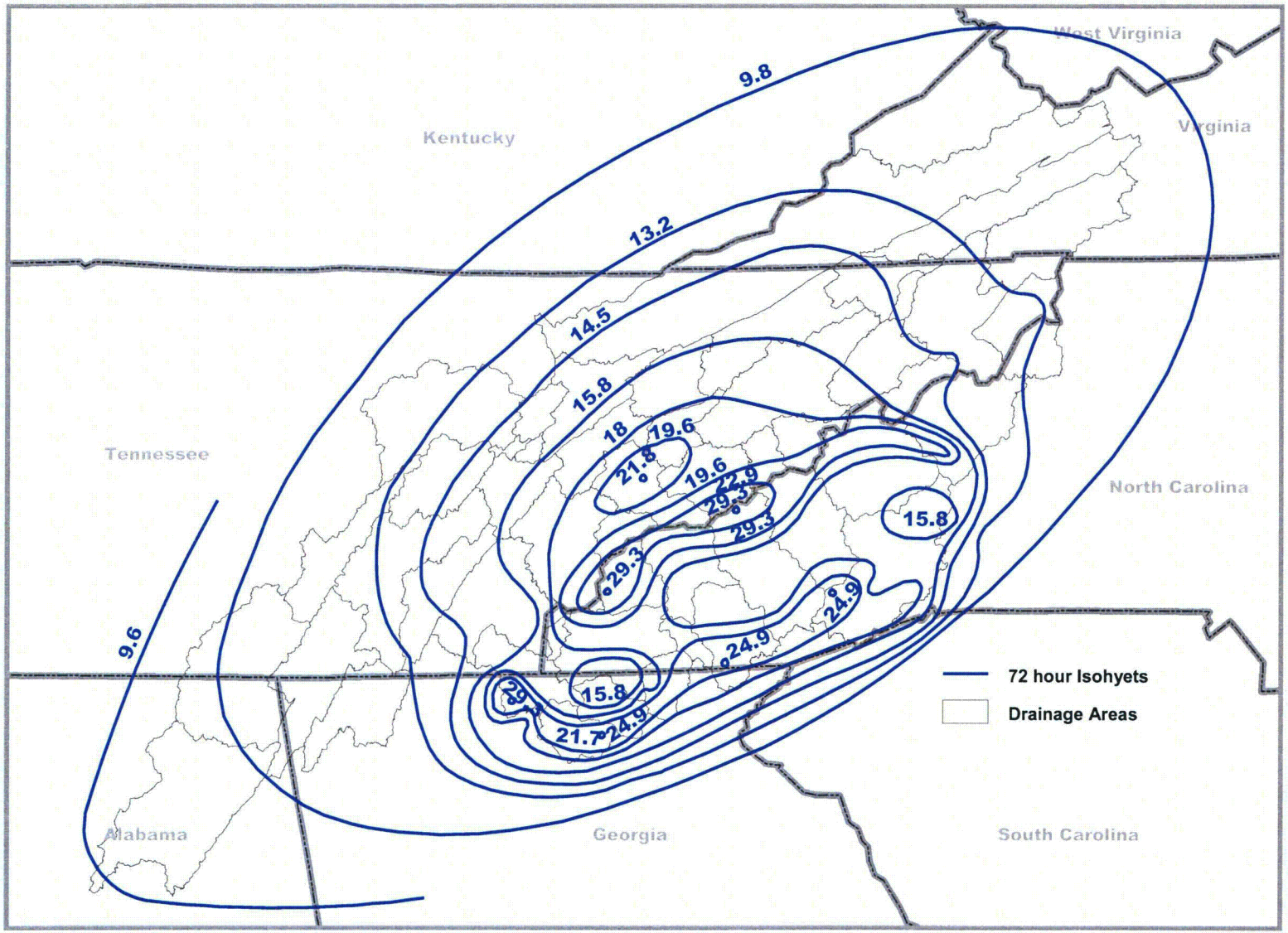
Probable Maximum Flood (PMF)

PMP was defined for TVA by the U.S. Weather Bureau in Hydrometeorological Report (HMR) 41. This report defined depth-area-duration characteristics, seasonal variations, and antecedent storm potentials.

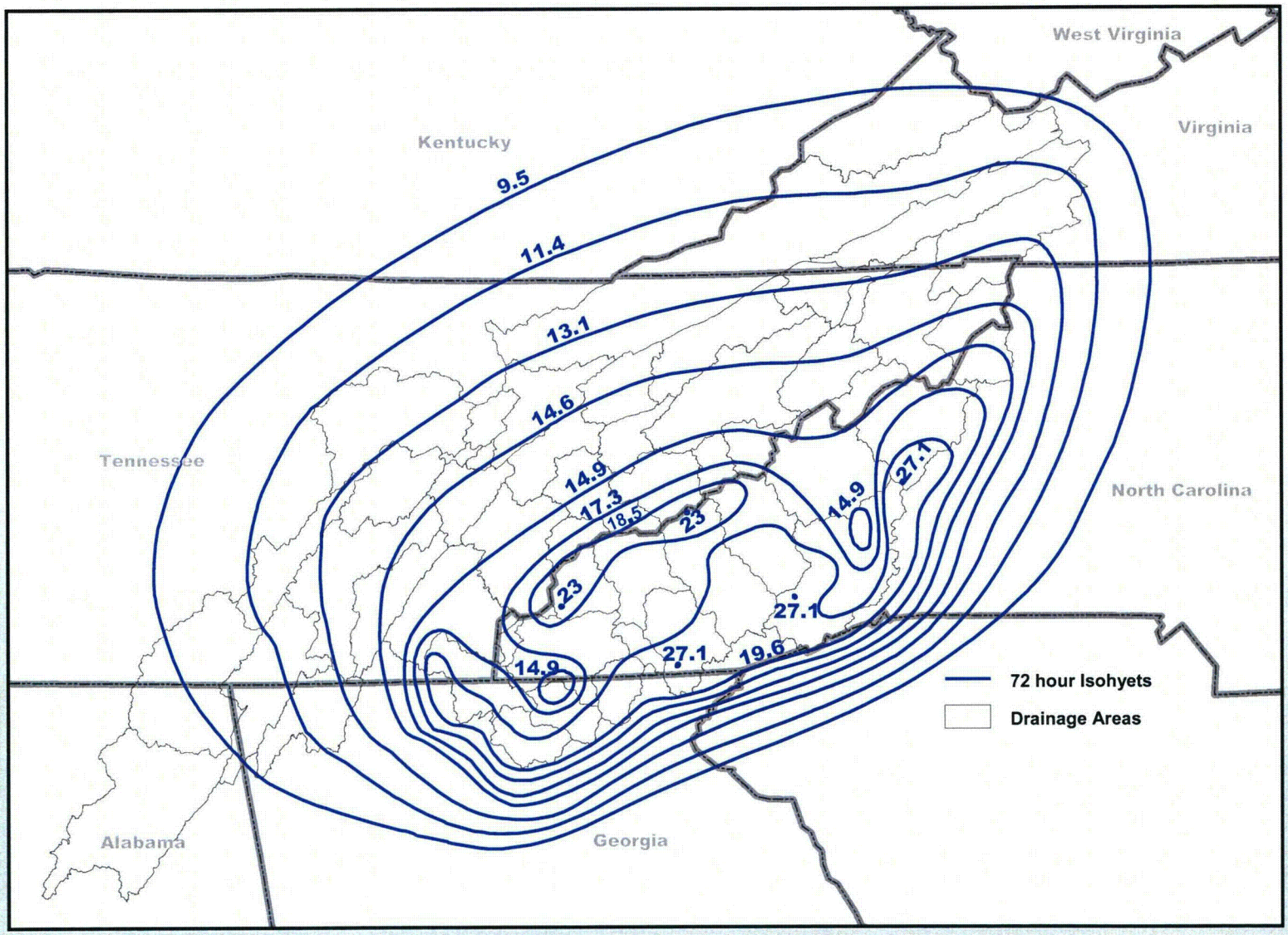
Two storms are defined:

- Storm producing PMP depths on the 21,400-square-mile watershed above Chattanooga—two isohyetal patterns—both patterns are geographically fixed.
  - Downstream pattern (average rain above Guntersville Dam = 15.56 inches).
  - Upstream pattern (average rain above Guntersville Dam = 14.10 inches).
- Storm producing PMP depths on a 7,980 square-mile watershed centered in the Valley below the major tributary dams.
  - This pattern may be moved parallel to the long axis of the basin.

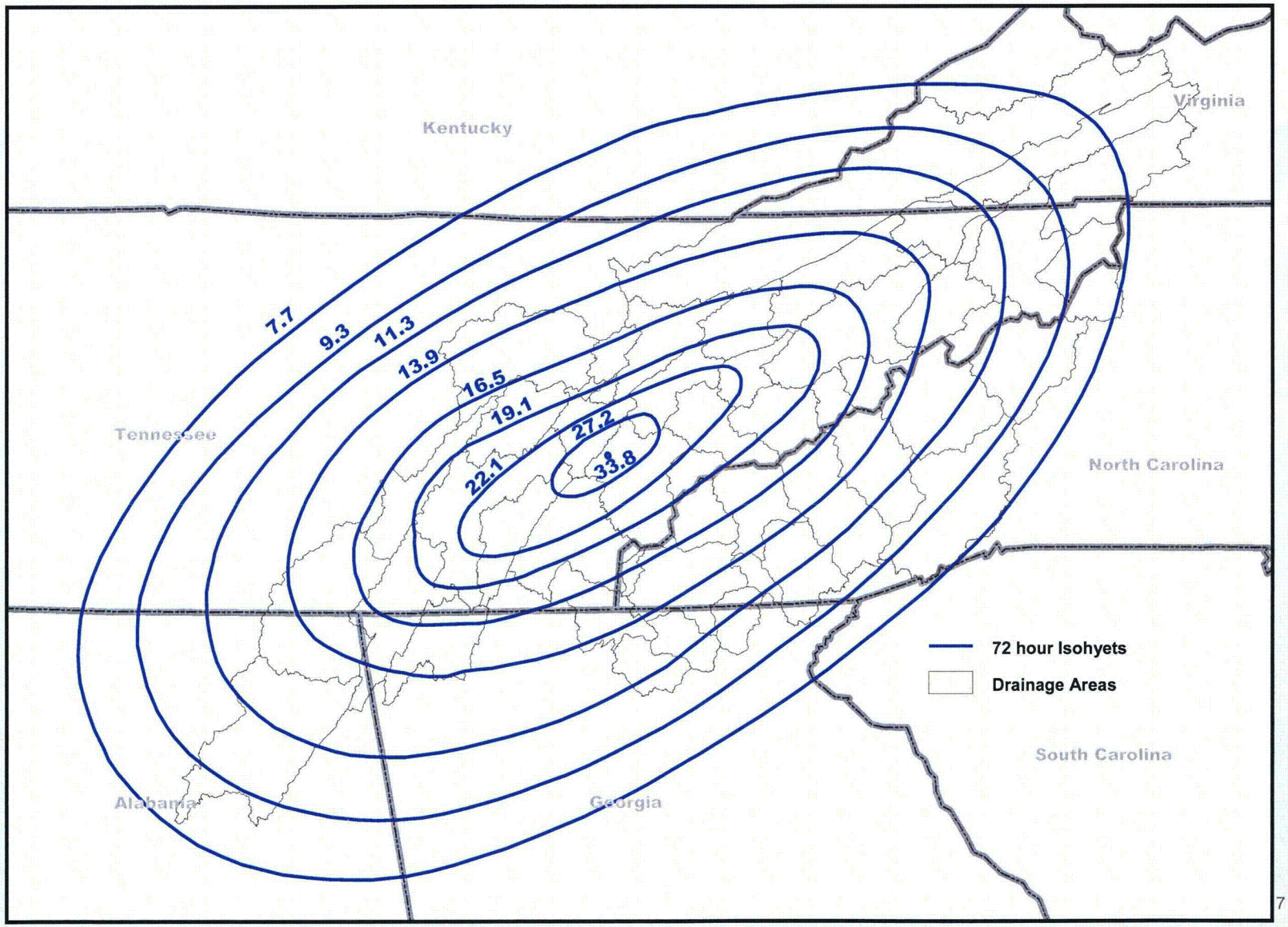
72-Hour March Probable Maximum Storm Depths
(21,400 Square Miles Downstream)



72-Hour March Probable Maximum Storm Depths
(21,400 Square Miles Upstream)



72-Hour March Probable Maximum Storm Depths
(7,980 Square Miles)



21,400 Square-Mile PMP

Tributary Dams	Rainfall — Inches	
	*Downstream Center	Upstream Center
Douglas	17.28	17.37
Cherokee	13.59	13.42
South Holston	12.30	12.84
Watauga	13.30	14.98
Fontana	20.22	20.21
Norris	13.80	12.09
Chatuge	21.40	20.97
Nottely	19.10	18.25
Hiwassee	19.43	18.29
Blue Ridge	22.10	20.63
Average rain on basin above Guntersville	**15.56**	**14.10**

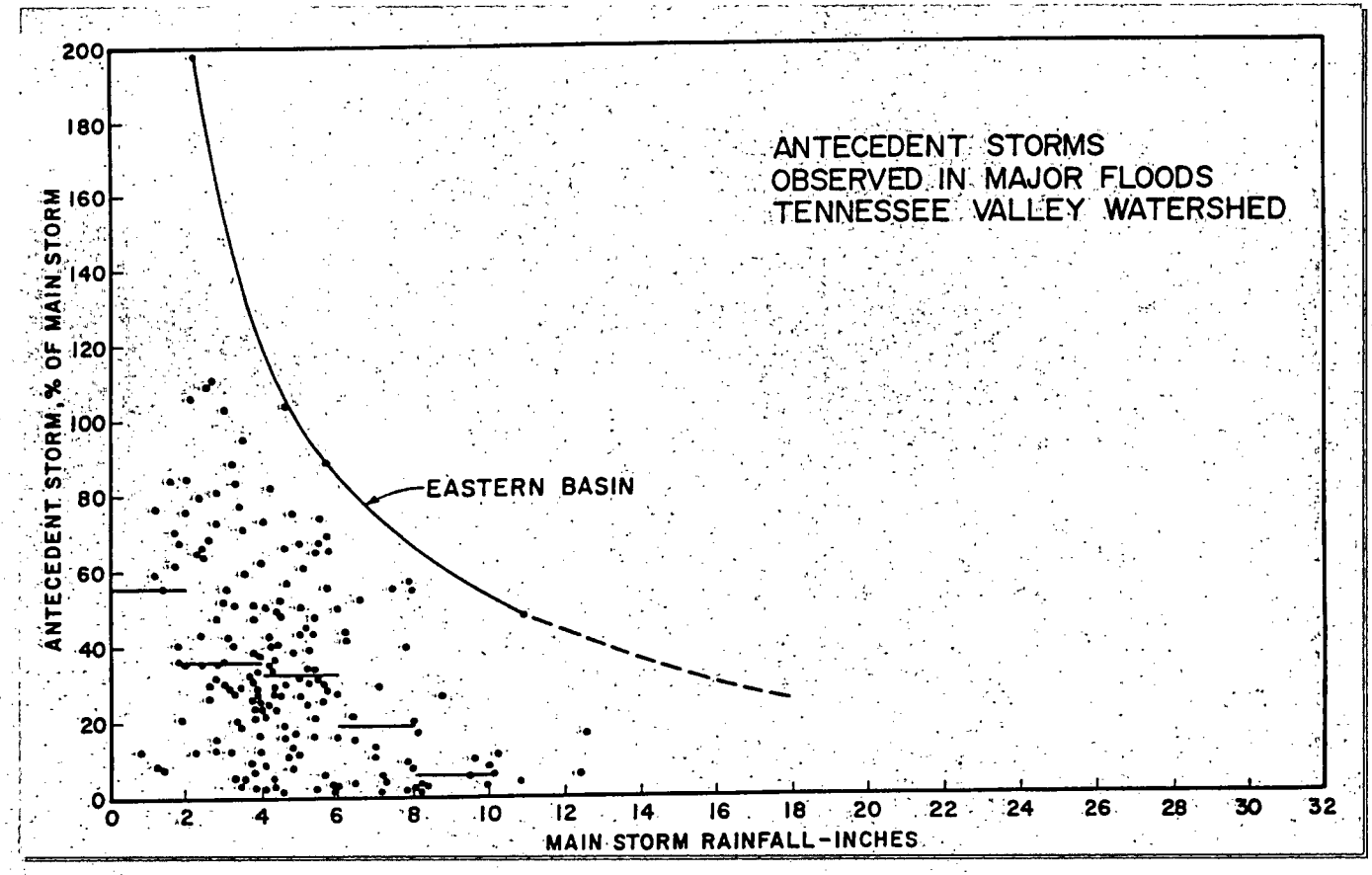
* Controlling event at Bellefonte

Antecedent Storm Rainfall

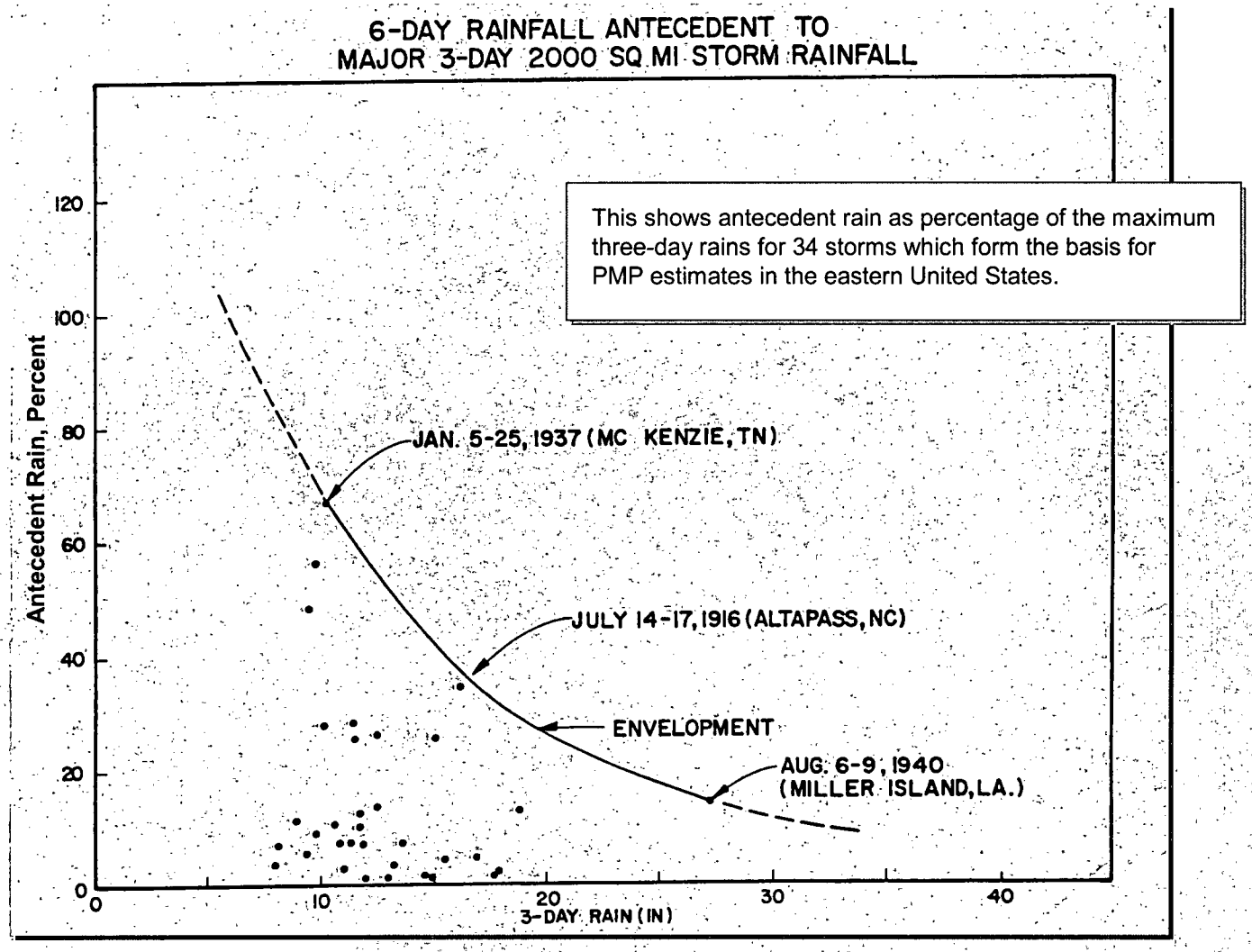
For the Tennessee Valley, studies by TVA have shown major floods are typically caused by a pair of storms with a three-day interval between them.

- Antecedent storm rainfall depths vary from 15 to 50 percent depending on storm durations, location, and size of the watershed.
- Antecedent rain shown as a percentage of the maximum three-day rain for 34 major storms in the eastern United States.

Historical Antecedent Storms



Historical Antecedent Storms



This shows antecedent rain as percentage of the maximum three-day rains for 34 storms which form the basis for PMP estimates in the eastern United States.

Antecedent Storm Rainfall

A three-day antecedent storm was postulated to occur three days prior to the three-day PMP storm in all PMF determinations.

- Antecedent rain is 40 percent of main storm
  - Uniformly areally distributed (HMR Report 41 recommended) to avoid compounding of probabilities.
- All storms are nine-day events
  - Three-day antecedent rainfall
  - Three-day dry period
  - Three-day PMP

Seasonal Variations of Rainfall (PMP)

Month	Antecedent (Inches)			Dry Interval Before PMP (Days)	Three-Day PMP (Inches)	
	Ratio to Main Storm (Percent)	7,980 Square-Mile Basin	21,400 Square-Mile Basin		7,980 Square-Mile Basin	21,400 Square-Mile Basin
March	40	8.14	6.71	3	20.36	16.78
April	40	8.08	6.44	3	20.20	16.11
May	40	7.96	6.10	3	19.92	15.27
June	40	7.81	5.63	3	19.53	14.09
July	30	5.72	3.87	2 ½	19.07	12.92
August	30	5.72	3.87	2 ½	19.07	13.09
September	30	6.09	4.47	2 ½	20.30	14.92

Source: HMR Report 41

The March 21,400-square-mile storm (downstream centered) is the controlling storm at Bellefonte.

Time Distribution of PMP

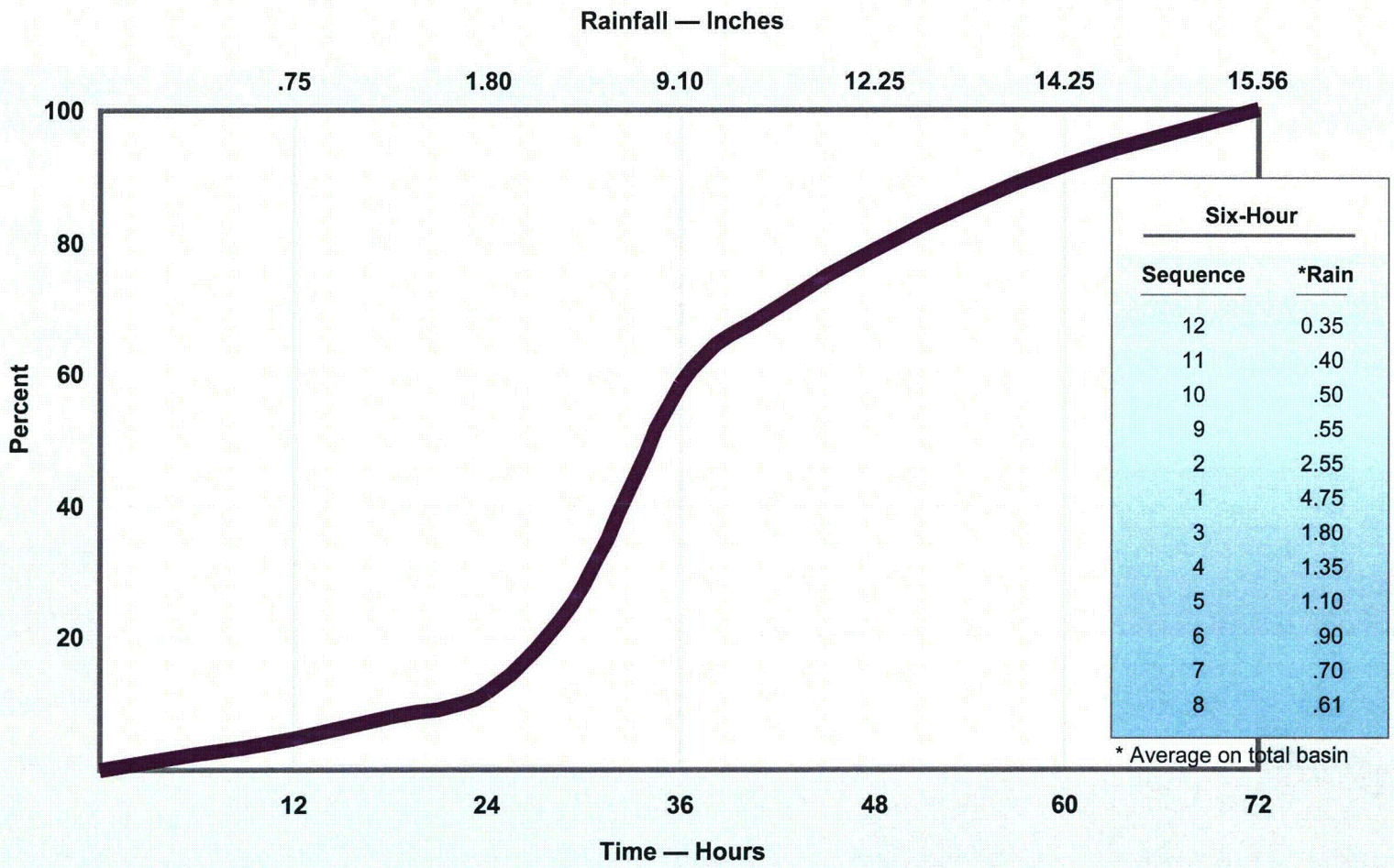
The time distribution of the PMP involves two separate issues. These are addressed in HMR Report 41.

Duration (Hours)	Rainfall (Inches)
6	5.03
24	11.18
72	16.78

- Concentration of rainfall
- Sequential arrangement of the rainfall.
  - Group the four heaviest six-hour increments in a 24-hour sequence, the middle four in a 24-hour sequence, and the smallest in a 24-hour sequence.
  - Arrange the four increments within the 24-hour sequences:
    - Second highest next to the highest,
    - Third highest adjacent to these,
    - Fourth highest at either end.
  - Arrange the three, 24-hour sequences
    - Second highest next to the highest,
    - Third highest at either end.

Probable Maximum Precipitation

Adopted Rainfall-Time Distribution



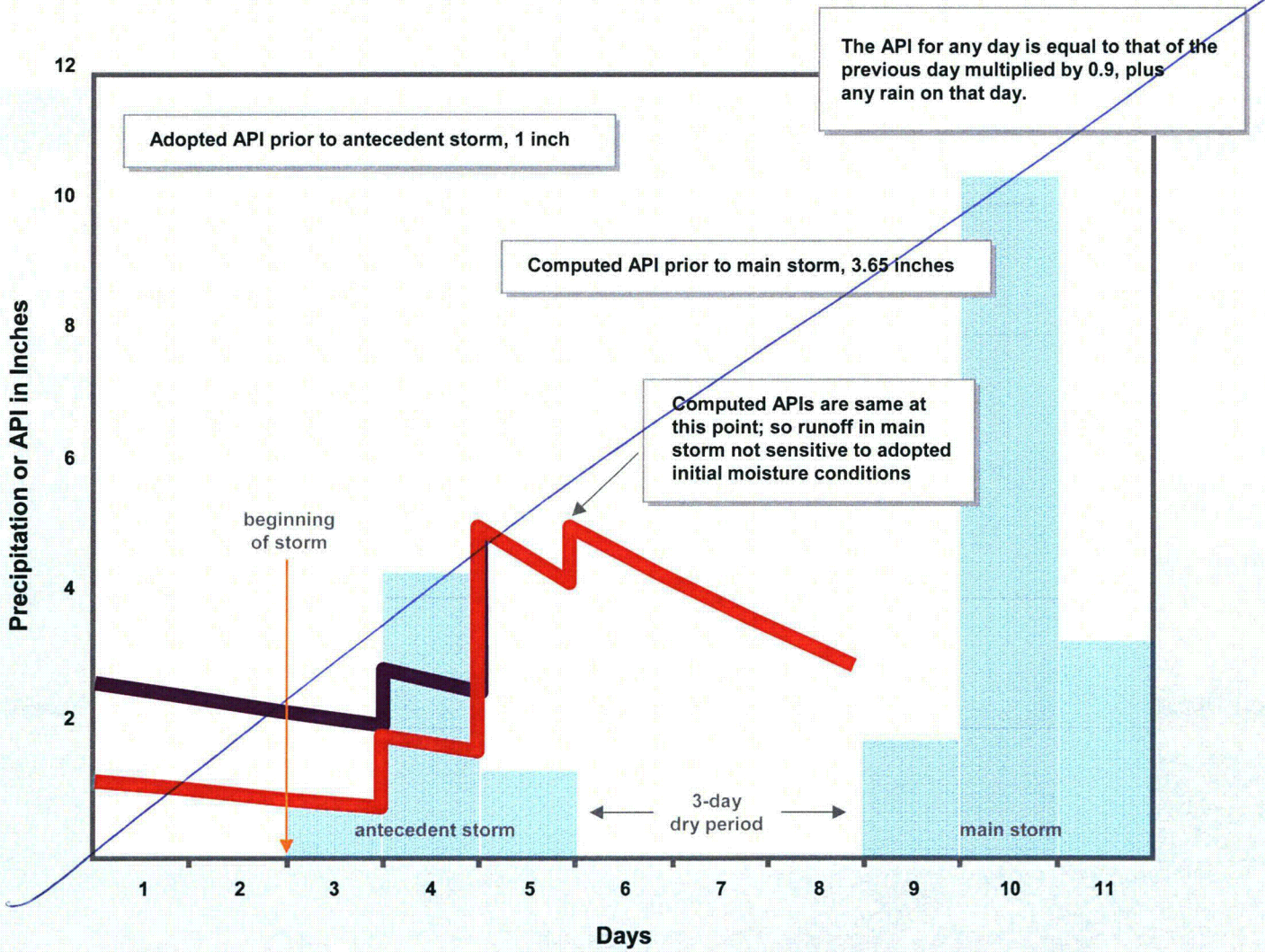
Six-Hour	
Sequence	*Rain
12	0.35
11	.40
10	.50
9	.55
2	2.55
1	4.75
3	1.80
4	1.35
5	1.10
6	.90
7	.70
8	.61

* Average on total basin

Infiltration Loss Rates

- Precipitation losses are estimated with multivariable relationships used in the day-to-day operation of the Tennessee River System.
- Median moisture conditions, determined from past records, were used to determine the API at the start of the storm sequence.
- Because the antecedent storm is so large, variations in initial moisture conditions will not alter computed precipitation excess in the main storm.
- Precipitation loss in the main storm becomes zero early on the second day resulting in 100 percent runoff for the major part of the storm.
- Precipitation loss
  - Antecedent storm, 2.24 inches (35 percent of rainfall).
  - Main storm, 1.76 inches (11 percent of rainfall).

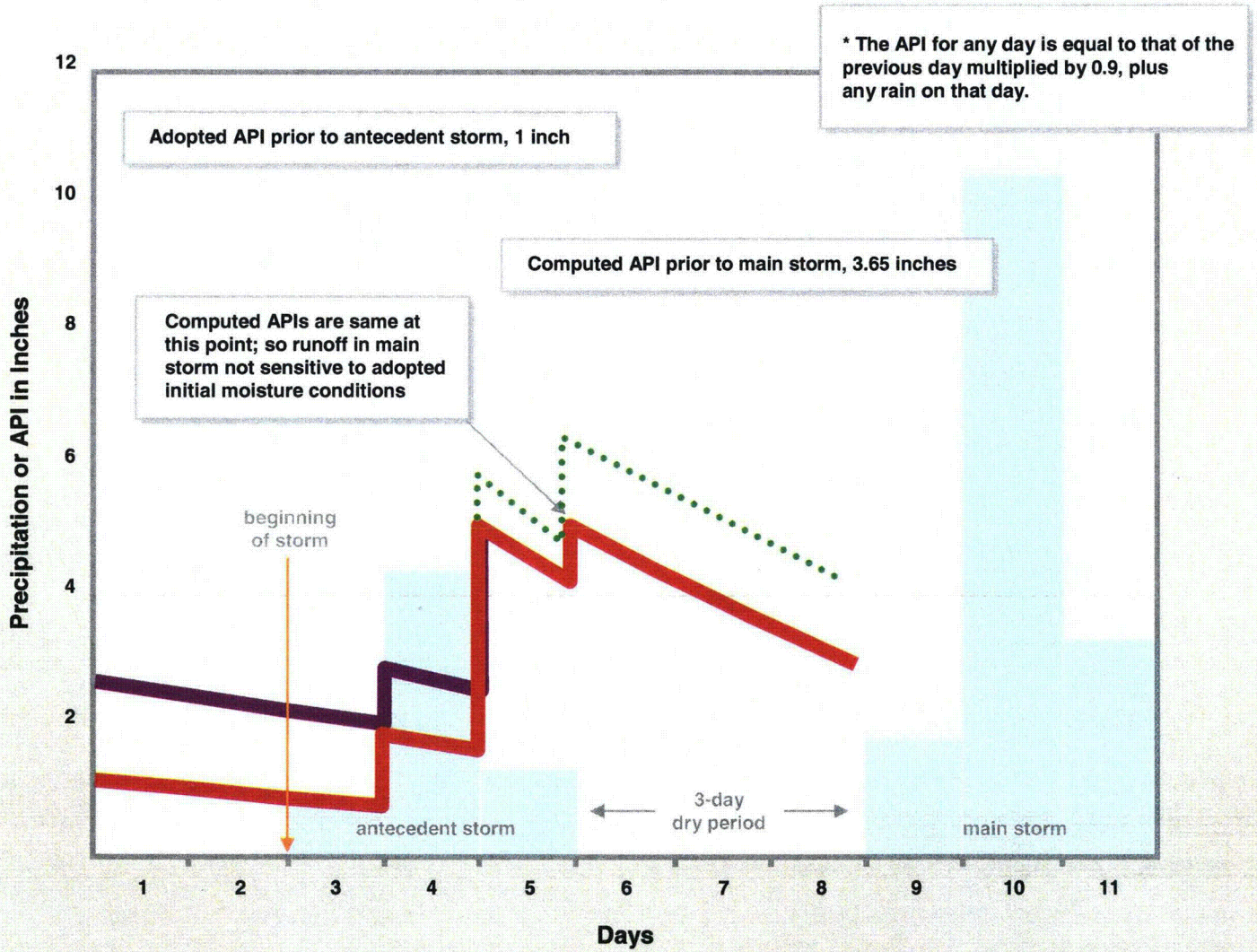
Adopted API Prior to Antecedent Storm



see updated figure

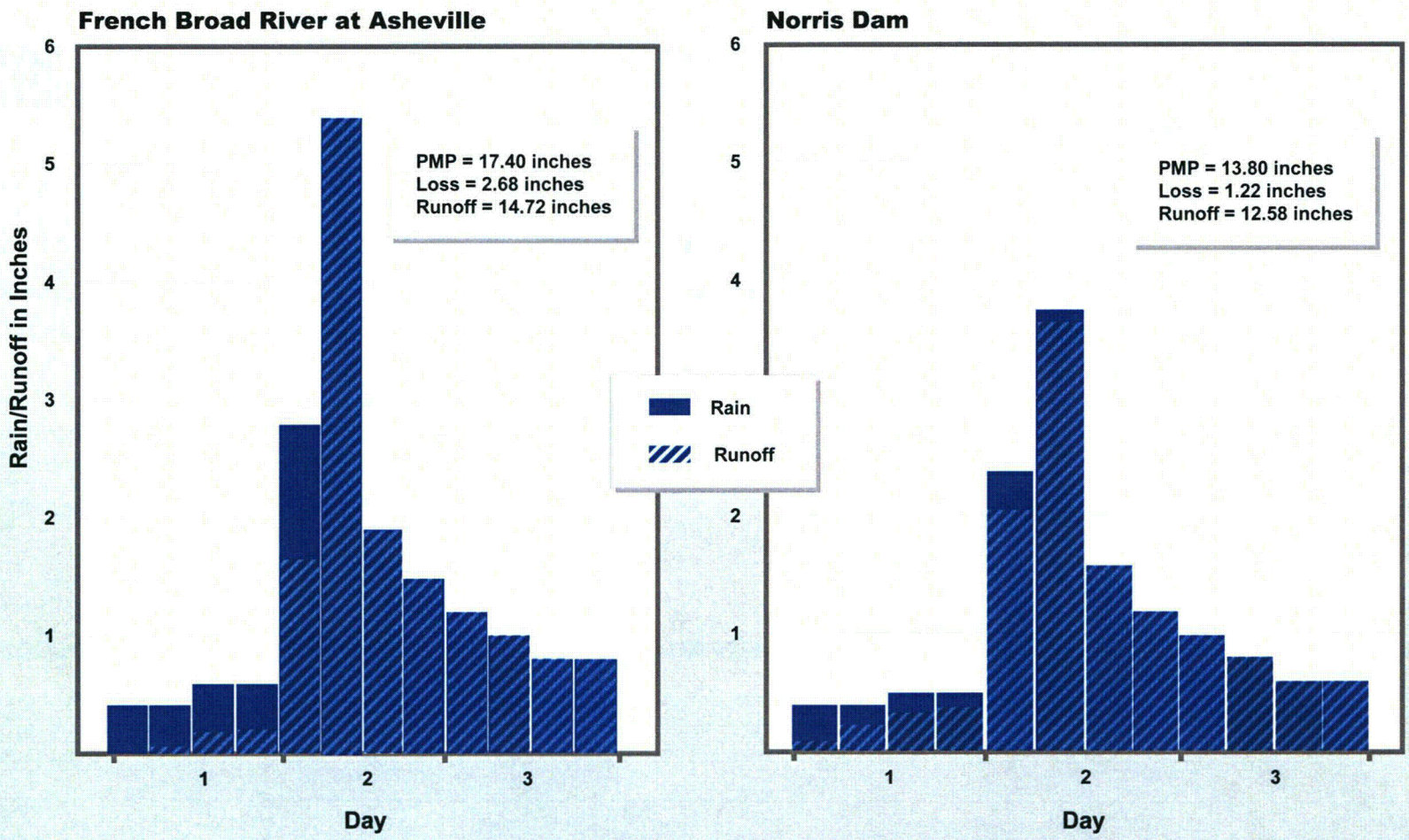
Adopted API Prior to Antecedent Storm

Updated Figure



* Red and purple lines — API limited to maximum of 5.0.
Green dashed line — API not limited.

Probable Maximum Rain and Runoff



Probable Maximum Storm and Precipitation Excess

Unit Area	Area	Antecedent Storm Rain Inches	Antecedent Storm P_e[a] Inches	Main Storm Rain Inches	Main Storm P_e[b] Inches
1	French Broad River at Asheville	6.44	2.99	17.40	14.72
2	French Broad River, Newport to Asheville	6.44	4.04	18.50	16.51
3	Pigeon River at Newport	6.44	4.04	19.30	17.31
4	Nolichucky River at Embreeville	6.44	4.04	15.10	13.11
5	Nolichucky local, Embreeville to Nolichucky Dam	6.44	4.04	15.50	13.51
6	Douglas Dam local	6.44	4.86	17.10	15.88
7	Little Pigeon River at Sevierville	6.44	4.04	20.90	18.91
8	French Broad River local	6.44	4.19	18.60	16.81
9	South Holston Dam	6.44	4.52	12.30	10.70
10	Watauga Dam	6.44	4.04	13.30	11.31
11	Boone local	6.44	4.04	14.10	12.11
12	Fort Patrick Henry Dam	6.44	4.86	14.40	13.18
13	North Fork Holston River near Gate City	6.44	4.86	12.30	11.08
14	Holston River at Surgoinsville below Fort Patrick Henry Dam and Gate City	6.44	4.86	14.60	13.38
15	Cherokee local below Surgoinsville	6.44	4.86	15.80	14.58
16	Holston River local, Cherokee Dam to Knoxville gage	6.44	4.52	17.10	15.50
17	Little River at mouth	6.44	4.04	21.50	19.51
18	Fort Loudoun local	6.44	4.04	17.60	15.61
19	Little Tennessee River at Needmore	6.44	2.99	21.20	18.52
20	Nantahala Dam	6.44	2.99	21.50	18.82
21	Tuckasegee River at Bryson City	6.44	2.99	19.10	16.42
22	Fontana local	6.44	2.99	20.70	18.02
23	Little Tennessee River local, Fontana Dam to Chilhowee Dam	6.44	2.99	24.00	21.32

Probable Maximum Storm and Precipitation Excess

Unit Area	Area	Antecedent Storm Rain Inches	Antecedent Storm P_e[a] Inches	Main Storm Rain Inches	Main Storm P_e[b] Inches
24	Little Tennessee River local, Chilhowee Dam to Tellico Dam	6.44	4.04	21.00	01
25	Watts Bar local above Clinch River	6.44	4.04	15.80	13.81
26	Norris Dam	6.44	4.86	13.80	12.58
27[c]	Melton Hill local	6.44	4.56	15.48	14.07
33	Clinch River local above Mile 16	6.44	4.52	15.30	13.89
34	Poplar Creek at mouth	6.44	4.52	14.90	13.49
35	Emory River at mouth	6.44	4.52	13.10	11.69
36	Clinch River local, mouth to Mile 16	6.44	4.52	14.90	13.49
37	Watts Bar local below Clinch River	6.44	4.52	14.40	12.99
38	Chatuge Dam	6.44	2.99	21.40	18.72
39	Nottely Dam	6.44	2.99	19.10	16.42
40	Hiwassee River local below Chatuge and Nottely	6.44	2.99	18.90	16.22
41	Apalachia local	6.44	2.99	17.90	15.22
42	Blue Ridge Dam	6.44	2.99	22.10	19.42
43	Ocoee 1 local, Ocoee1 to Blue Ridge Dam	6.44	4.04	18.30	16.31
44[d]	Lower Hiwassee	6.44	4.19	15.20	13.41
45	Chickamauga local	6.44	4.52	14.50	13.09
46	South Chickamauga Creek near Chattanooga	6.44	4.35	12.30	10.89
47	Nickajack local	6.44	4.52	11.70	10.29
48	Sequatchie River at Whitwell	6.44	4.52	9.80	8.39
49	Guntersville North local	6.44	4.52	9.80	8.39
50	Guntersville South local	6.44	4.52	9.80	8.39
	Average above Guntersville Dam	6.44	4.20	15.56	13.80

a. Adopted API prior to antecedent storm, 1.0 inch.
b. Computed API prior to main storm, 3.65 inches.
c. Replaces original Unit Areas 27–32.
d. Lower Hiwassee local to be divided into two Unit Areas—44A and 44.

PMF Determination

- Unit hydrographs were used to compute PMF inflows from each Unit Area using the FLDHYDRO code.
- Unit Area PMF inflows were combined with the TRBROUTE code with time sequencing or Muskingum channel-routing procedures to compute inflows into upstream tributary reservoirs.
- Tributary reservoir routings, except for Tellico and Melton Hill, were made with the TRBROUTE code assuming flat-pool storage conditions.
- Resulting reservoir outflows, together with additional local PMF inflows at selected locations, were input to the SOCH code.

Reservoir Routing

Tributary routings were made assuming flat-pool storage conditions.

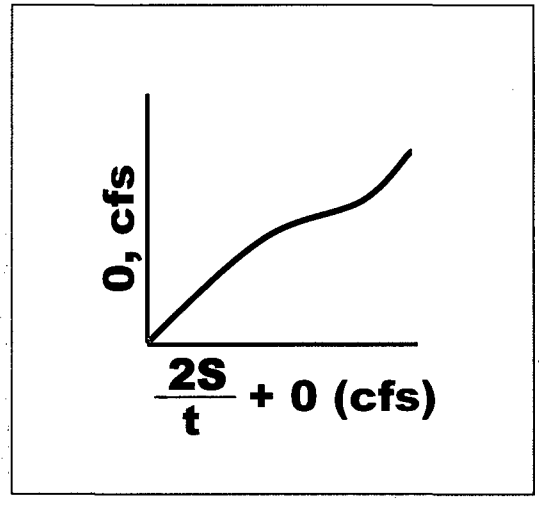
$$I - O = \frac{dS}{dt}$$

Or, more commonly $\bar{I} - \bar{O} = \frac{\Delta S}{t}$

Where I = inflow rate
O = outflow rate
S = storage volume
T = routing period

$$\frac{I_1 + I_2}{2} t - \frac{O_1 + O_2}{2} t = S_2 - S_1$$

$$^{1}I_1 + I_2 + \frac{(2S_1 - O_1)}{t} = \frac{2S_2}{t} + O_2$$



[1] R.D. Goodrich, Rapid Calculation of Reservoir Discharge, Civil Engr., Vol. 1, 1931.

Reservoir Operations in PMF

Median initial reservoir elevations used at the start of the storm sequence.

53 percent of the total reserved flood detention capacity was occupied at the start of the main flood.

Normal reservoir operating procedures were used in the antecedent storm.

- This included use of turbine and sluice discharge in tributary reservoirs.
- Turbine discharges not used in main river reservoirs after large flows develop.

Flood operating procedures were used in the main storm.

- No turbine discharge.

All spillway gates were determined to be operable.

Gate crews called to dams during or before the first hours of the main storm when access would not be a problem.

Gates on main river dams fully raised before the main storm is over, requiring no additional operations.

Gate crews remain at the dams during the flood.

Embankment Breaching

Dam safety modifications made by TVA have eliminated the potential for failure from overtopping in most cases. The exceptions are:

- Chickamauga Dam
- Nickajack Dam (north embankment—controlled section)
- West saddle dike at Watts Bar Dam

To estimate time of failure when a dam is overtopped, the relationship developed by the Bureau of Reclamation (1966) is used. It relates the volume of eroded fill material to the volume of water flowing through the breach.

An instantaneous disappearance of the failed section is postulated. At the time of failure, the SOCH routing would shift to an after-failure curve.

Dam Safety Modification Status (Hydrologic)

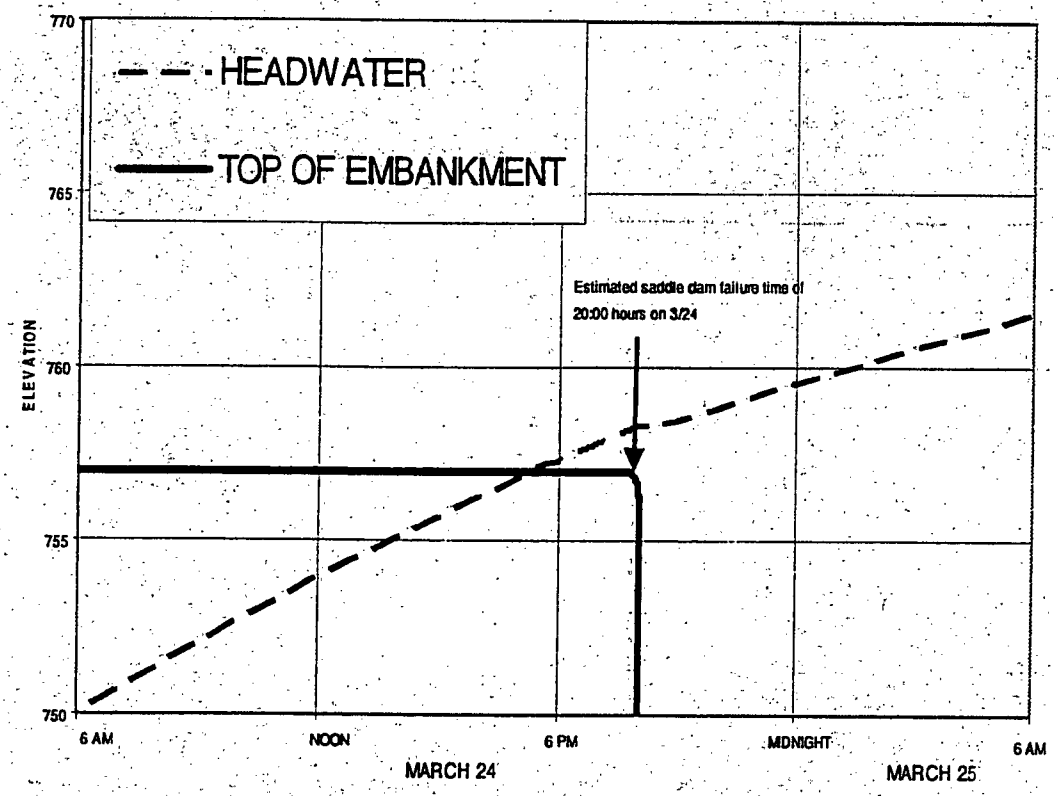
Main River Dams	*Dam Modification	Year Modifications Completed
Fort Loudoun-Tellico	Fort Loudoun Dam was raised 3.25 feet with a concrete wall to elevation 833.25. A 2000-foot uncontrolled spillway with crest at elevation 817 was added at Tellico Dam.	1989
Watts Bar	Embankment was raised 10 feet with earth fill/concrete wall to elevation 767.	1997
Nickajack	South embankment was raised 5 feet with earth fill/concrete wall to elevation 657. A 1900-foot roller-compacted concrete overflow dam with top at elevation 634 was added below the north embankment.	1992
Guntersville	Embankments were raised 7.5 feet with earth fill and concrete walls to elevation 617.5.	1996
Tributary Dams		
Blue Ridge	Three additional spillway bays were added in 1982. Embankment was raised 7 feet with earth fill/concrete wall to elevation 1713, and a 295-foot uncontrolled spillway with crest at elevation 1691 was added in 1995.	1995
Boone	Embankment was raised 8.5 feet with earth fill to elevation 1408.5	1984
Chatuge	Embankment was raised 6.5 feet with earth fill to elevation 1946.5.	1986
Cherokee	A portion (600) feet of the nonoverflow dam was raised 7.75 feet to elevation 1089.75.	1982
Douglas	A portion of the nonoverflow dam was raised 13.5 feet to elevation 1022.5, and 8 saddle dams were raised 6.5 feet with earth fill to elevation 1023.5.	1988
Nottely	Embankment was raised 13.5 feet with rock fill to elevation 1807.5.	1988
Watauga	Embankment was raised 10 feet with rock fill to elevation 2012.	1983
Fontana	Dam post-tensioned.	1988
Melton Hill	Dam post-tensioned.	1988

* These dam safety modifications enable these projects to safely pass the PMF.

Probable Maximum Rainfall/Runoff Data

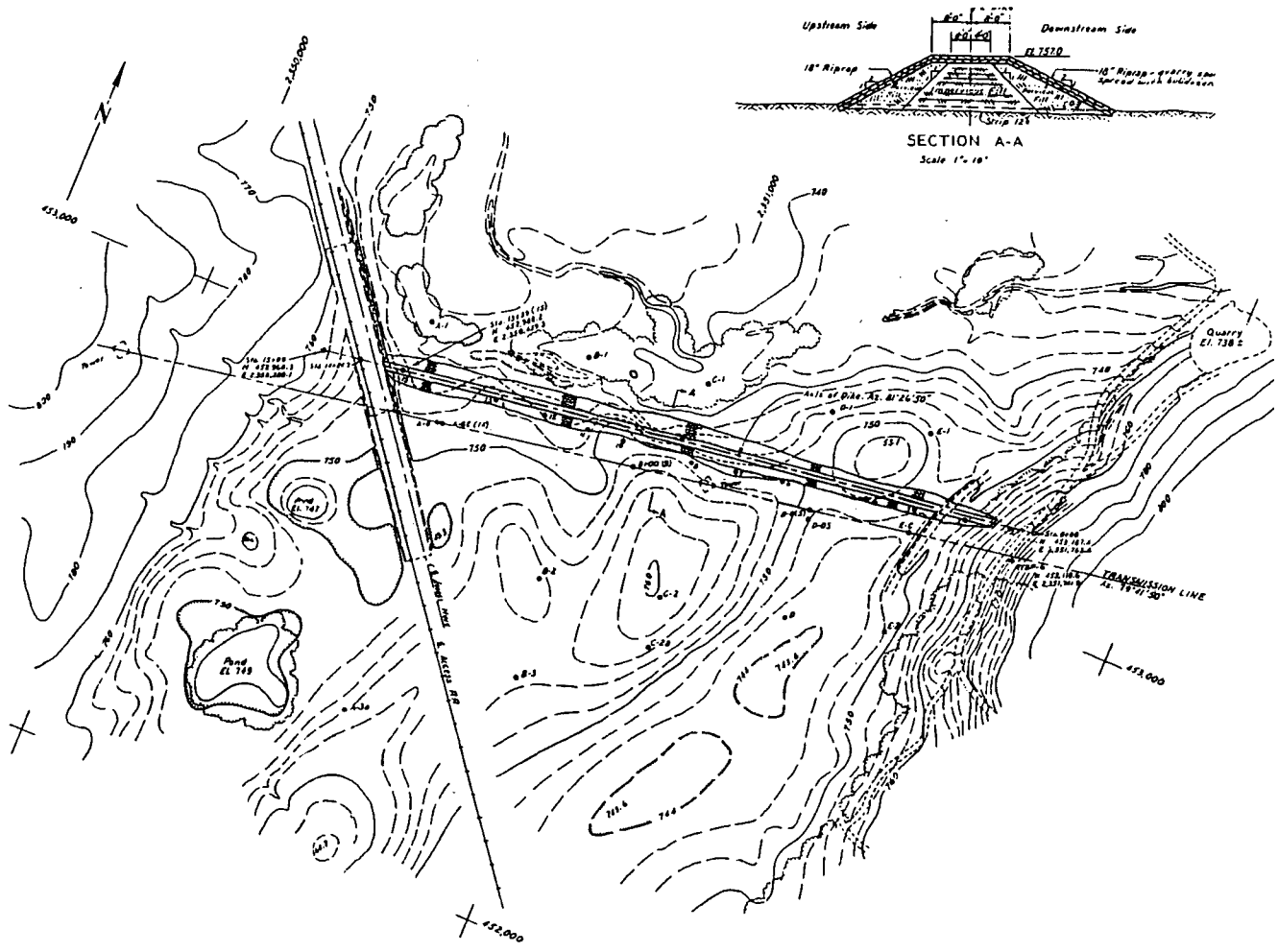
Project	Drainage Area (Sq. Miles)	Project Design Storm: Storm Duration (Days) Ant	Dry	Main	Rain (Inches) Ant	Main	Runoff (Inches) Ant	Main	Bellefonte Design Storm: Storm Duration (Days) Ant	Dry	Main	Basin Average: Rain (Inches) Ant	Main	Runoff (Inches) Ant	Main
Apalachia	1,018	3	3	3	8.4	28.1	2.4	24.3	3	3	3	6.4	17.9	3.0	15.2
Blue Ridge	232	3	3	3	12.0	40.1	6.7	36.2	3	3	3	6.4	22.1	3.0	19.4
Boone	1,840	3	3	3	6.6	22.2	2.0	19.6	3	3	3	6.4	13.2	4.2	11.4
Chatuge	189	3	3	3	11.9	39.8	5.7	35.9	3	3	3	6.4	21.4	3.0	18.7
Cherokee	3,428	3	3	3	6.2	20.7	2.2	18.3	3	3	3	6.4	13.6	4.5	12.0
Douglas	4,541	3	3	3	6.0	19.4	1.8	16.4	3	3	3	6.4	17.3	4.0	15.3
Fontana	1,571	3	3	3	7.3	24.4	1.9	20.5	3	3	3	6.4	20.2	3.0	17.5
Fort Patrick Henry	1,903	3	3	3	6.6	22.2	2.0	19.5	3	3	3	6.4	12.3	4.9	13.2
Hiwassee	968	3	3	3	8.4	28.1	2.4	24.3	3	3	3	6.4	19.4	3.0	16.8
Melton Hill	3,343	3	3	3	6.2	20.6	2.5	18.3	3	3	3	6.4	15.5	4.6	14.1
Norris	2,912	3	3	3	6.5	21.6	2.7	19.4	3	3	3	6.4	13.8	4.9	12.6
Nottely	214	3	3	3	11.2	37.2	5.3	33.3	3	3	3	6.4	19.1	3.0	16.4
Ocoee 1	595	3	3	3	9.5	31.7	3.3	28.0	3	3	3	6.4	19.8	3.6	17.5
South Holston	703	3	3	3	7.9	26.4	3.1	24.0	3	3	3	6.4	12.3	4.5	10.7
Watauga	468	3	3	3	9.3	30.9	3.7	28.0	3	3	3	6.4	13.3	4.0	11.3

Watts Bar West Saddle Dam

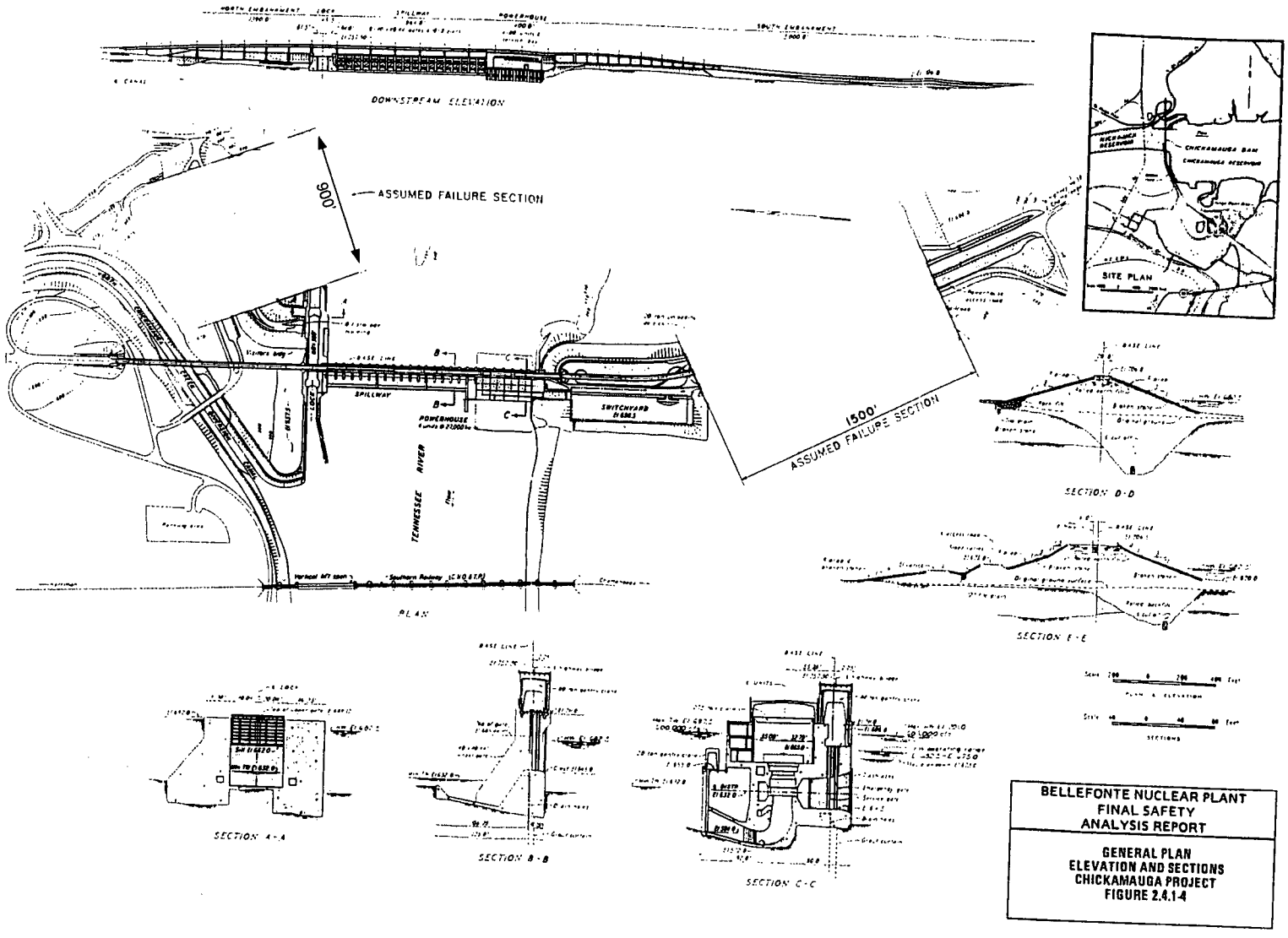


NOTE: FAILURE WOULD CONTINUE TO GROUND LEVEL, EL. 750

Watts Bar Saddle Dam



Chickamauga Dam—Failed Condition



TVA

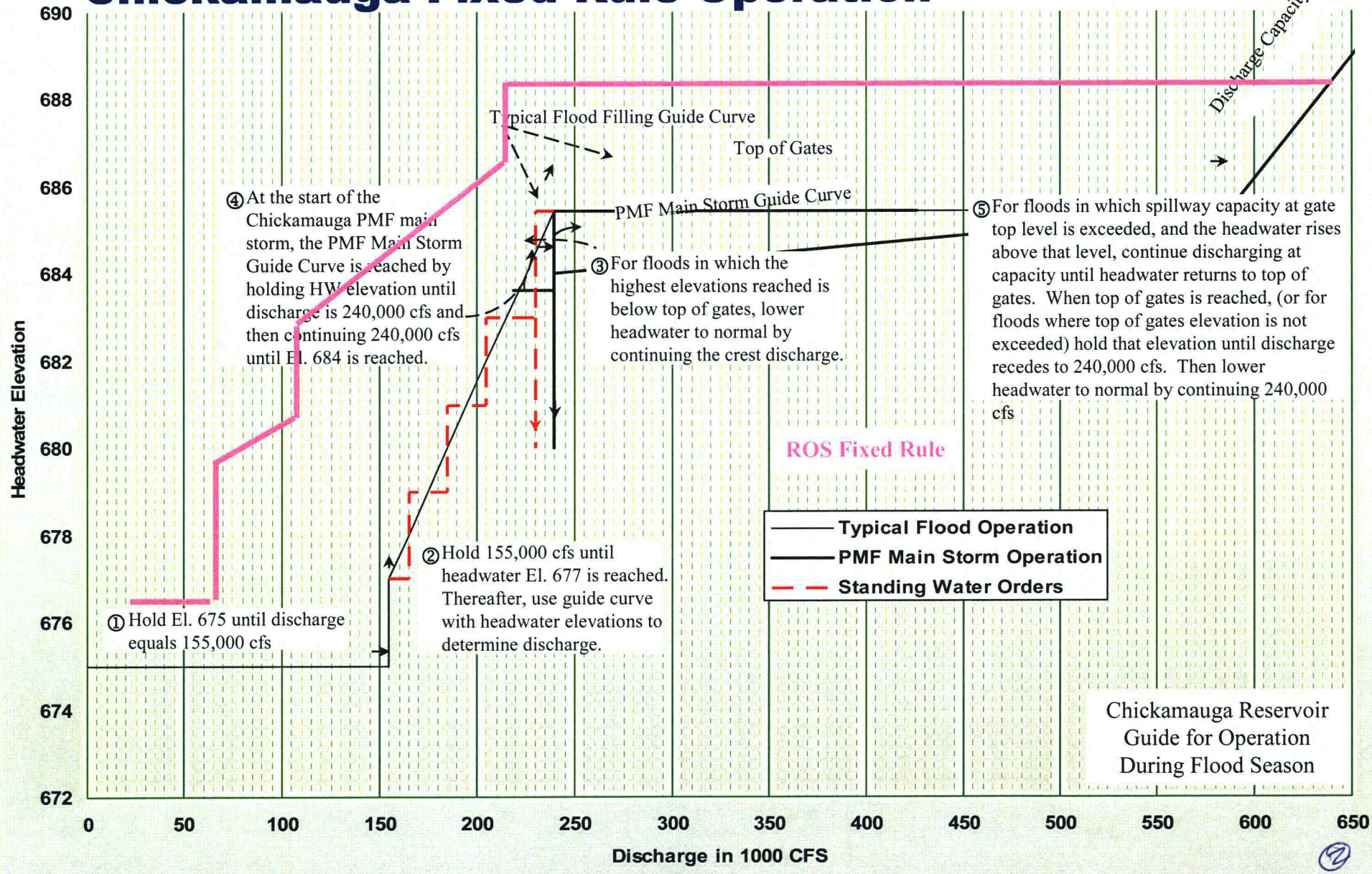
TVA/NRC Workshop

June 23–27, 2008

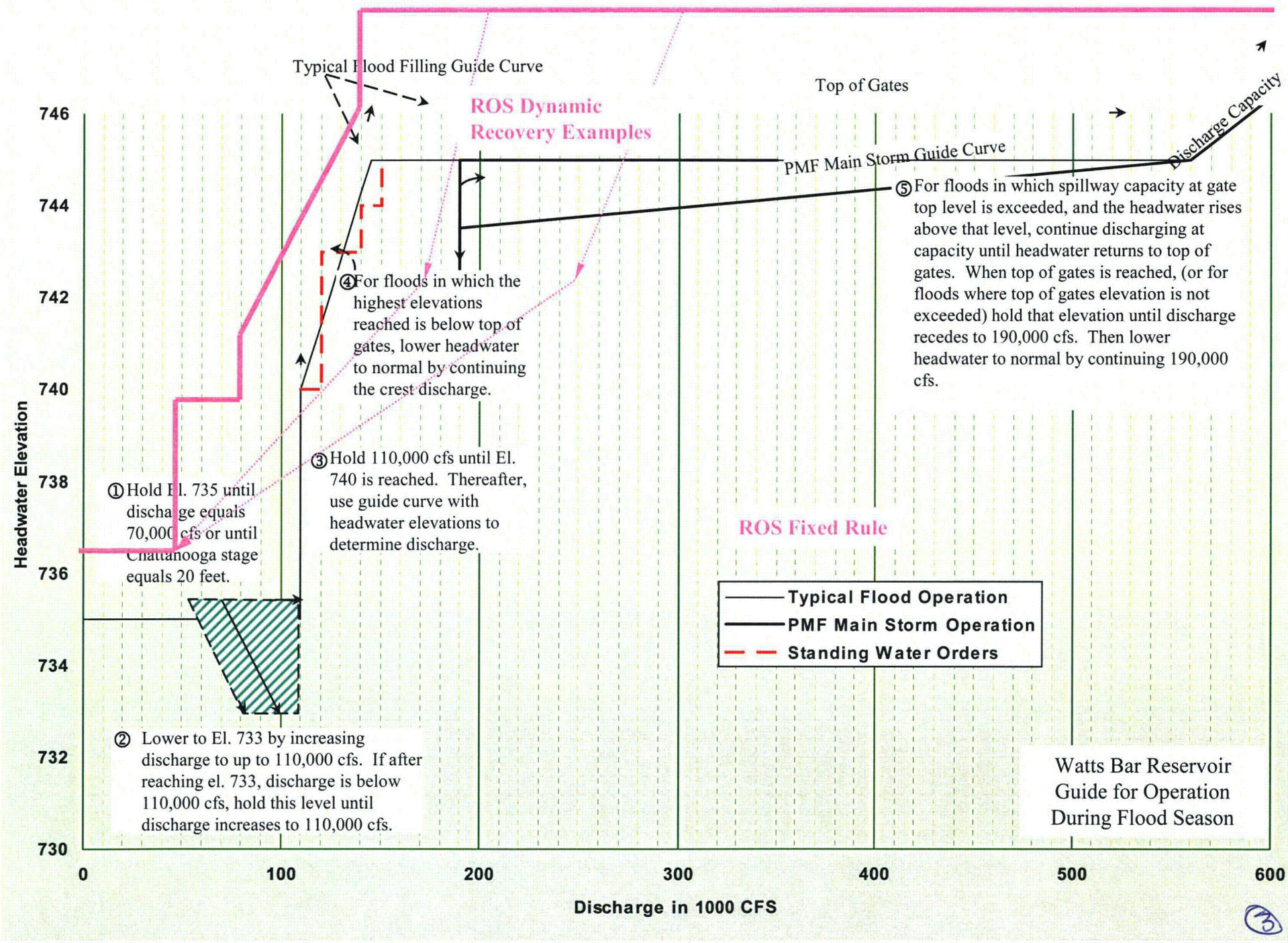
Fixed-Rule Operation

1

Chickamauga Fixed Rule Operation



②


Typical Flood Filling Guide Curve
ROS Dynamic Recovery Examples
Top of Gates
PMF Main Storm Guide Curve
Discharge Capacity
⑤For floods in which spillway capacity at gate top level is exceeded, and the headwater rises above that level, continue discharging at capacity until headwater returns to top of gates. When top of gates is reached, (or for floods where top of gates elevation is not exceeded) hold that elevation until discharge recedes to 190,000 cfs. Then lower headwater to normal by continuing 190,000 cfs.
④For floods in which the highest elevations reached is below top of gates, lower headwater to normal by continuing the crest discharge.
③Hold 110,000 cfs until El. 740 is reached. Thereafter, use guide curve with headwater elevations to determine discharge.
①Hold El. 735 until discharge equals 70,000 cfs or until Chattanooga stage equals 20 feet.
ROS Fixed Rule
Typical Flood Operation
PMF Main Storm Operation
Standing Water Orders
② Lower to El. 733 by increasing discharge to up to 110,000 cfs. If after reaching el. 733, discharge is below 110,000 cfs, hold this level until discharge increases to 110,000 cfs.
Watts Bar Reservoir Guide for Operation During Flood Season
Headwater Elevation
746
744
742
740
738
736
734
732
730
0
100
200
300
400
500
600
Discharge in 1000 CFS
3

Fixed-Rule Operation Guides

TVA uses fixed rules primarily for two purposes:

- Provide operation staff, “last resort” instructions for use during major floods.
- Facilitate planning studies, by using fixed rules to “drive” computer simulation models.

Fixed-Rule Operation Guides
Continued

- River Scheduling (RvS) staff responsible for integrated operation of the TVA reservoir system, DO NOT EMPLOY FIXED RULES FOR DIRECTING OPERATION OF THE SYSTEM DURING FLOOD OPERATIONS.

- RvS staff uses state-of-the-art hydrologic data collection, weather forecasts, and computer models to derive an operating plan based on the latest observed and forecasted weather conditions while looking at the entire river system as an integrated unit.

Fixed-Rule Operation Guides
Continued

- With redundant communication systems available, RvS staff have never been out of communication with any plants for any extended period of time.

- The fixed rules have never been implemented by plant staff for flood-control operations.

Fixed-Rule Operation Guides
Continued

- Example model studies which have depended on fixed rule for operation.
  - Final Safety Analysis Reports (FSAR's) for TVA nuclear plants.
  - TVA dam safety simulations.
  - Flood risk simulations as part of the 2004 Reservoir Operations Study (ROS).

Fixed-Rule Summary

- Fixed Rules used for reservoir system simulations for FSAR's and operation at plants if communication lost for more than 2 hours essentially the same.
- TVA does not expect these curves to be used at the plants with today's communication systems.
- TVA evaluating providing additional communication redundancy contact system between River Scheduling and the plants by providing satellite phones.
- TVA is evaluating emergency rules provided to each plant to further simplify to best accomplish total operating mission in the extremely unlikely event communication is lost for more than 2 hours.

Fixed-Rule Summary
Continued

- TVA has never experienced a flood event approaching the magnitude of the PMF, thus it is difficult to fine tune a fixed rule for these simulations. However, we expect for events of PMF magnitude that any operating policy driver will rapidly converge to unregulated conditions at most projects.

PMF – SOCH Run Sequence

PMF Determination

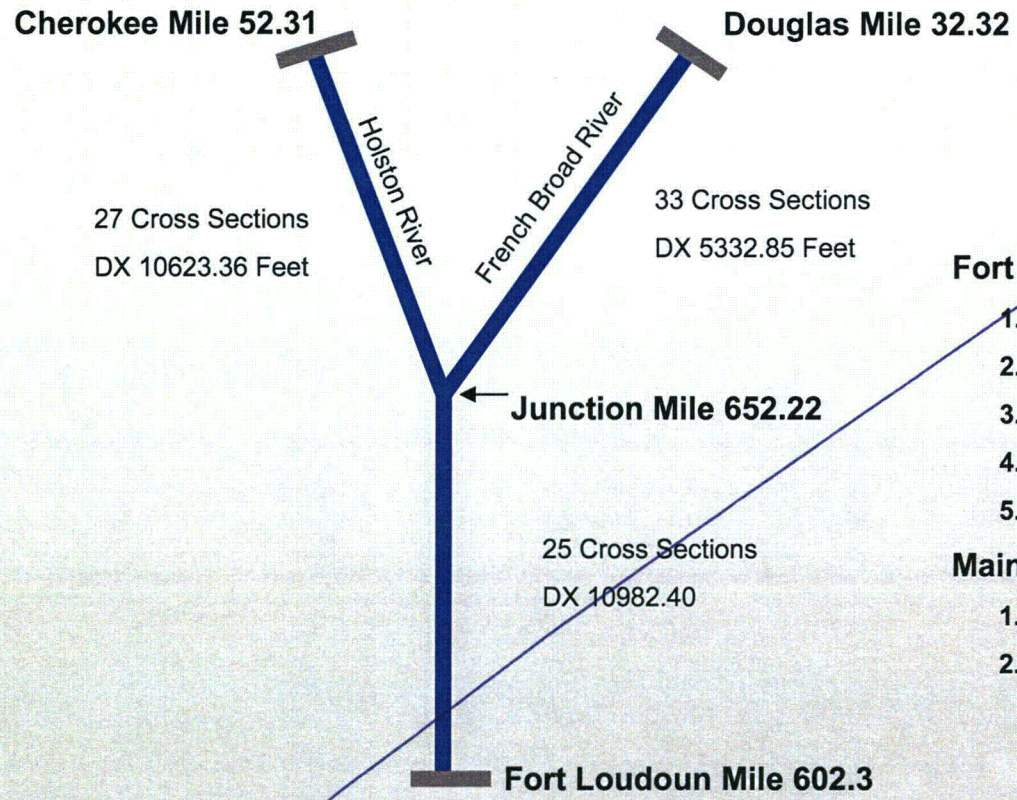
- 9 day storm critically centered on the watershed
- PMP and critical isohytel pattern presented in Hydrometeorological Report 41. Three basic storms with 5 possible isohytel patterns and seasonal variations examined to produce maximum flood levels at BLN.
- 3-day antecedent storm postulated to occur 3 days prior to the 3-day PMP storm.
- Critical storm commencing on March 15, assumed median moisture conditions and initial reservoir elevations. Median reservoir elevations selected to be consistent with statistical experience and to avoid unreasonable combinations of extreme events.
- Antecedent storm depths equivalent to 40 percent of the main storm with uniform areal distribution.

PMF Determination

- At the start of the main storm **53%** of the total reserved system flood detention capacity was occupied. Neither the initial reservoir levels nor the operating rules would have significant effect on maximum flood discharges and elevations at Bellefonte because spillway capacity and thus uncontrolled conditions, are reached early in the flood.

- A standard time distribution pattern adopted for all storms. Examination of alternatively placing the maximum 24-hour precipitation of the first, second or third day results in comparable flood levels at Bellefonte.

PMF Routing Sequence — Bellefonte Unit 1 and 2



See Updated Figure

Fort Loudoun Fixed Rule — Antecedent Storm

1. Elevation 807 to 50k
2. Q Constant to 810
3. Rating Curve to Gate Top
4. Gate Top to 120k Empty Rate
5. Empty Rate

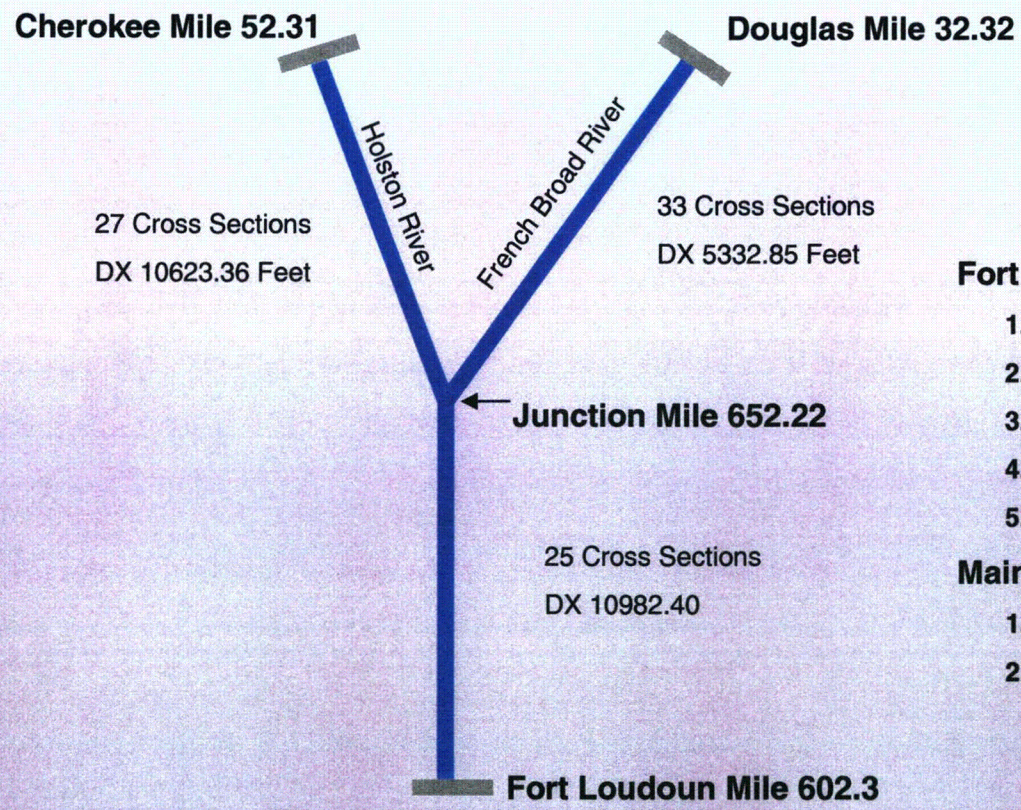
Main Storm

1. To Fill Curve at Fort Loudoun
2. Filling Curve to Spillway Capacity

Fort Loudoun Reservoir to Cherokee and Douglas

PMF Routing Sequence — Bellefonte Unit 1 and 2

Updated figure



Fort Loudoun Fixed Rule — Antecedent Storm

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4. Gate Top to 120k Empty Rate
5. Empty Rate

Main Storm

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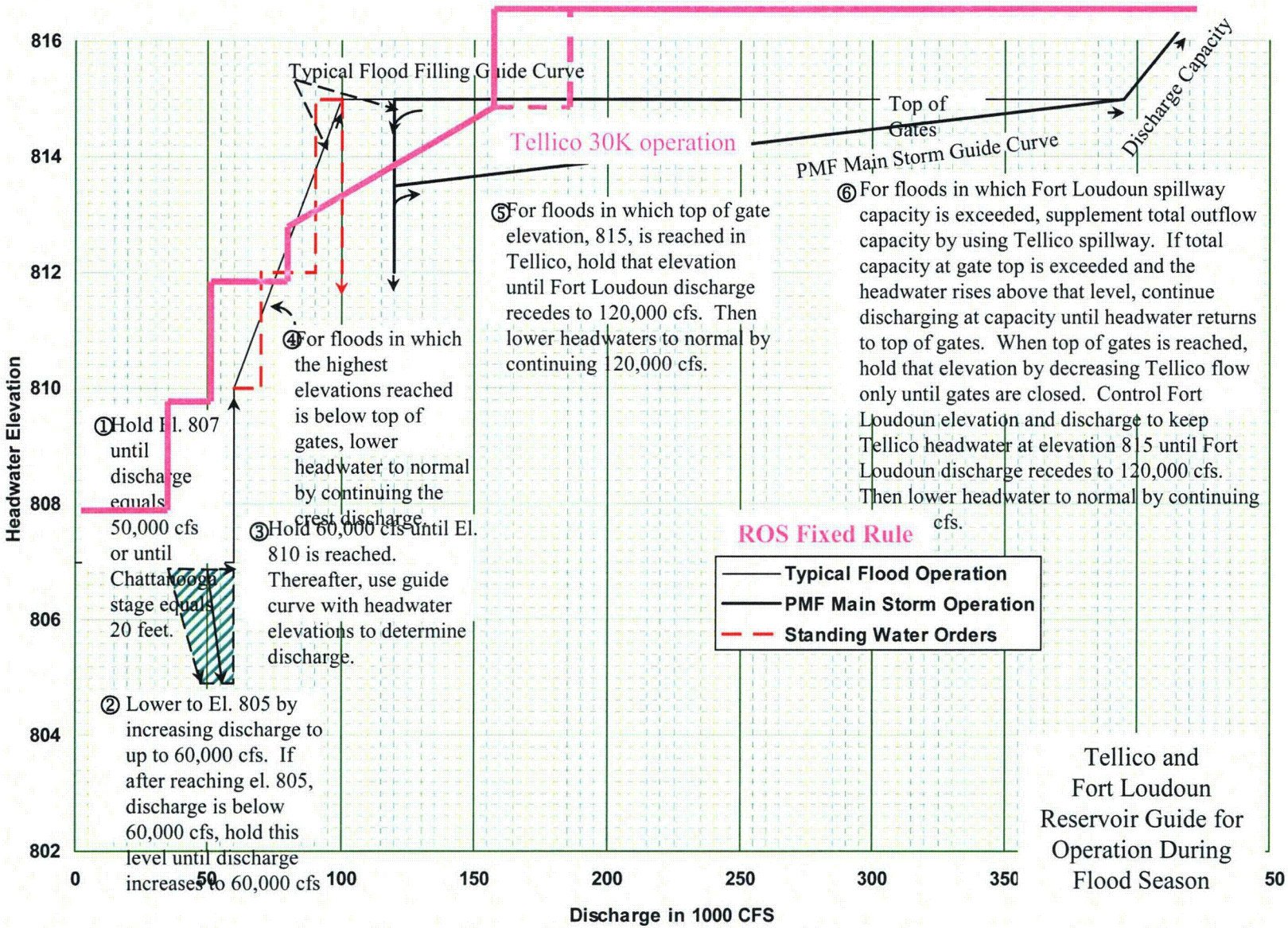
Fort Loudoun Reservoir to Cherokee and Douglas


816
814
812
810
808
806
804
802
Headwater Elevation
0
50
100
150
200
250
300
350
50
Discharge in 1000 CFS
Typical Flood Filling Guide Curve
Tellico 30K operation
Top of Gates
PMF Main Storm Guide Curve
Discharge Capacity
①Hold El. 807 until discharge equals 50,000 cfs or until Chattanooga stage equals 20 feet.
② Lower to El. 805 by increasing discharge to up to 60,000 cfs. If after reaching el. 805, discharge is below 60,000 cfs, hold this level until discharge increases to 60,000 cfs
③Hold 60,000 cfs until El. 810 is reached. Thereafter, use guide curve with headwater elevations to determine discharge.
④For floods in which the highest elevations reached is below top of gates, lower headwater to normal by continuing the crest discharge.
⑤For floods in which top of gate elevation, 815, is reached in Tellico, hold that elevation until Fort Loudoun discharge recedes to 120,000 cfs. Then lower headwaters to normal by continuing 120,000 cfs.
⑥For floods in which Fort Loudoun spillway capacity is exceeded, supplement total outflow capacity by using Tellico spillway. If total capacity at gate top is exceeded and the headwater rises above that level, continue discharging at capacity until headwater returns to top of gates. When top of gates is reached, hold that elevation by decreasing Tellico flow only until gates are closed. Control Fort Loudoun elevation and discharge to keep Tellico headwater at elevation 815 until Fort Loudoun discharge recedes to 120,000 cfs. Then lower headwater to normal by continuing cfs.
ROS Fixed Rule
Typical Flood Operation
PMF Main Storm Operation
Standing Water Orders
Tellico and Fort Loudoun Reservoir Guide for Operation During Flood Season

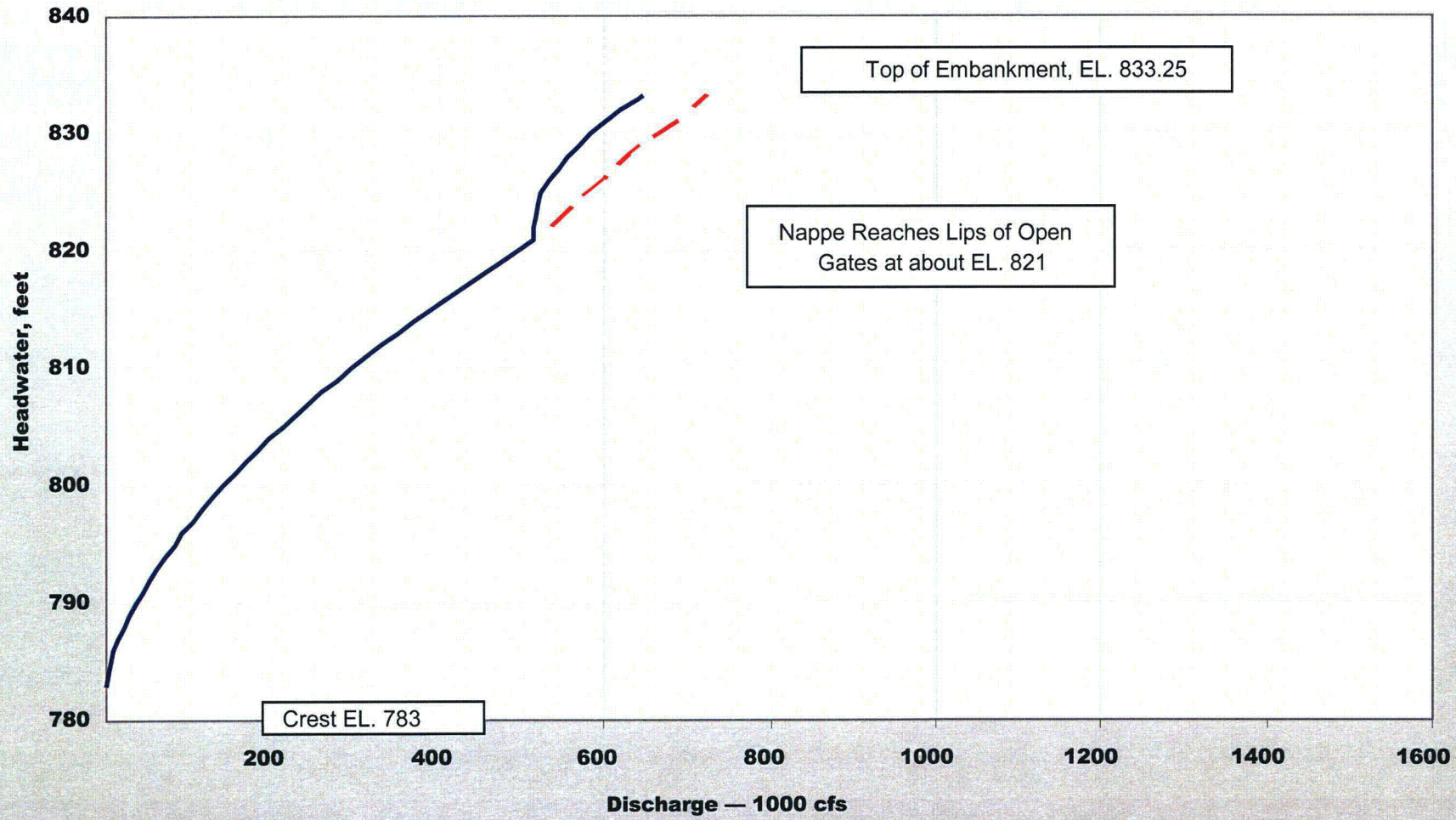
5

21,400 Square Mile PMF — Reservoir Levels
Initial vs. Main Storm

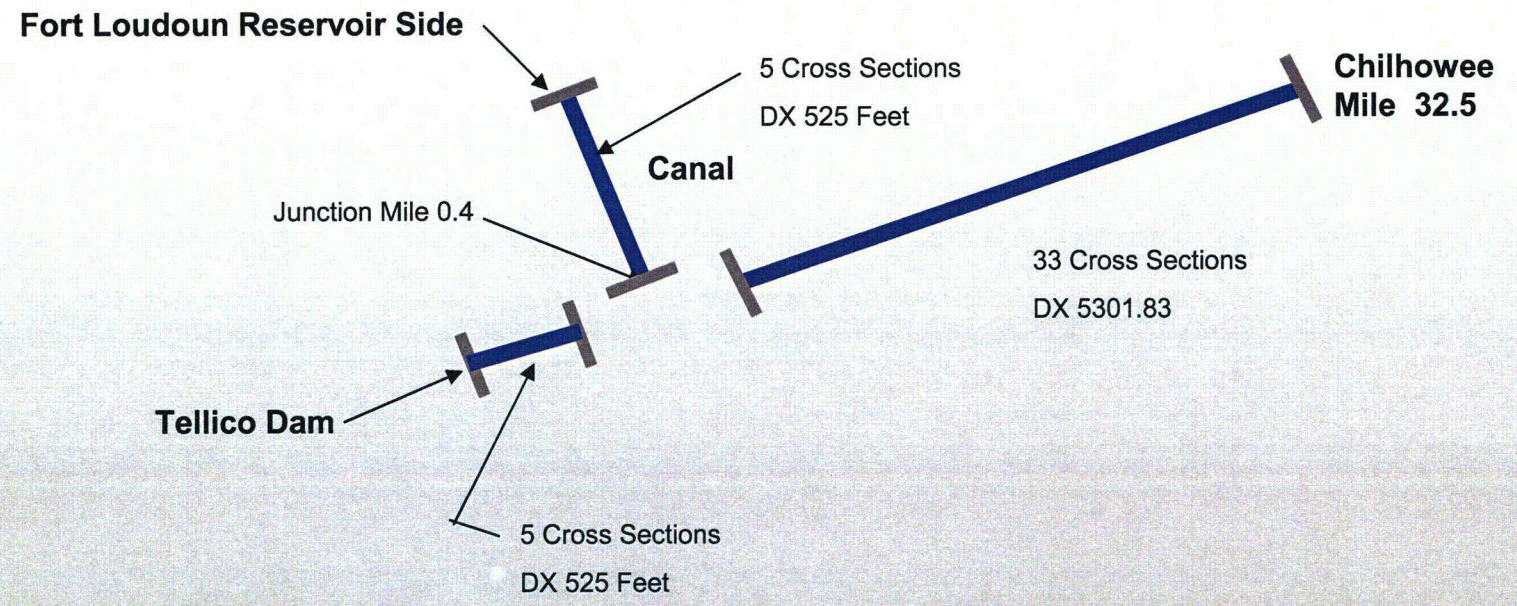
	Start Level 3/15	Ant Storm 3/18	Main Storm 3/21	Top of Gates
Tributary				
Cherokee	1042	1055.8	1065.24	1075
Douglas	958	984	992	1002
Fontana	1644	1654	1668	1710
Norris	998	1010	1021.68	1034
Mainstem				
Fort Loudoun/Tellico	807	815	812.28	815
Watts Bar	735	743.13	741.49	745
Chickamauga	675	680.18	682.53	685.4
Nickajack	632	632	632	635
Guntersville	593	593.59	595.11	595.44

Note: Reservoir Starting Levels on March 15 are median levels for time of year.

Fort Loudoun Headwater Rating

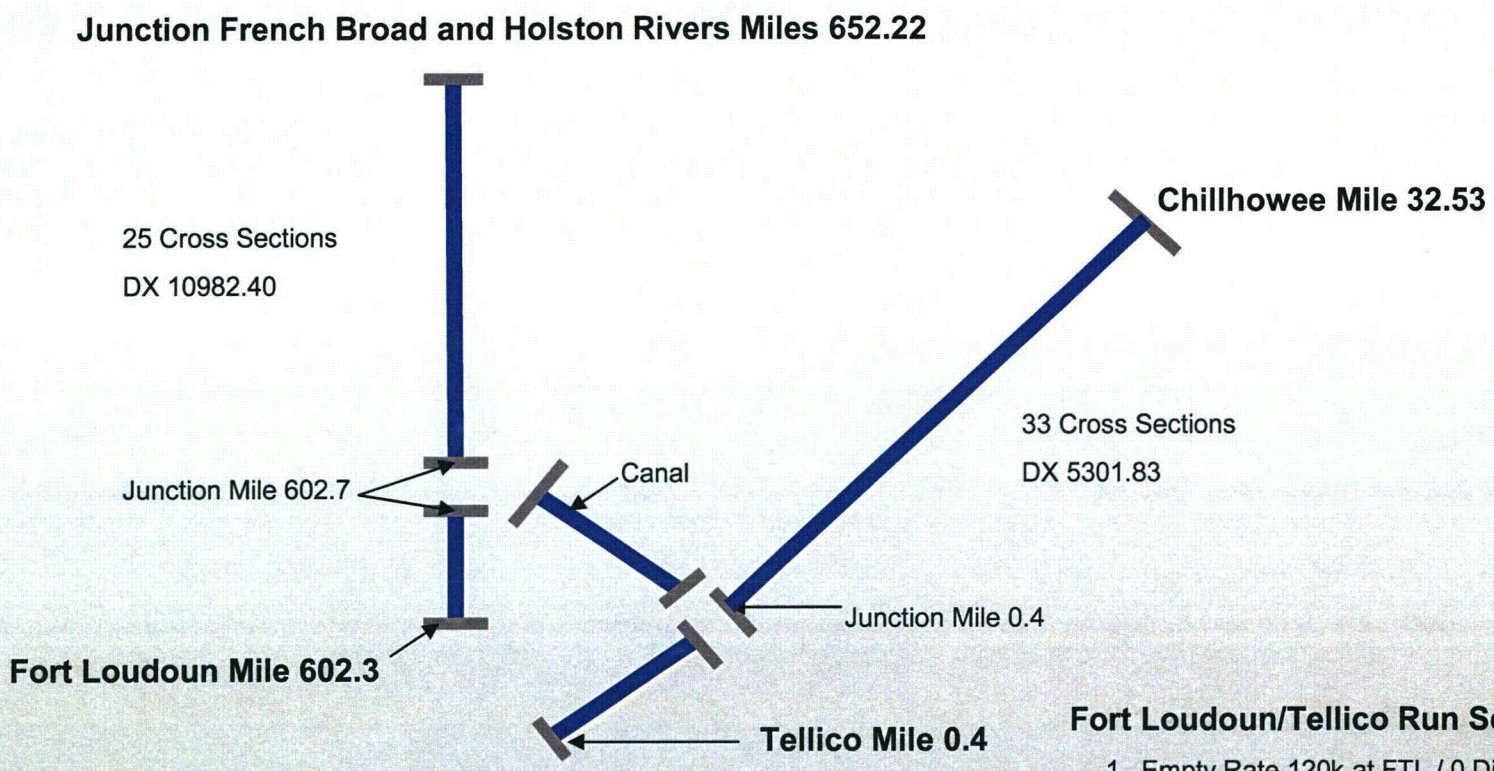


PMF Run Sequence — Bellefonte Unit 1 and 2



Tellico Reservoir — Canal Connection to Fort Loudoun

PMF Run Sequence — Bellefonte Unit 1 and 2

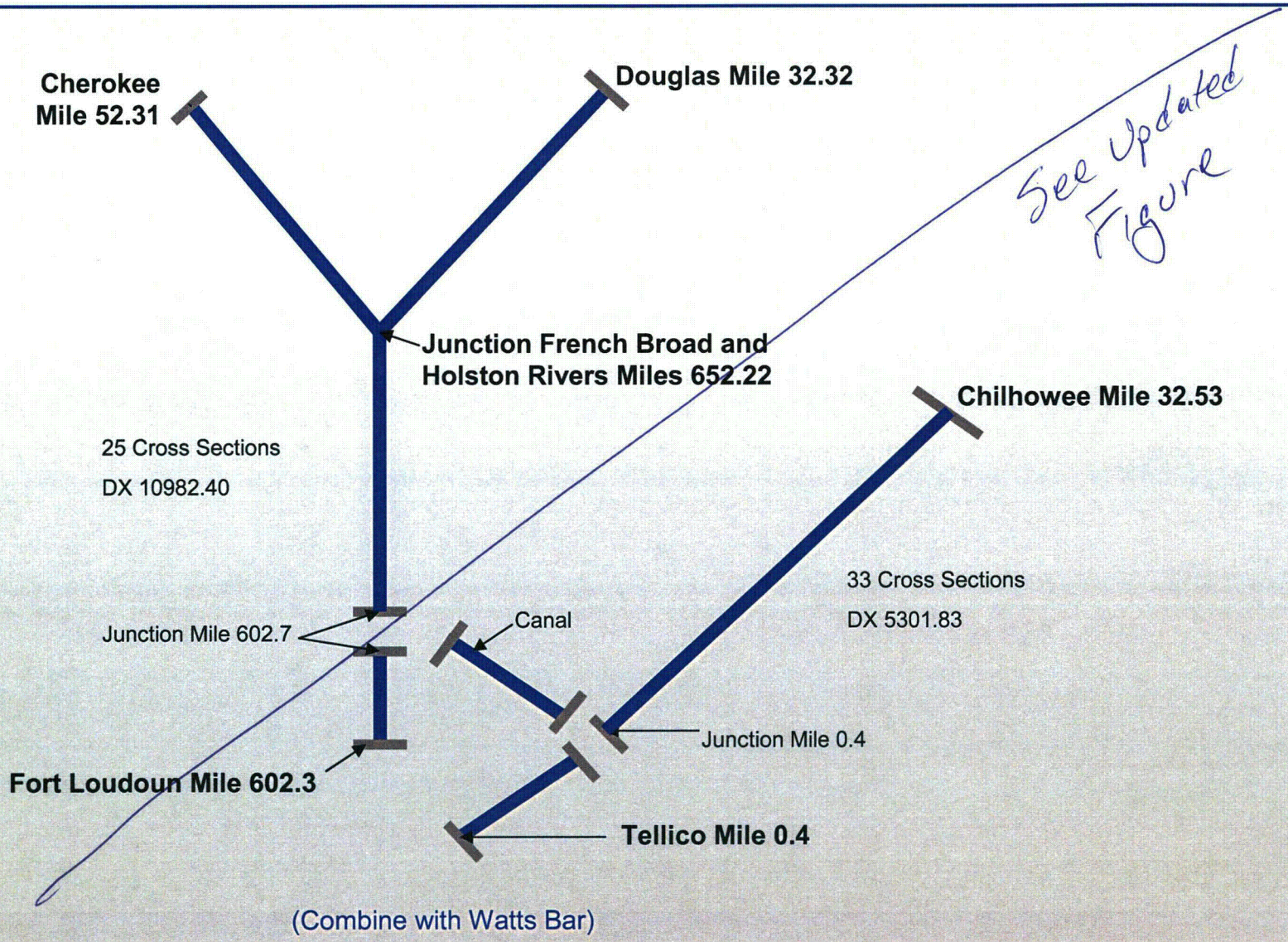


Fort Loudoun/Tellico Run Sequence

1. Empty Rate 120k at FTL / 0 Discharge @ Tellico
2. Filling Curve at FTL / 0 Discharge @ Tellico
3. Free Spillway at FTL / Open Gates @ Tellico
4. Free Spillway at FTL / Tellico Free Spillway

Fort Loudoun — Tellico — Canal Connection

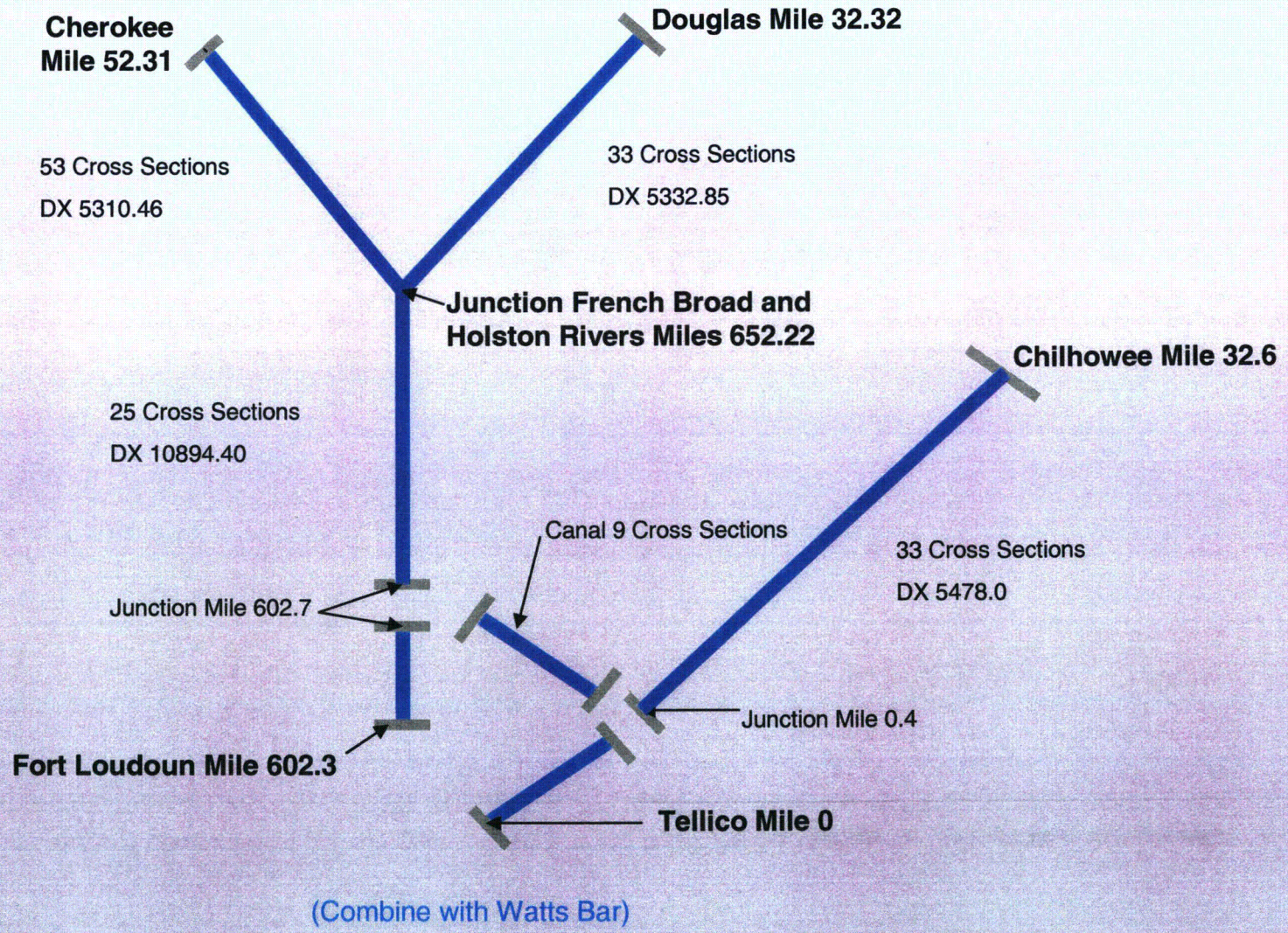
PMF Run Sequence — Bellefonte Unit 3 and 4



Fort Loudoun – Tellico – Canal Connection – Cherokee - Douglas

PMF Run Sequence — Bellefonte Unit 3 and 4

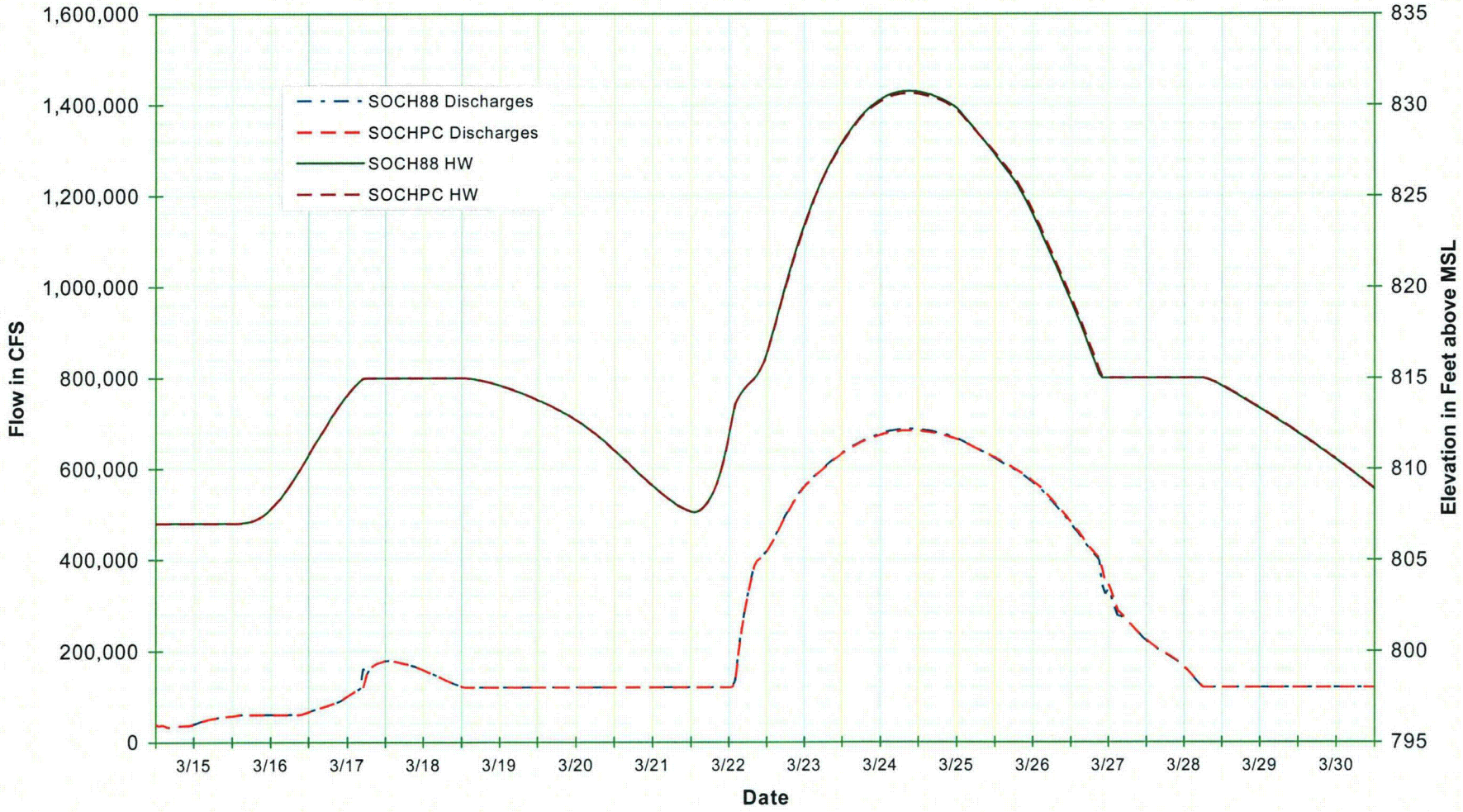
Updated Figure



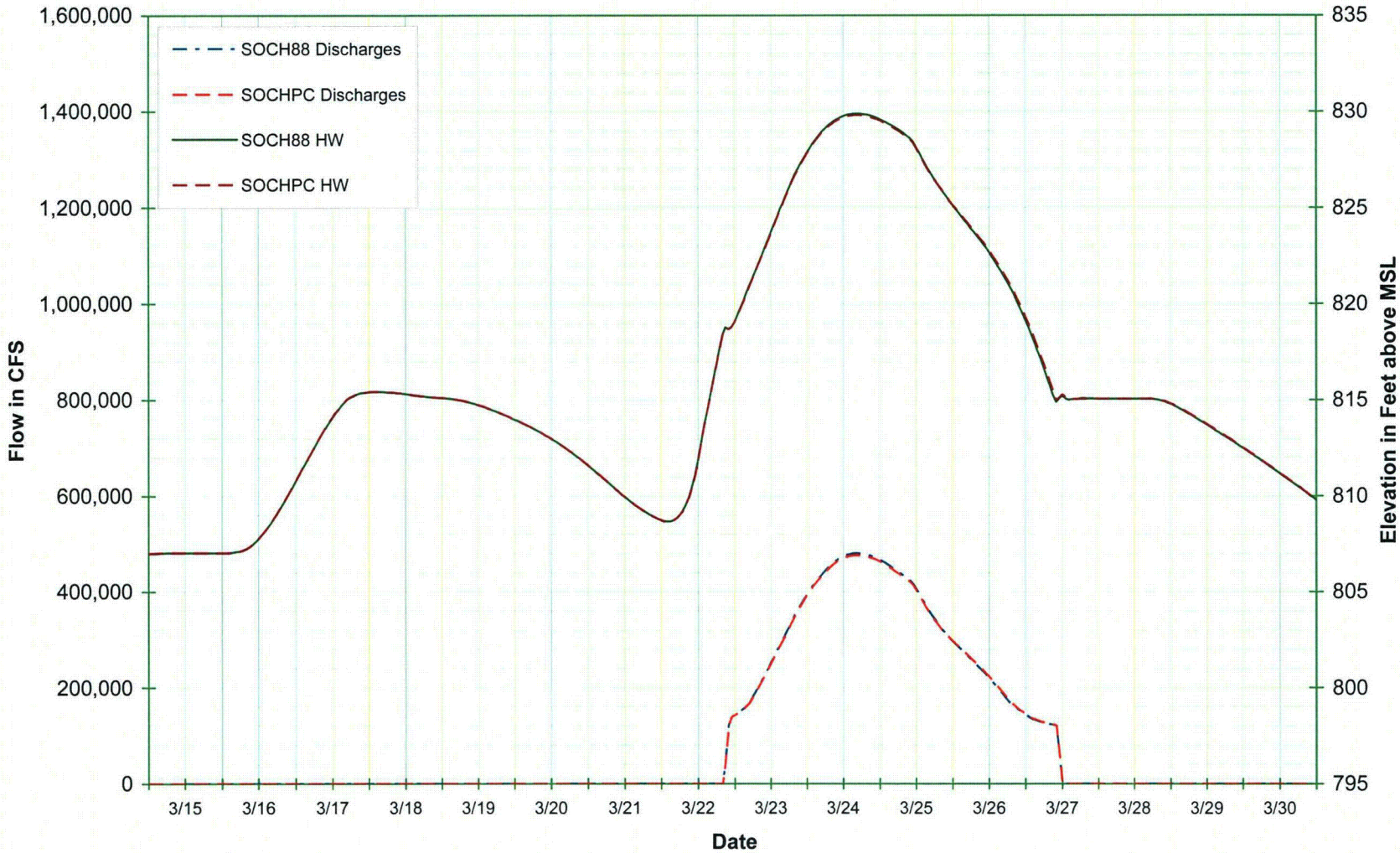
(Combine with Watts Bar)

Fort Loudoun – Tellico – Canal Connection – Cherokee - Douglas

SOCH88 vs. SOCHPC Results



SOCH88 vs. SOCHPC Results



PMF Run Sequence — Bellefonte Units 1, 2, 3, and 4

See Updated Figure

Norris Dam Mile 79.8

10 Local Inflows @ points

55 Cross Sections

DX 5544.00

Melton Hill Run Sequence

1. Elevation constant to filling curve
2. Before failure rating curve at Melton Hill
3. After failure rating curve at Melton Hill

Melton Hill Mile 23.1

(Combine with Watts Bar)

Melton Hill Reservoir (No Reserved Flood Storage)

PMF Run Sequence — Bellefonte Units 1, 2, 3, and 4

Updated Figure

Norris Dam Mile 79.8

27 Cross Sections

DX 11514.46

Melton Hill Run Sequence

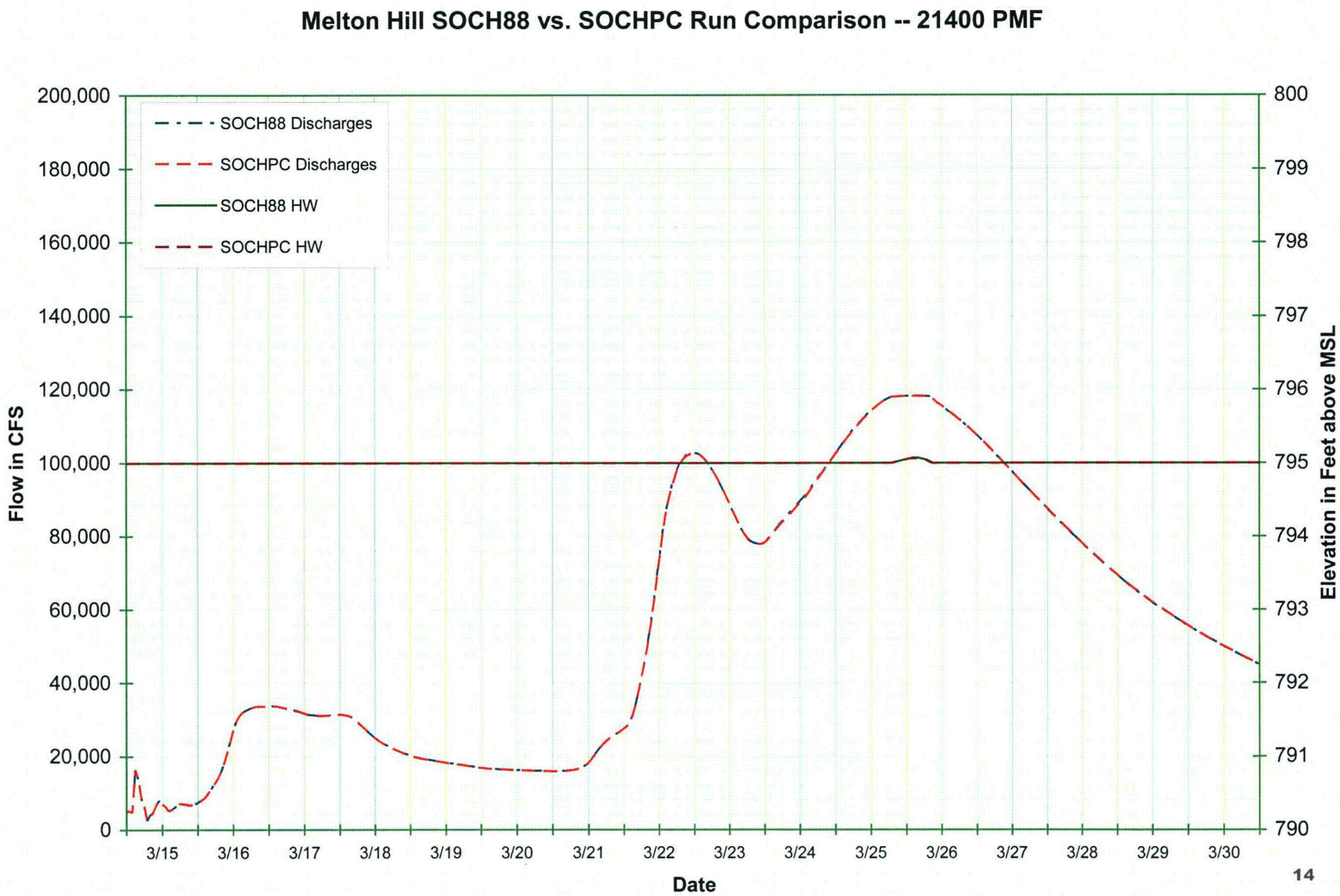
1. Elevation constant to filling curve
2. Before failure rating curve at Melton Hill

Melton Hill Mile 23.1

(Combine with Watts Bar)

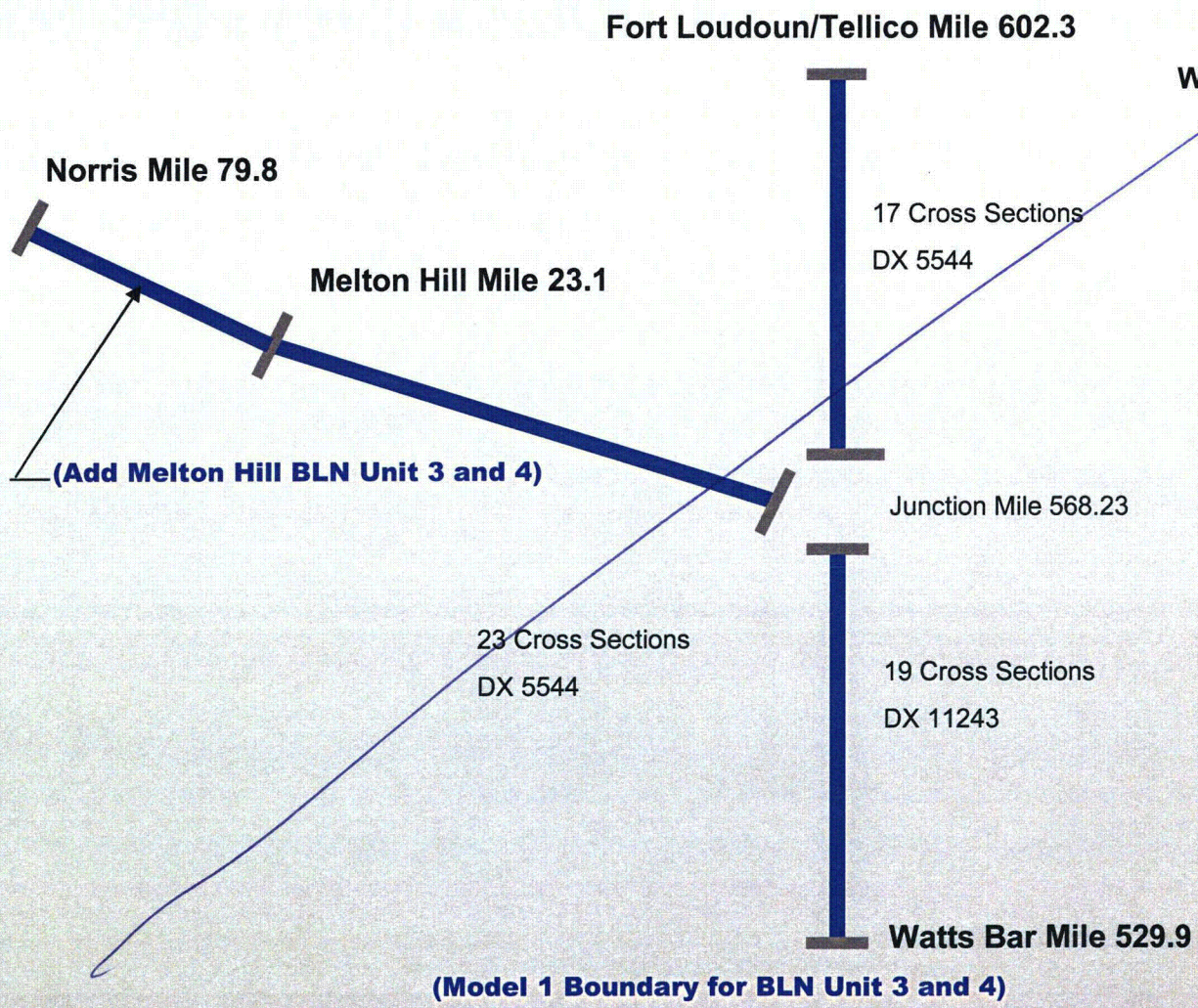
Melton Hill Reservoir (No Reserved Flood Storage)

SOCH88 vs. SOCHPC Results



Bellefonte Units 1, 2, 3, and 4

See Updated Figure



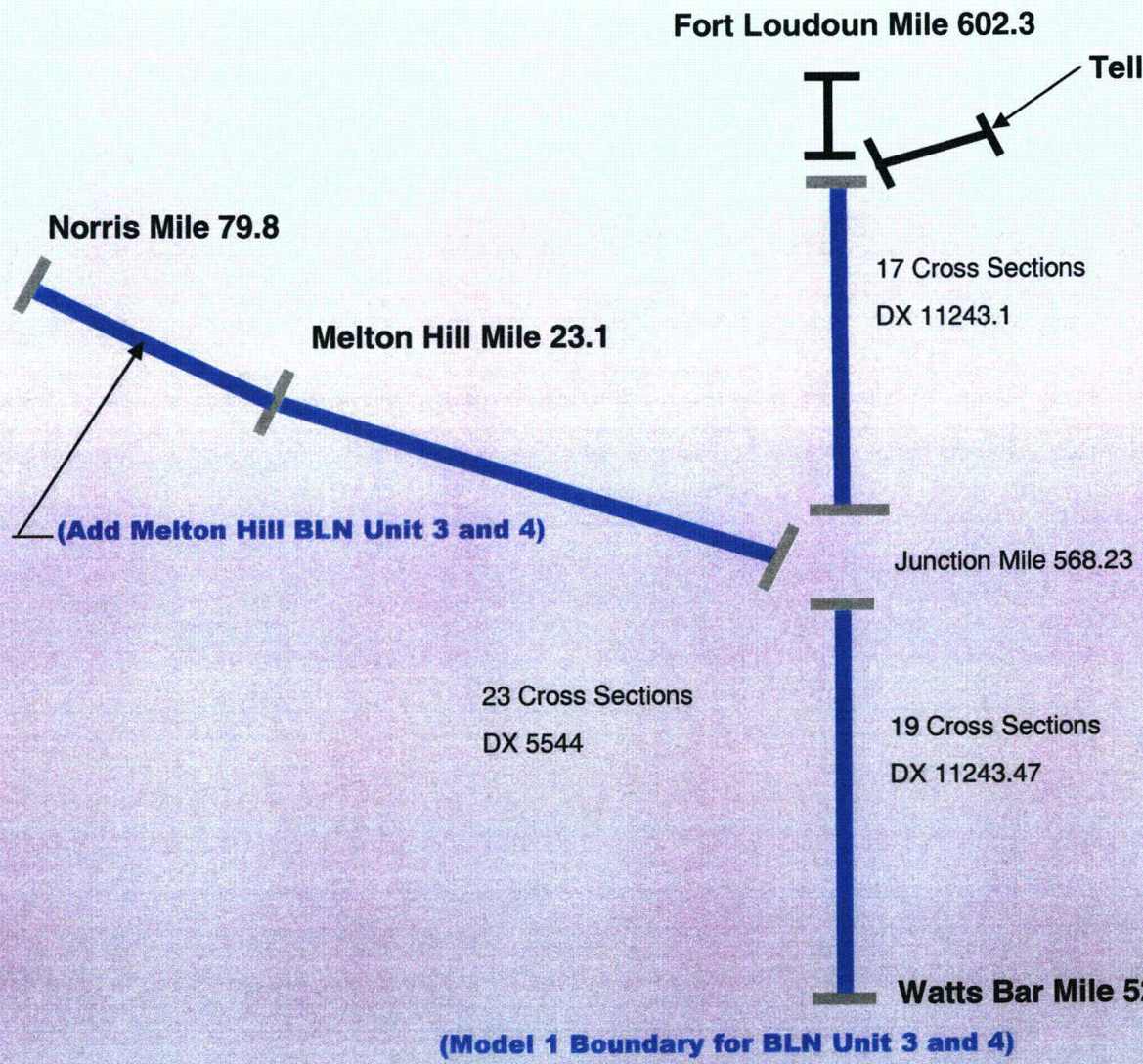
Watts Bar Run Sequence

1. Elevation constant at Watts Bar
2. Hold 110k cfs at Watts Bar
3. Filling curve to crest Q at Watts Bar
4. Hold crest Q at Watts Bar
5. Free Spillway at Watts Bar
6. Before failure at Watts Bar
7. After failure at Watts Bar

Watts Bar Reservoir

Bellefonte Units 1, 2, 3, and 4

Updated Figure

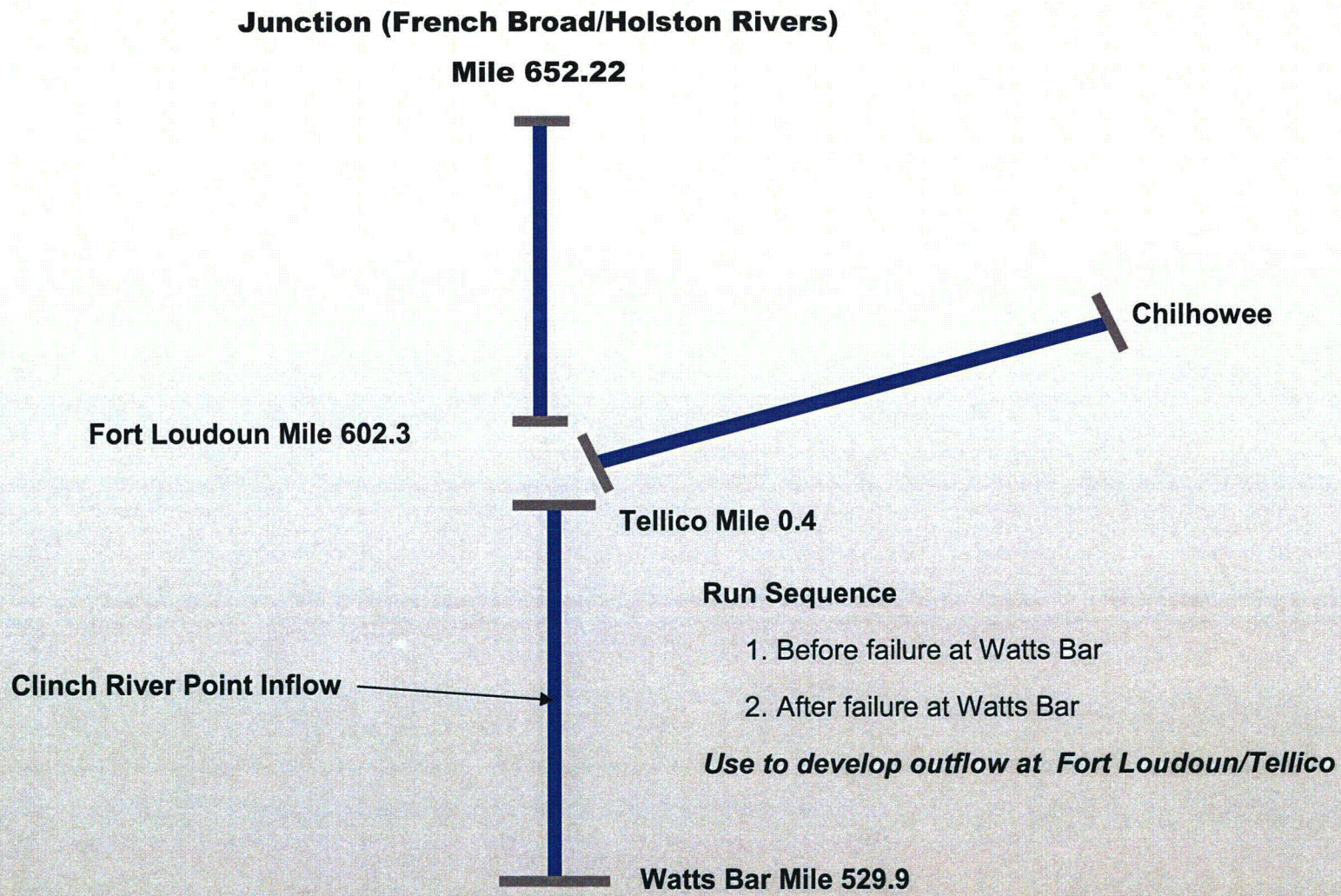


Watts Bar Run Sequence

1. Elevation constant at Watts Bar
2. Hold 110k cfs at Watts Bar
3. Filling curve to Gate Top at Watts Bar
4. Gate Top until Q is 190K
5. PMF filling curve
6. Free Spillway at Watts Bar
7. Before failure at Watts Bar
8. After failure at Watts Bar

Watts Bar Reservoir

PMF Run Sequence — Bellefonte Unit 1 and 2

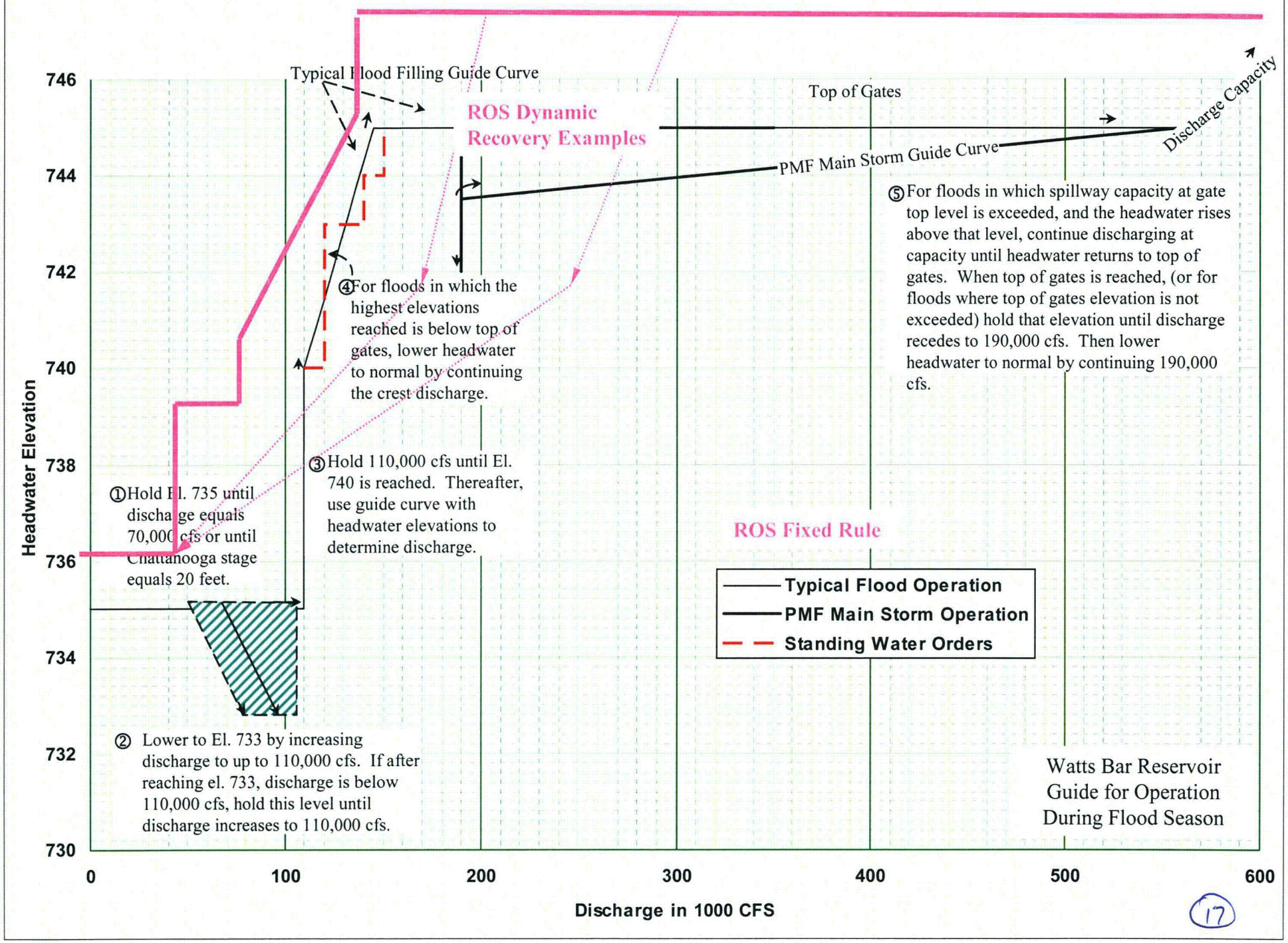


Run Sequence

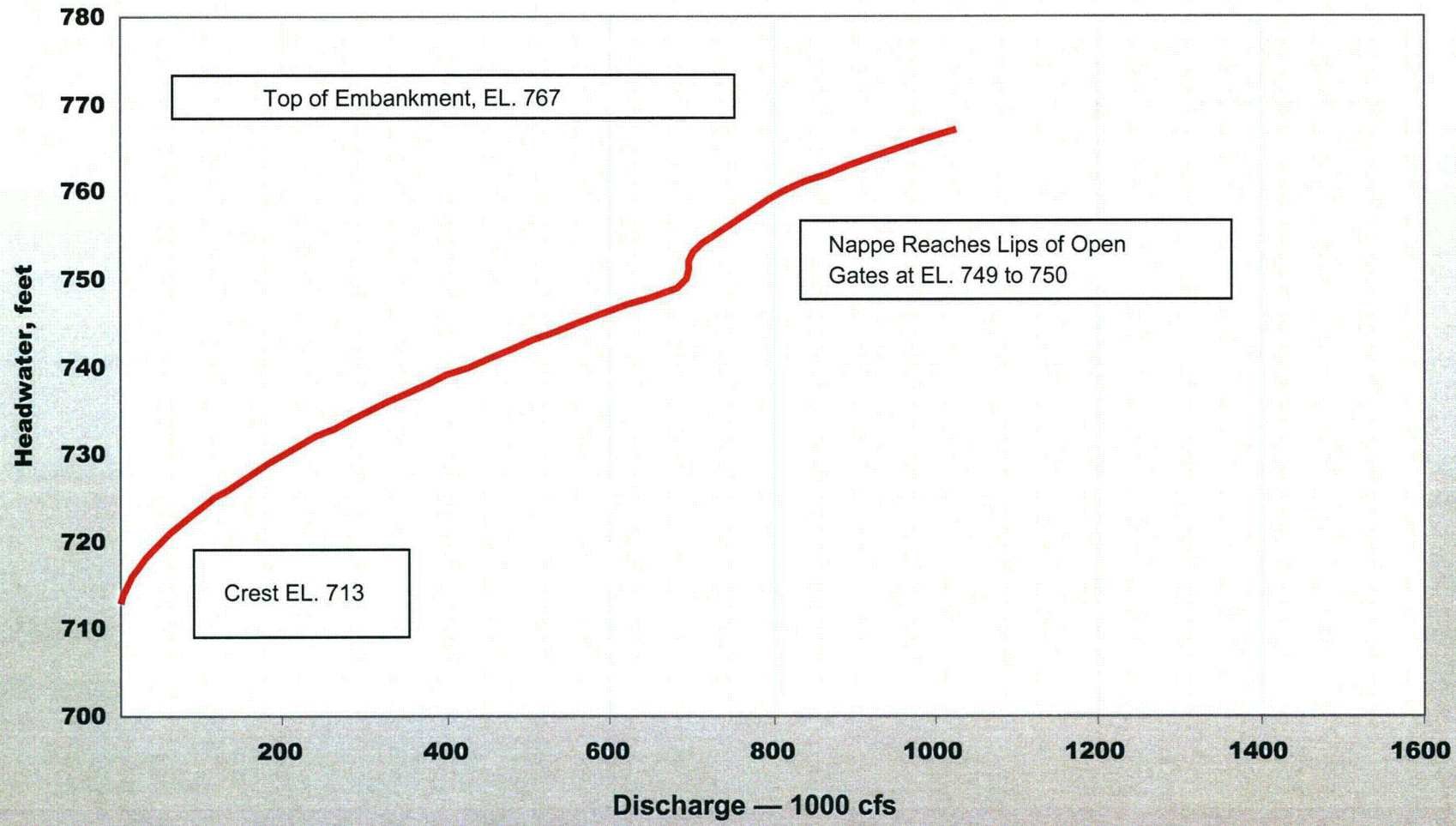
1. Before failure at Watts Bar
2. After failure at Watts Bar

Use to develop outflow at Fort Loudoun/Tellico

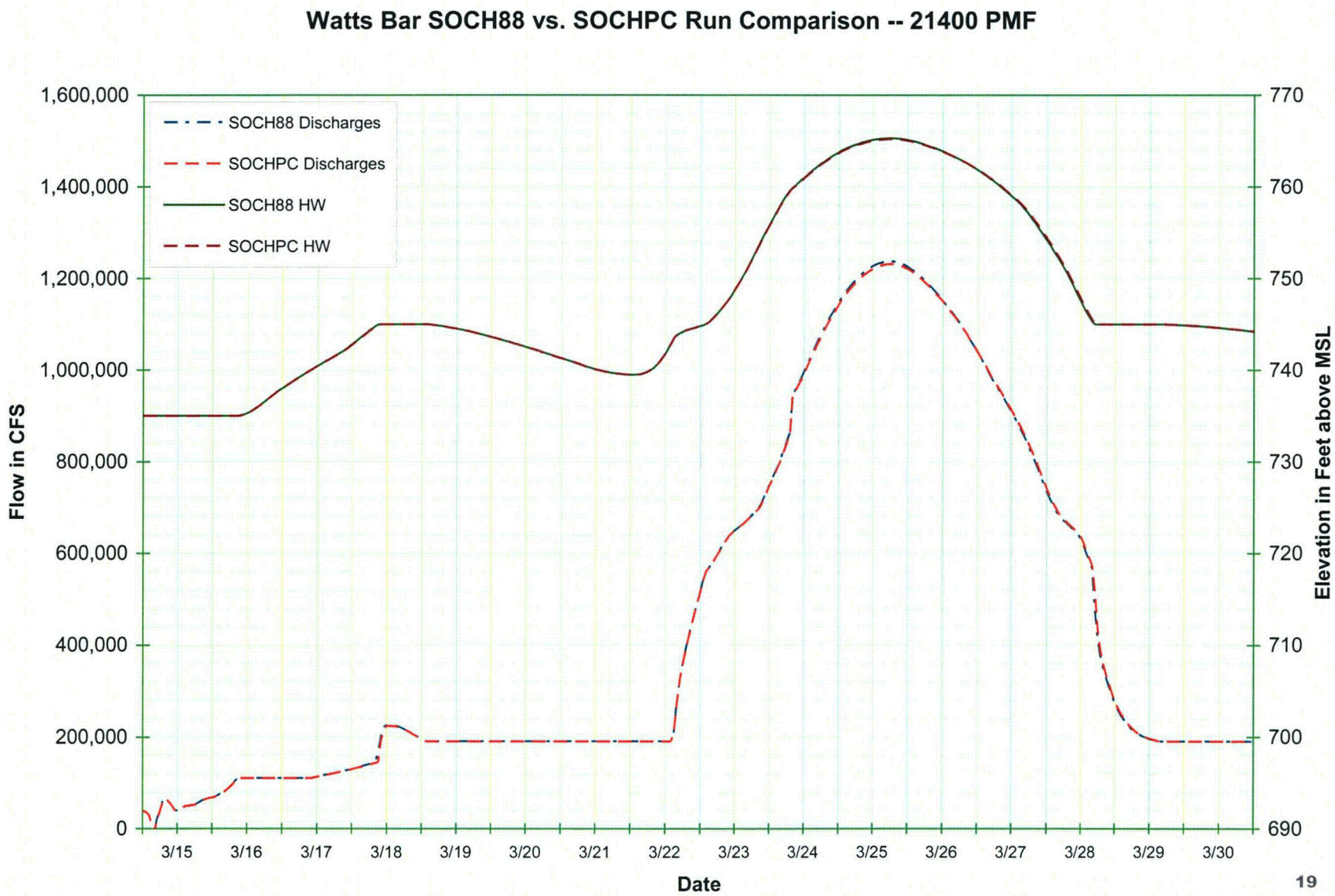
Watts Bar – Fort Loudoun - Tellico


Typical Flood Filling Guide Curve
ROS Dynamic Recovery Examples
Top of Gates
Discharge Capacity
PMF Main Storm Guide Curve
⑤For floods in which spillway capacity at gate top level is exceeded, and the headwater rises above that level, continue discharging at capacity until headwater returns to top of gates. When top of gates is reached, (or for floods where top of gates elevation is not exceeded) hold that elevation until discharge recedes to 190,000 cfs. Then lower headwater to normal by continuing 190,000 cfs.
④For floods in which the highest elevations reached is below top of gates, lower headwater to normal by continuing the crest discharge.
③Hold 110,000 cfs until El. 740 is reached. Thereafter, use guide curve with headwater elevations to determine discharge.
①Hold El. 735 until discharge equals 70,000 cfs or until Chattanooga stage equals 20 feet.
ROS Fixed Rule
Typical Flood Operation
PMF Main Storm Operation
Standing Water Orders
② Lower to El. 733 by increasing discharge to up to 110,000 cfs. If after reaching el. 733, discharge is below 110,000 cfs, hold this level until discharge increases to 110,000 cfs.
Watts Bar Reservoir Guide for Operation During Flood Season
Headwater Elevation
746
744
742
740
738
736
734
732
730
0
100
200
300
400
500
600
Discharge in 1000 CFS

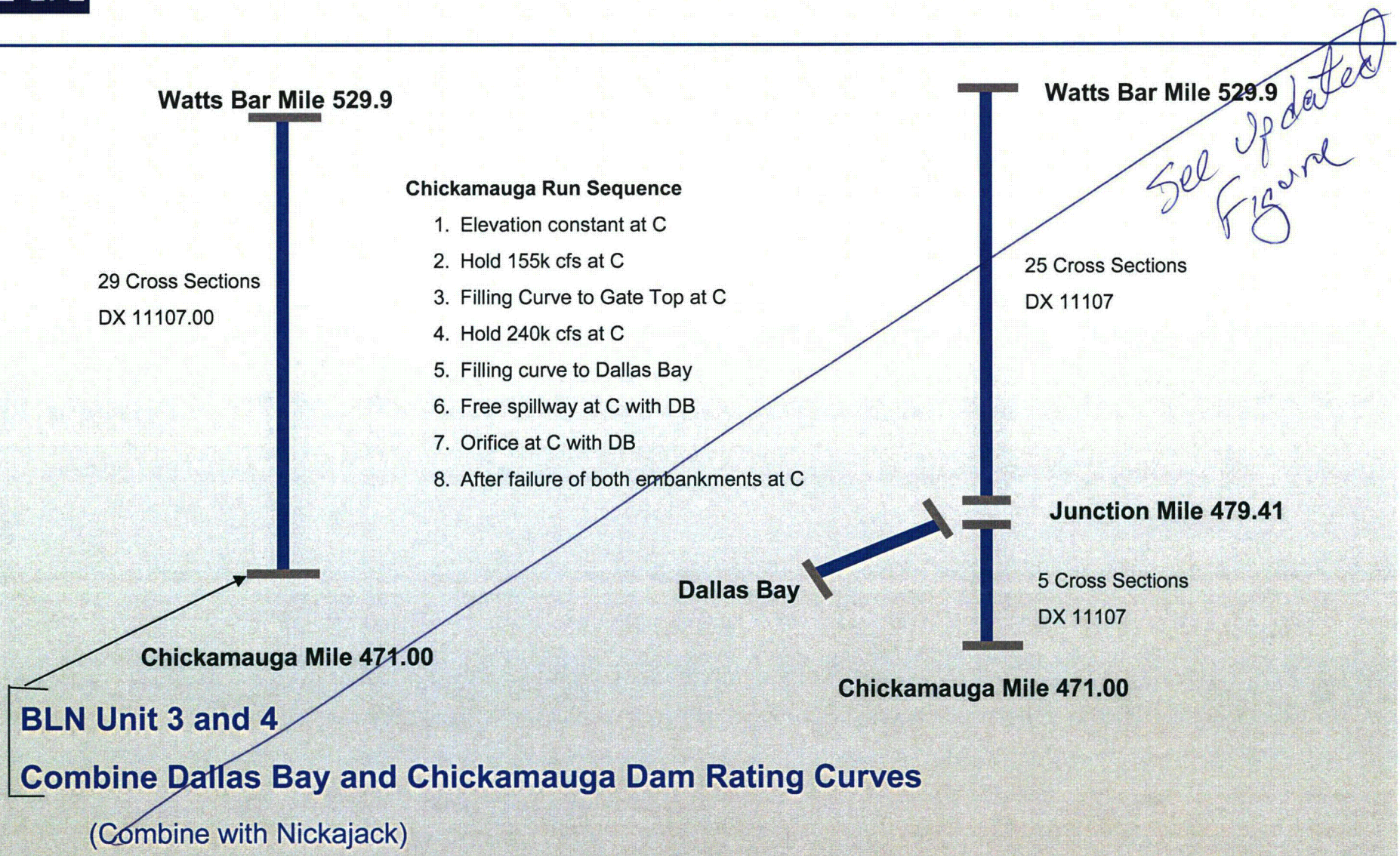
Watts Bar Headwater Rating



SOCH88 vs. SOCHPC Results



PMF Sequence — BLN Unit 1 and 2 / BLN Unit 3 and 4



BLN Unit 3 and 4

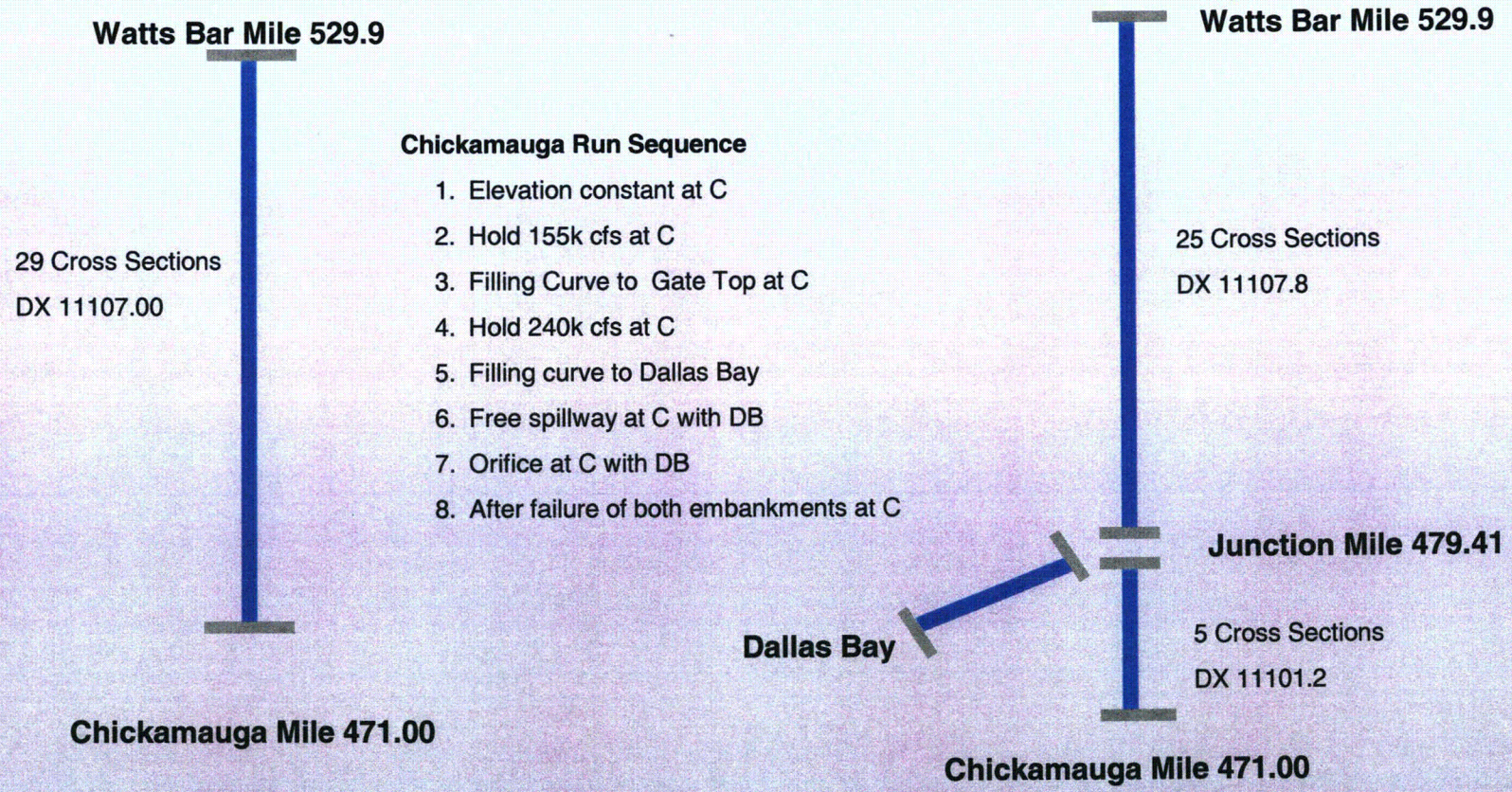
Combine Dallas Bay and Chickamauga Dam Rating Curves

(Combine with Nickajack)

Chickamauga / Chickamauga with Dallas Bay

PMF Sequence — BLN Unit 1 and 2 / BLN Unit 3 and 4

Updated Figure



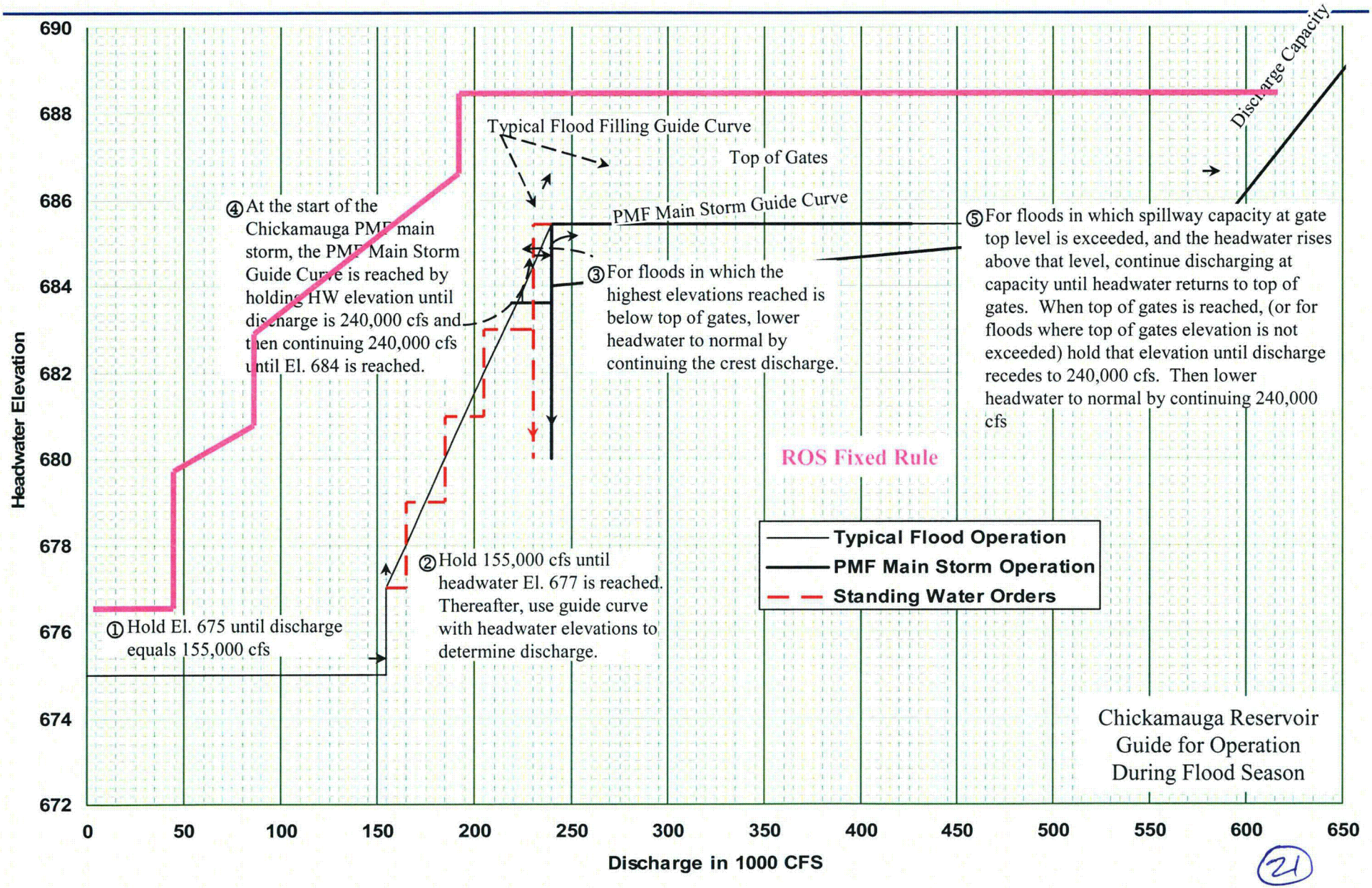
Chickamauga Run Sequence

1. Elevation constant at C
2. Hold 155k cfs at C
3. Filling Curve to Gate Top at C
4. Hold 240k cfs at C
5. Filling curve to Dallas Bay
6. Free spillway at C with DB
7. Orifice at C with DB
8. After failure of both embankments at C

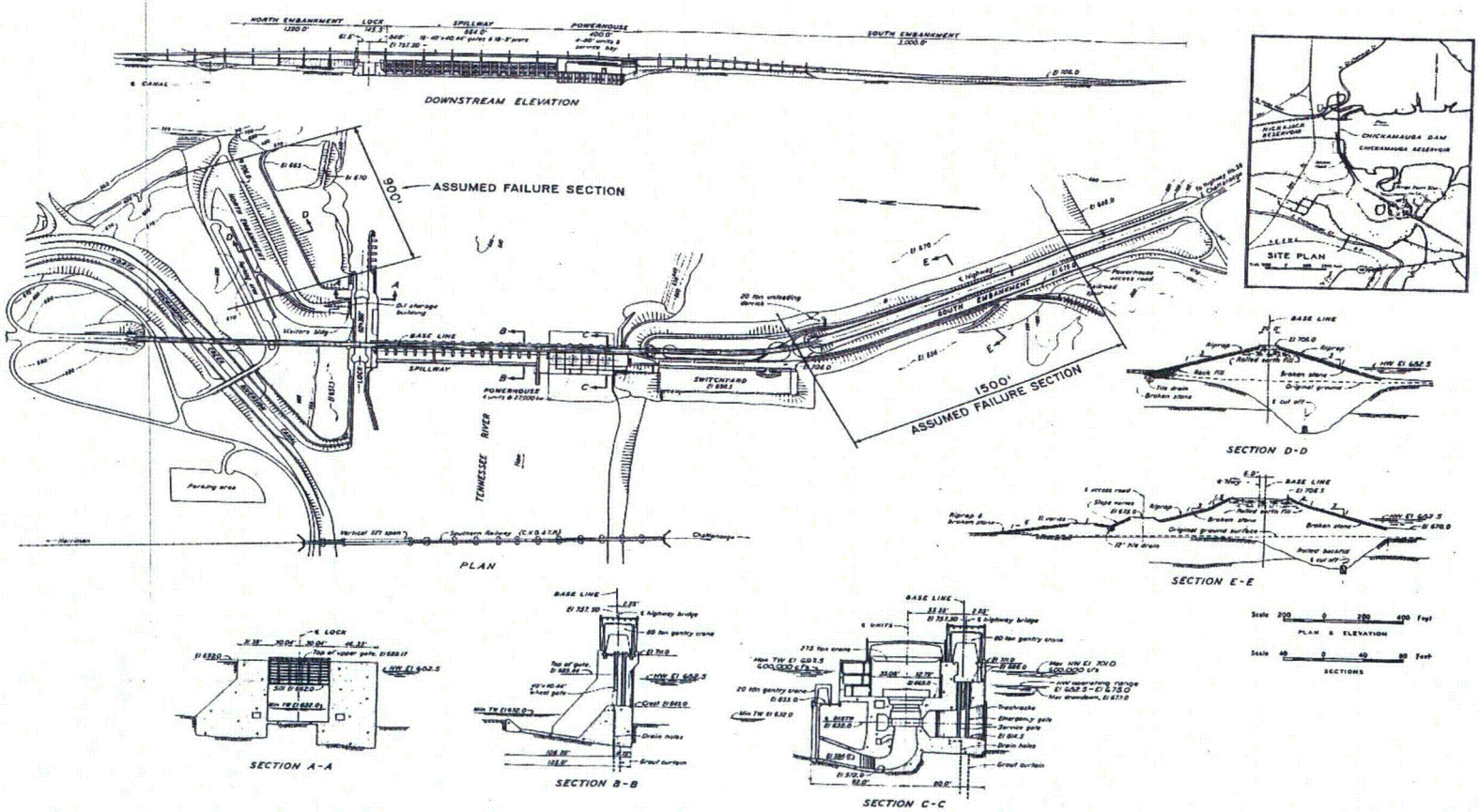
(Combine with Nickajack)

Chickamauga / Chickamauga with Dallas Bay

Chickamauga Dam Fixed Rule — Original / Revised

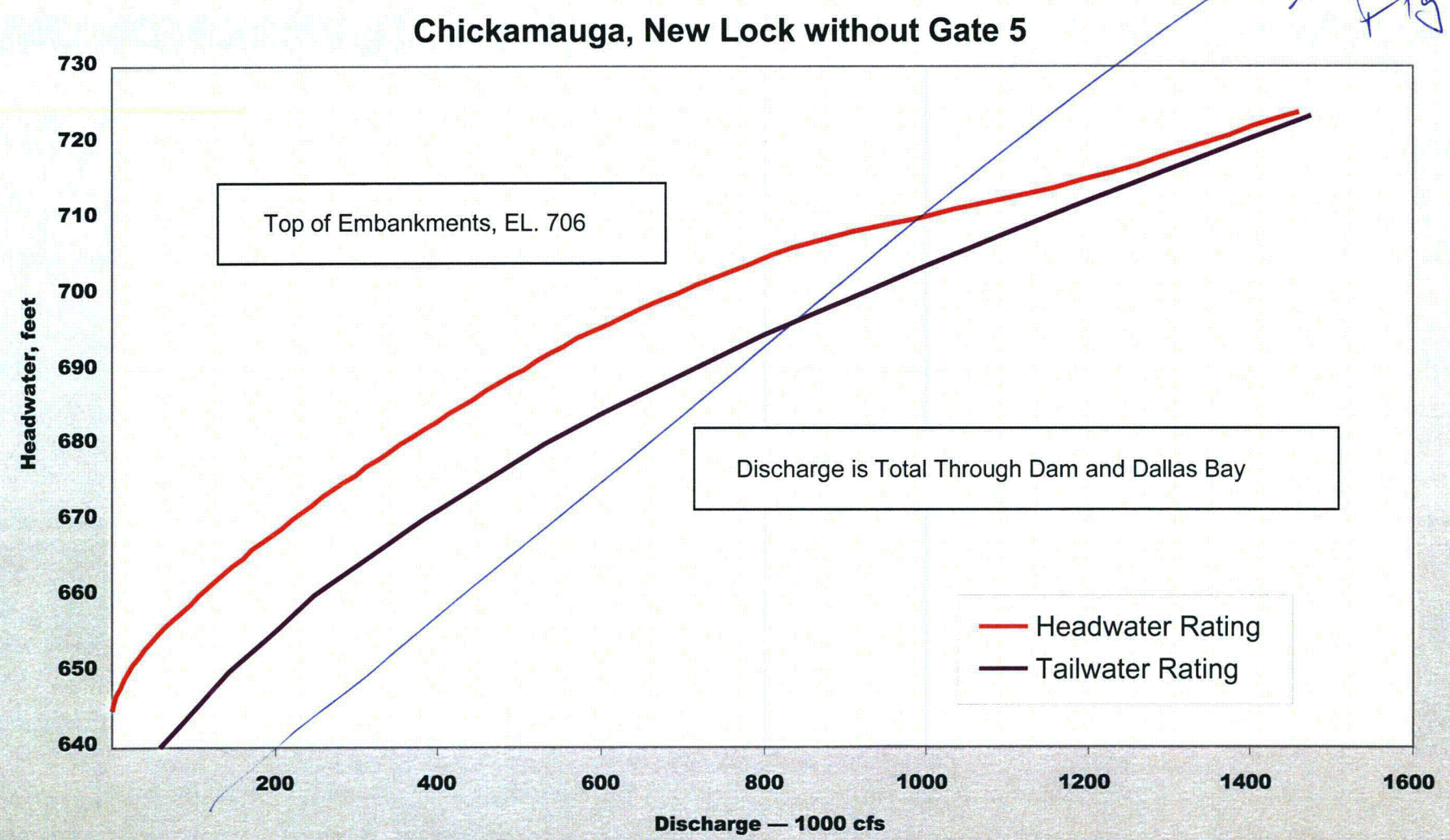


Chickamauga Dam — General Plan



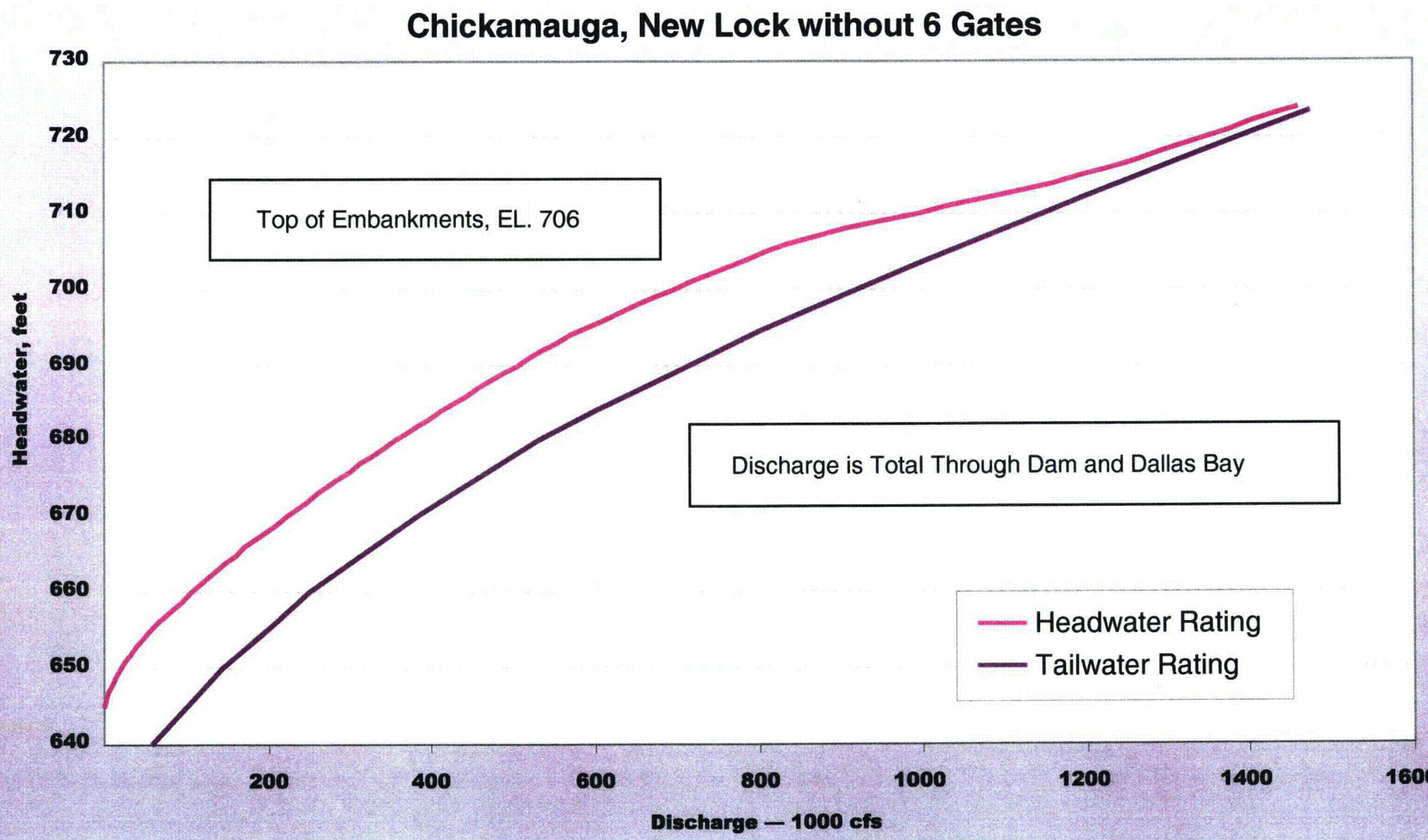
Rating Curves — BLN Unit 1 and 2 / BLN Unit 3 and 4

See Updated Figure

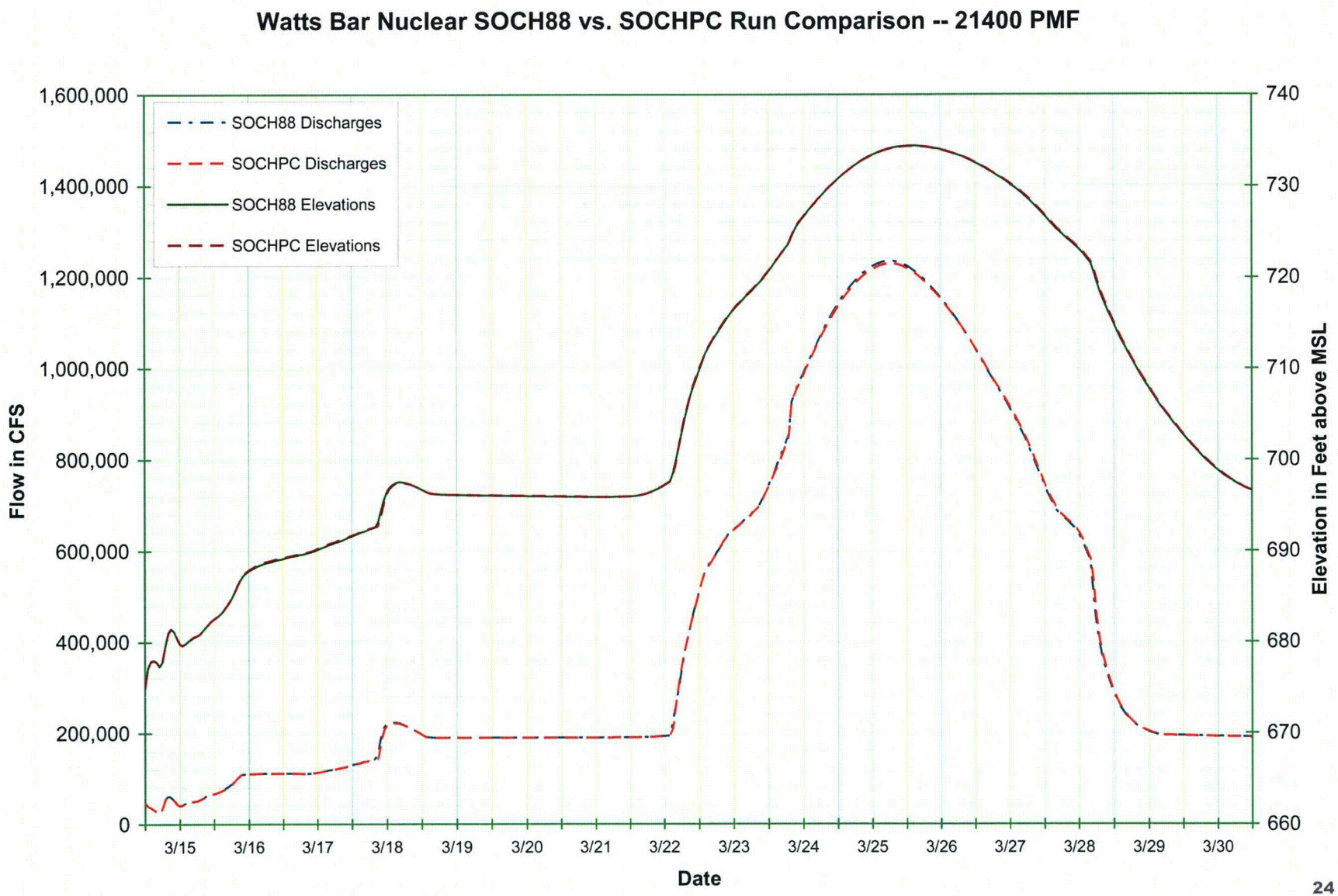


Rating Curves — BLN Unit 1 and 2 / BLN Unit 3 and 4

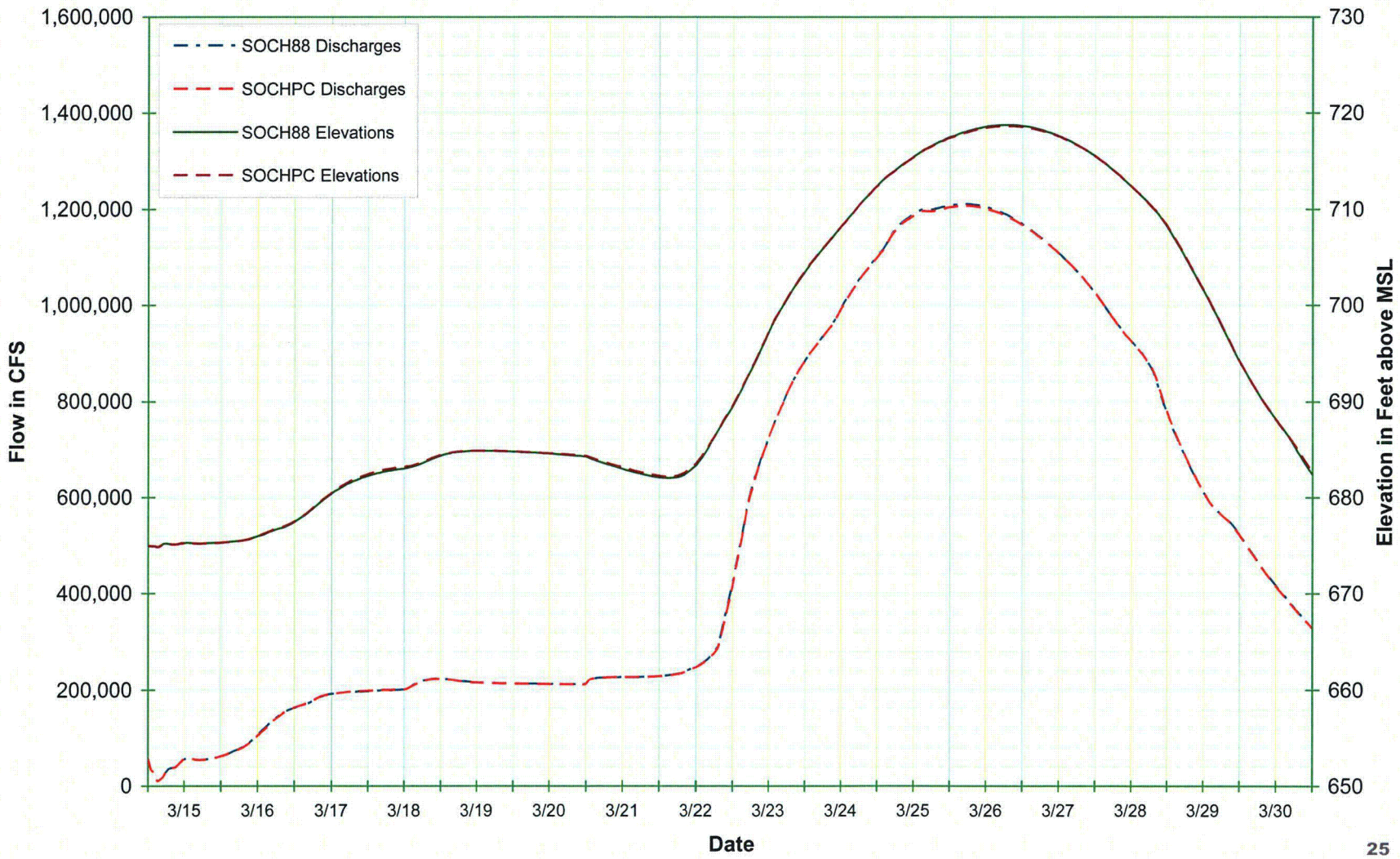
Updated Figure



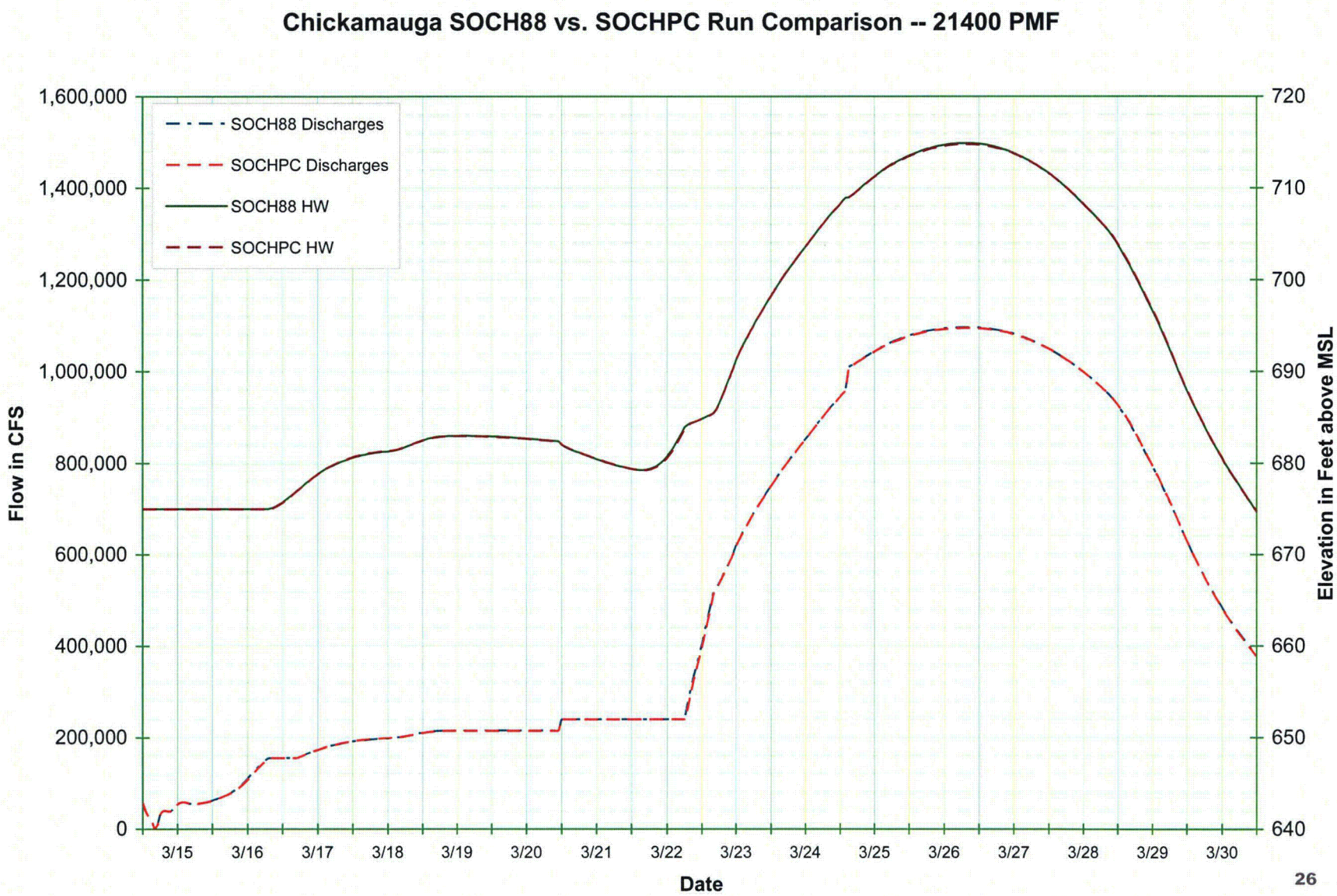
SOCH88 vs. SOCHPC Results



SOCH88 vs. SOCHPC Results

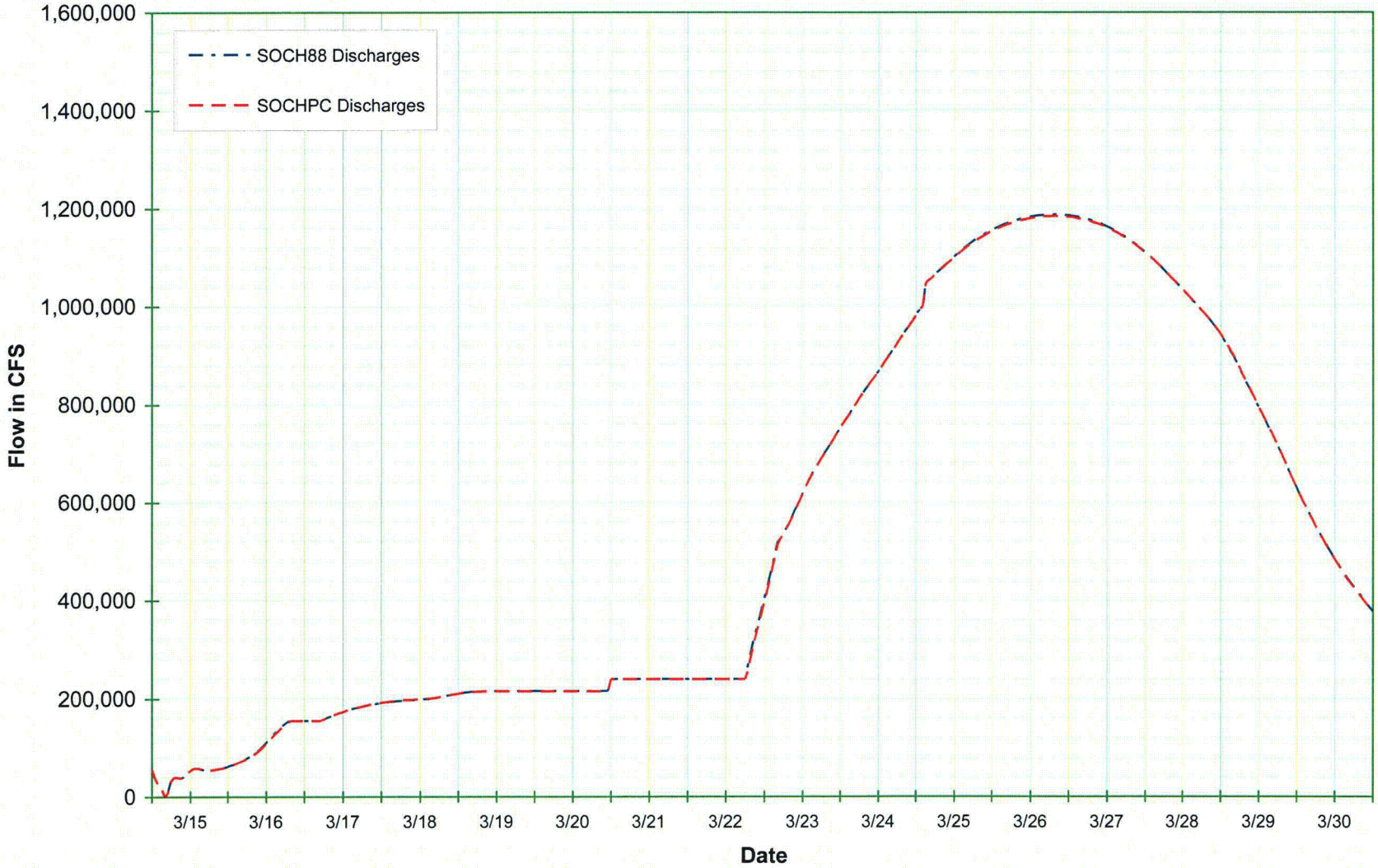


SOCH88 vs. SOCHPC Results



SOCH88 vs. SOCHPC Results

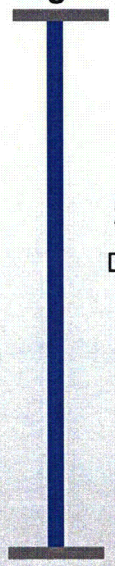
Chickamauga plus Dallas Bay SOCH88 vs. SOCHPC Run Comparison -- 21400 PMF



PMF Run Sequence — Bellefonte Units 1, 2, 3, and 4

(Combine with Chickamauga)

Chickamauga Mile 471.00



23 Cross Sections

DX 11112.00

Nickajack Run Sequence

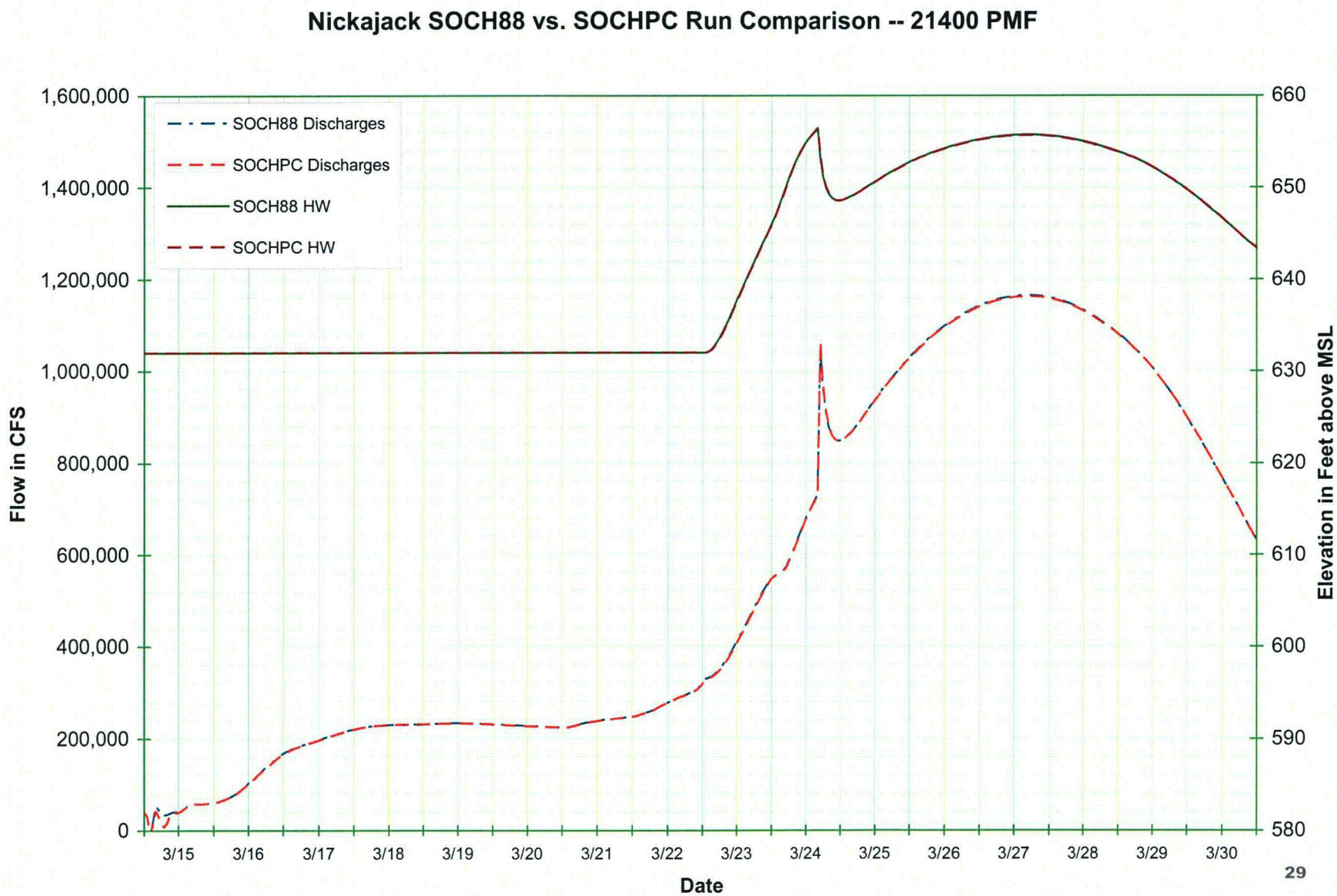
1. Elevation constant
2. Before failure
3. After failure

Nickajack Mile 424.70

(Combine with Guntersville)

Nickajack Reservoir

SOCH88 vs. SOCHPC Results



PMF Run Sequence — Bellefonte Units 1, 2, 3, and 4

See updated Figure

(Combine with Nickajack)

Nickajack Mile 424.70

37 Cross Sections

DX 11102.67

Guntersville Mile 349.00

Guntersville Reservoir

Guntersville Run Sequence

1. Elevation 593 to Q 150k at G
2. Q to 200k cfs and hold at G
3. Hold 225K cfs at G
4. Filling curve to gate top at G
5. Hold 591 at G
6. Hold 320k cfs at G
7. Rating curve to free spillway at G
8. Before failure rating curve at G
9. Orifice flow rating curve at G
10. After failure rating curve at G

PMF Run Sequence — Bellefonte Units 1, 2, 3, and 4

Updated Figure

(Combine with Nickajack)

Nickajack Mile 424.70

37 Cross Sections

DX 11102.67

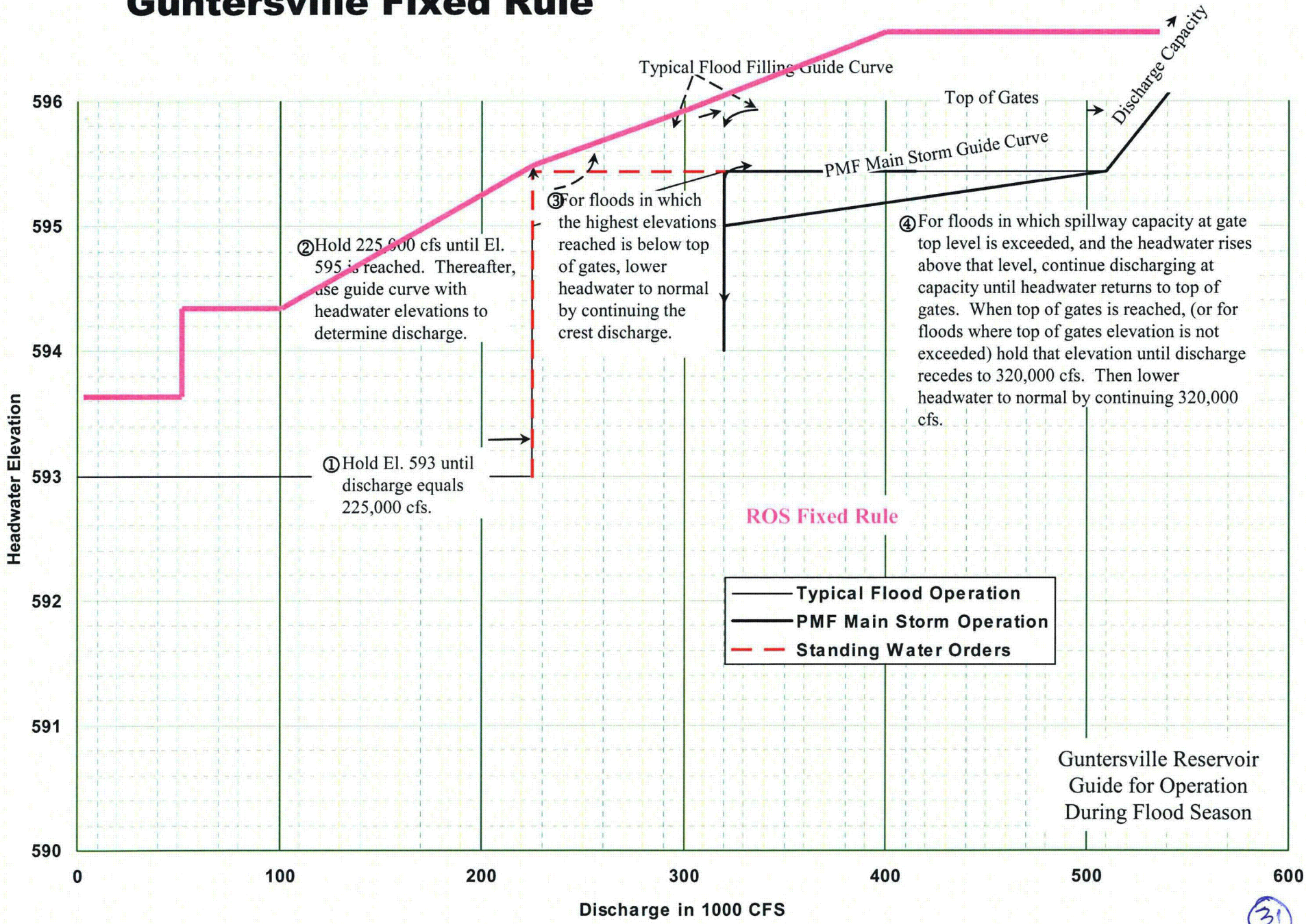
Guntersville Mile 349.00

Guntersville Run Sequence

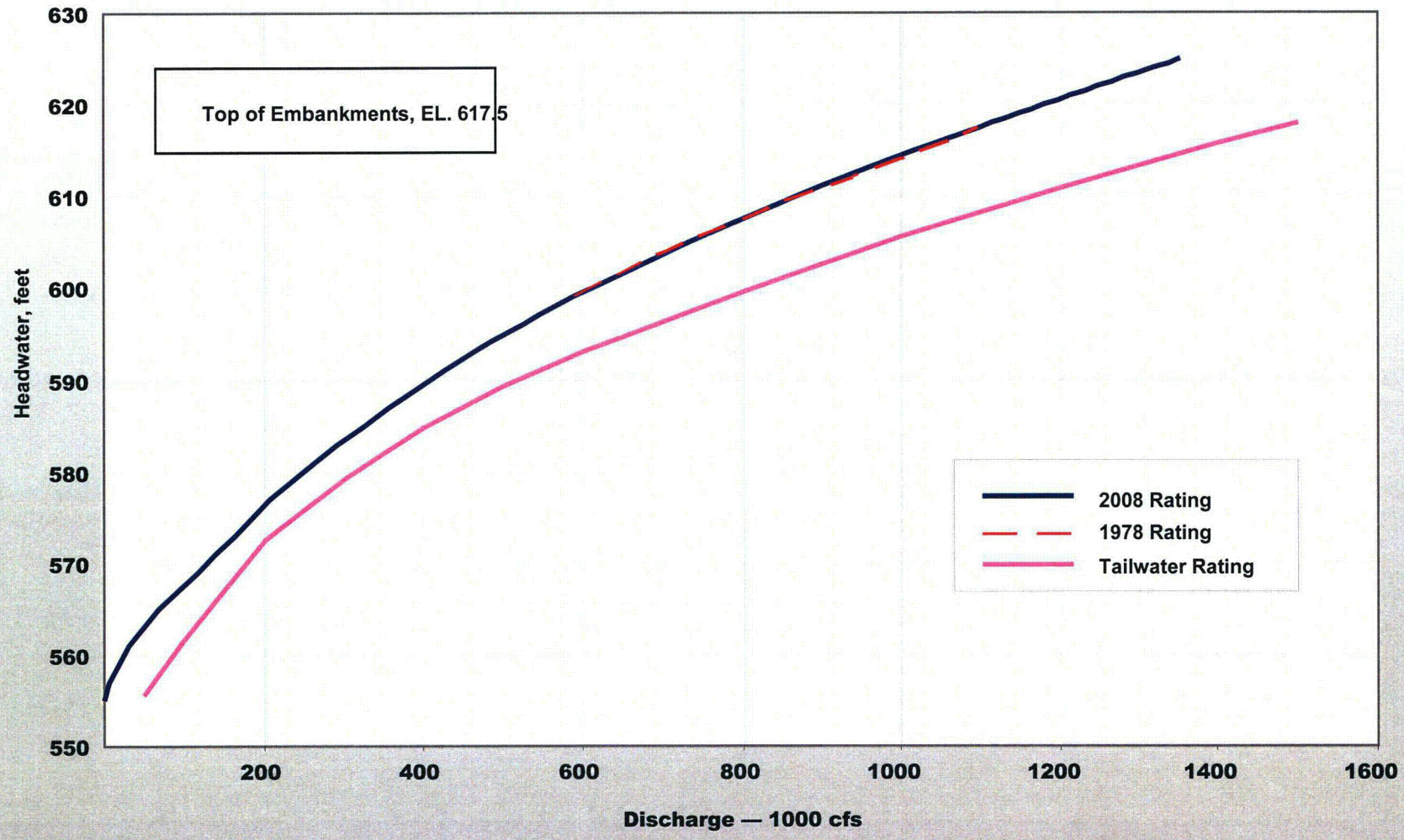
1. Elevation 593 to Q 225k at G
2.. Hold 225K cfs at G
3. Filling curve to gate top or crest Q at G
4. Hold 320k cfs at G
5. Rating curve to free spillway at G
6. Before failure rating curve at G

Guntersville Reservoir

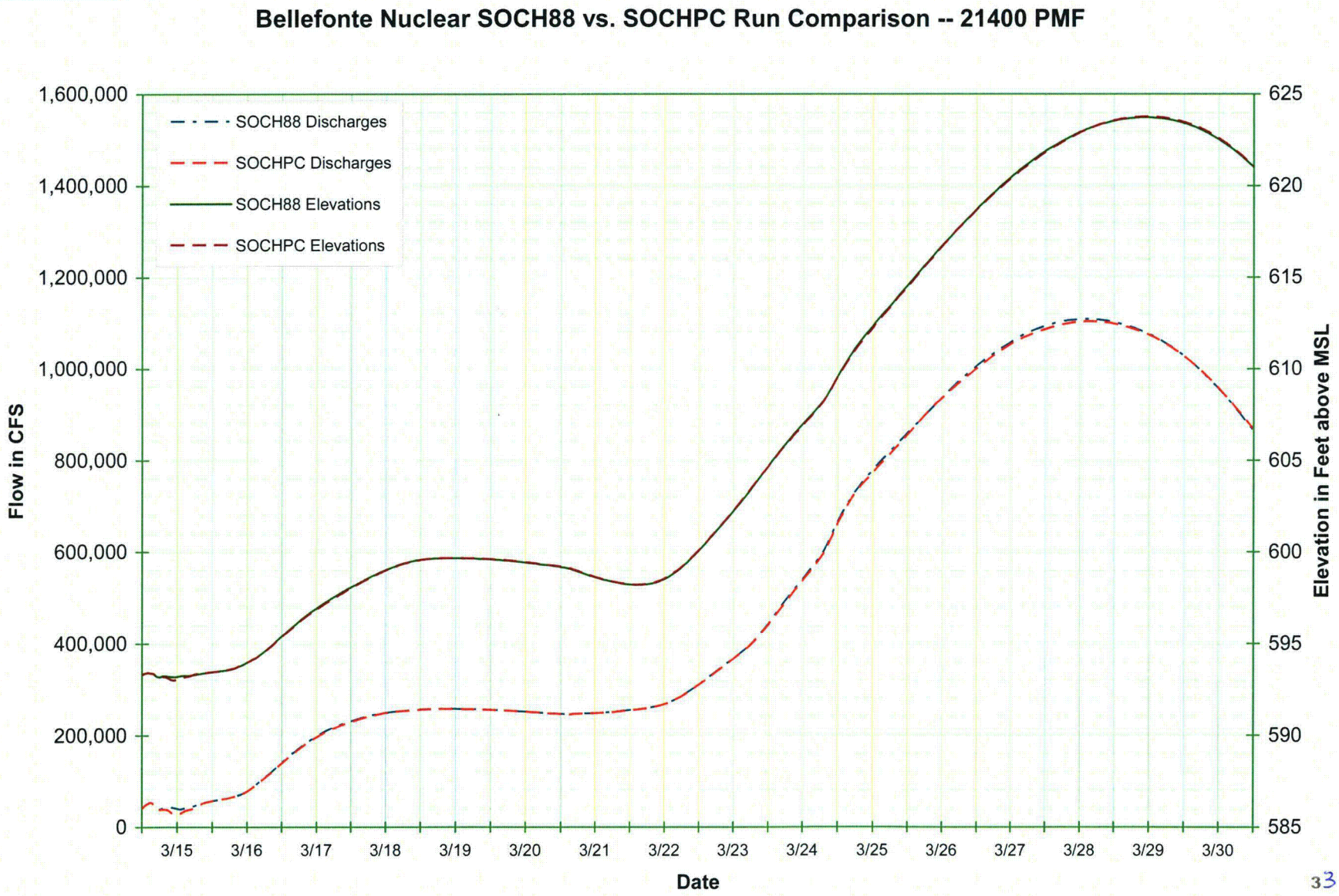
Guntersville Fixed Rule



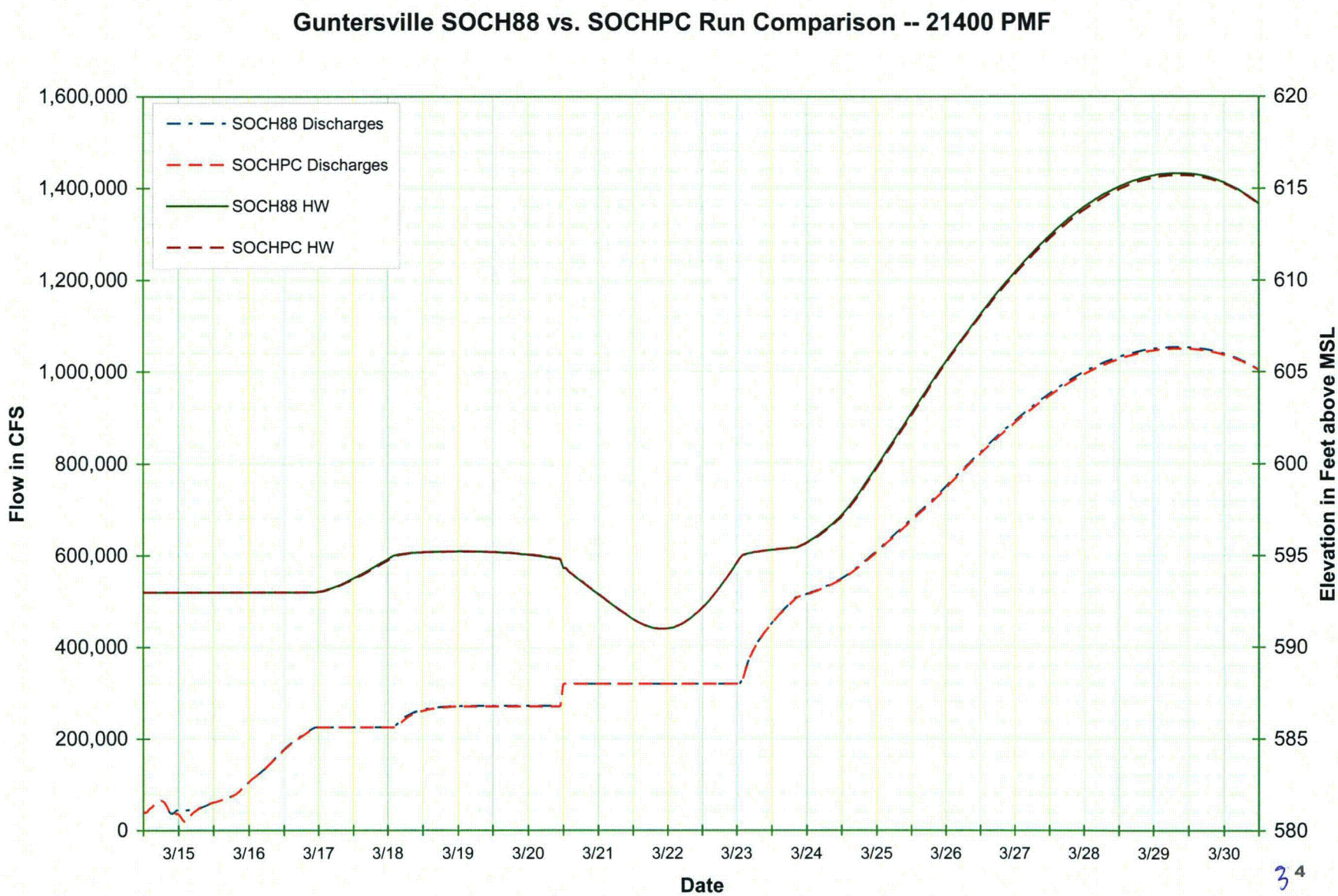
Guntersville Headwater Rating



SOCH88 vs. SOCHPC Results



SOCH88 vs. SOCHPC Results



TVA Stream Course Model

That's All Folks!!!!!!