

# **Corps of Engineers – SWD Methods in RiverWare for Alternative Reservoir and System Operation For Dam Safety Concerns**

**John Daylor, P.E.  
Corps of Engineers, Tulsa District**

**Contributors:**

**Sarah Harris, Corps of Engineers, Tulsa**

**Greg Estep, Corps of Engineers, Tulsa**

**David Neumann & CADSWES Staff**

**CoE National Dam Safety Team:  
Some problems identified with major  
damage centers downstream.**

**Currently, Keystone Reservoir is one of  
several reservoirs where lower 30% flood  
storage evacuation is delayed to provide scour  
and dredging in navigation channel.**

**Investigation requested for early screening  
process:**

**Operate Keystone Reservoir without delaying  
flood storage release.**

# Keystone Dam

**18 Tainter Gates  
and 9 Sluices**

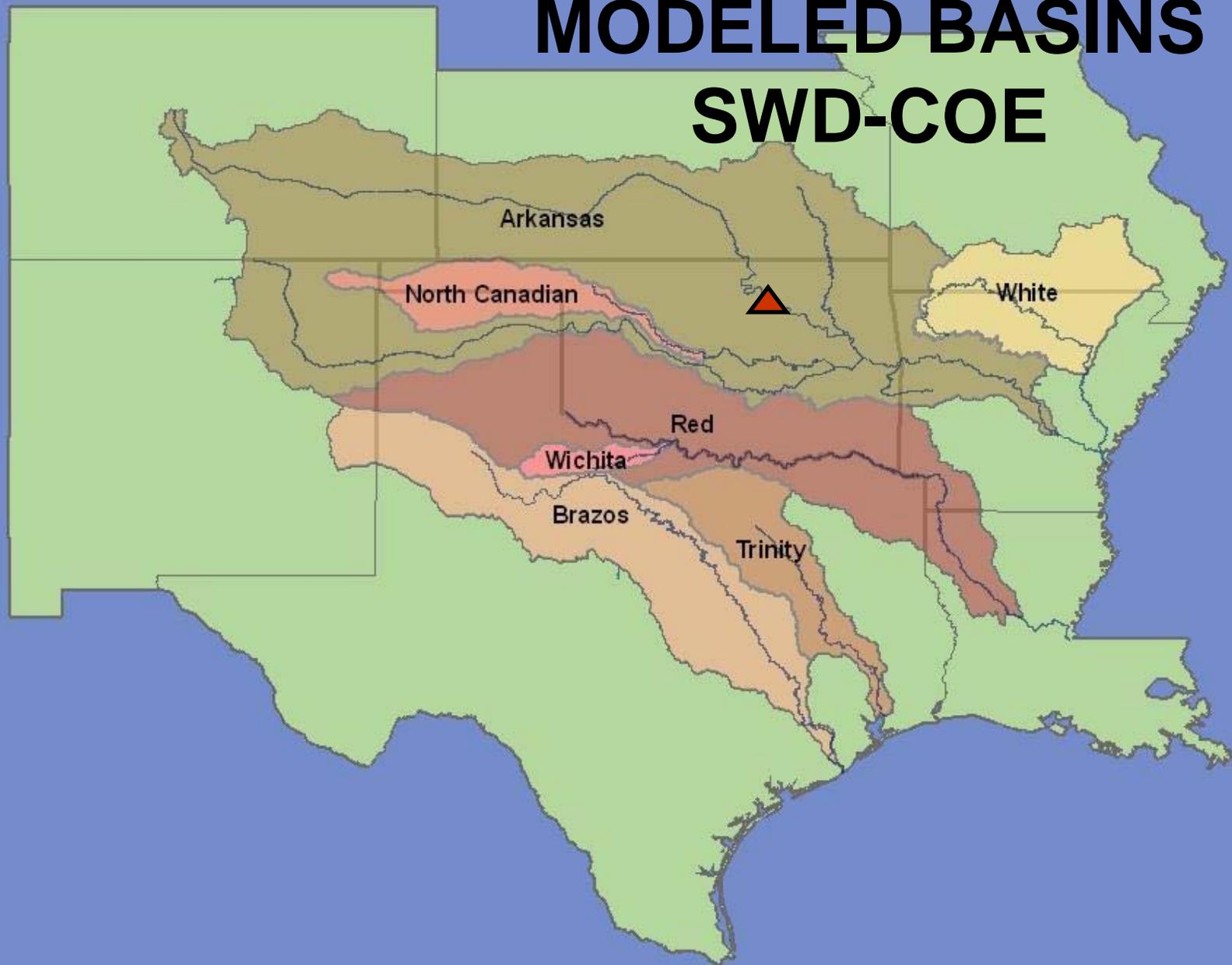
**HYDROPOWER:  
2 Units @ 35,000 KW**



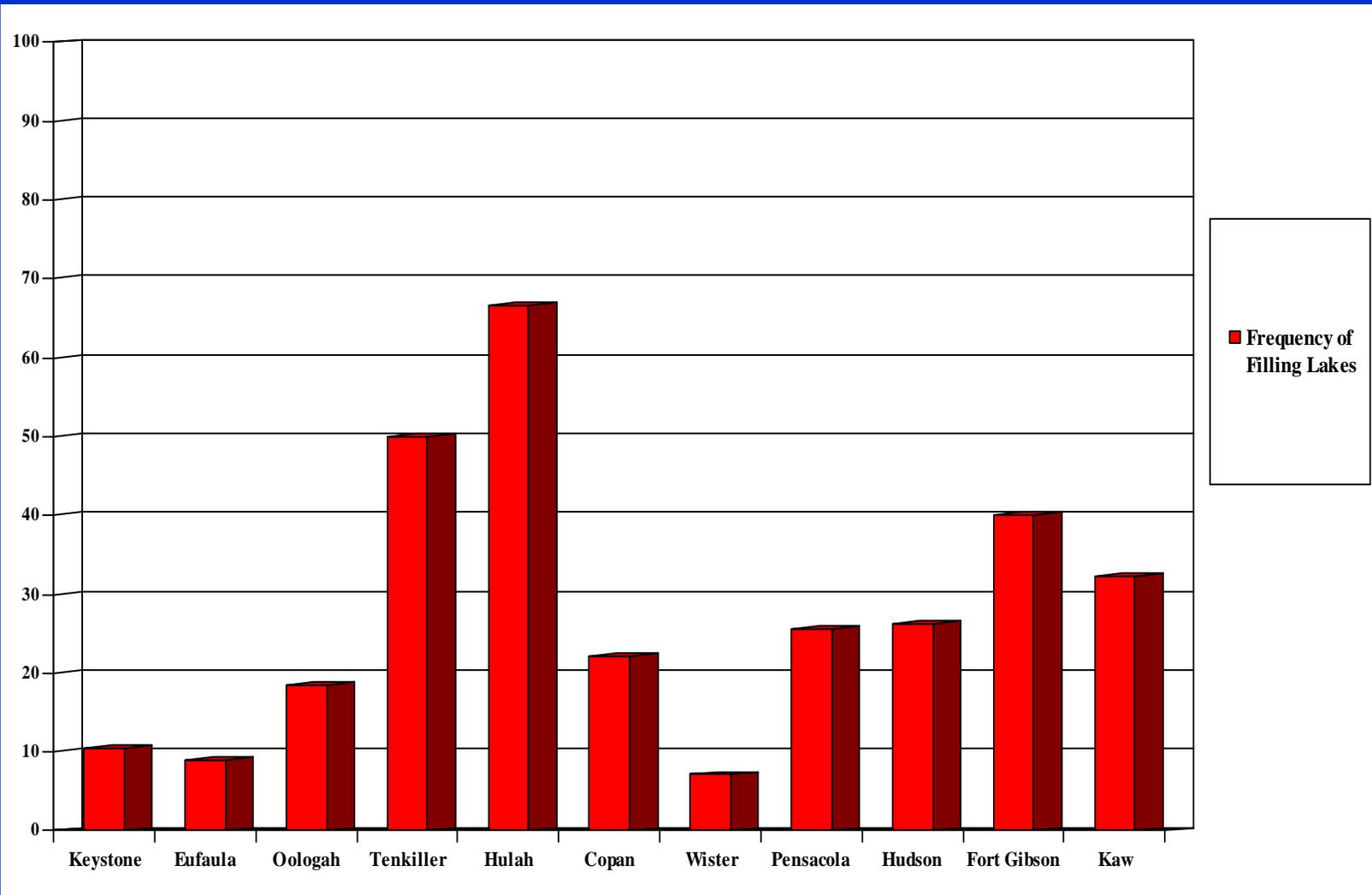
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# MODELED BASINS SWD-COE



# FREQUENCY OF FILLING LAKES



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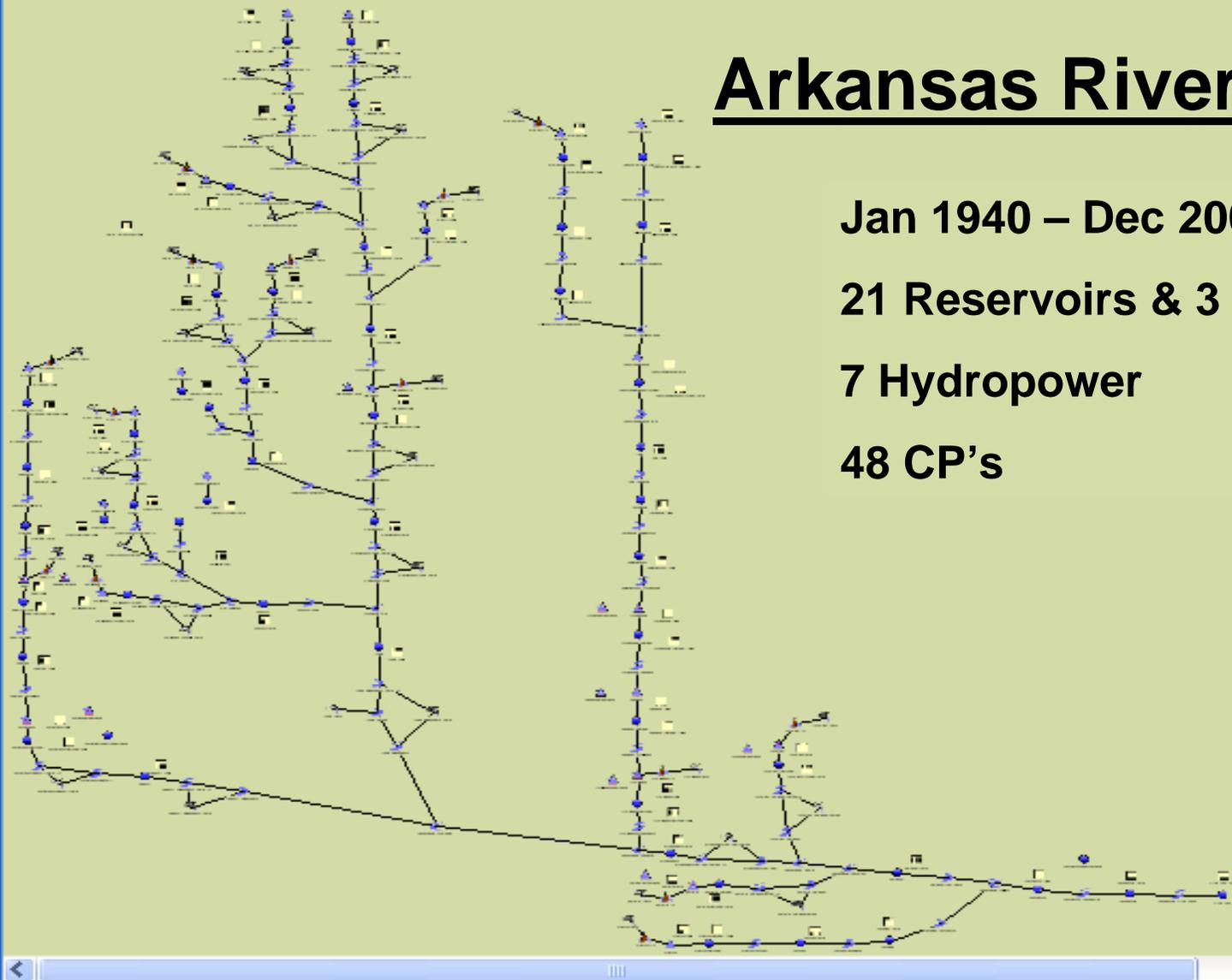
# Arkansas River System

Jan 1940 – Dec 2000

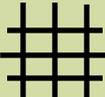
21 Reservoirs & 3 PIng Res.

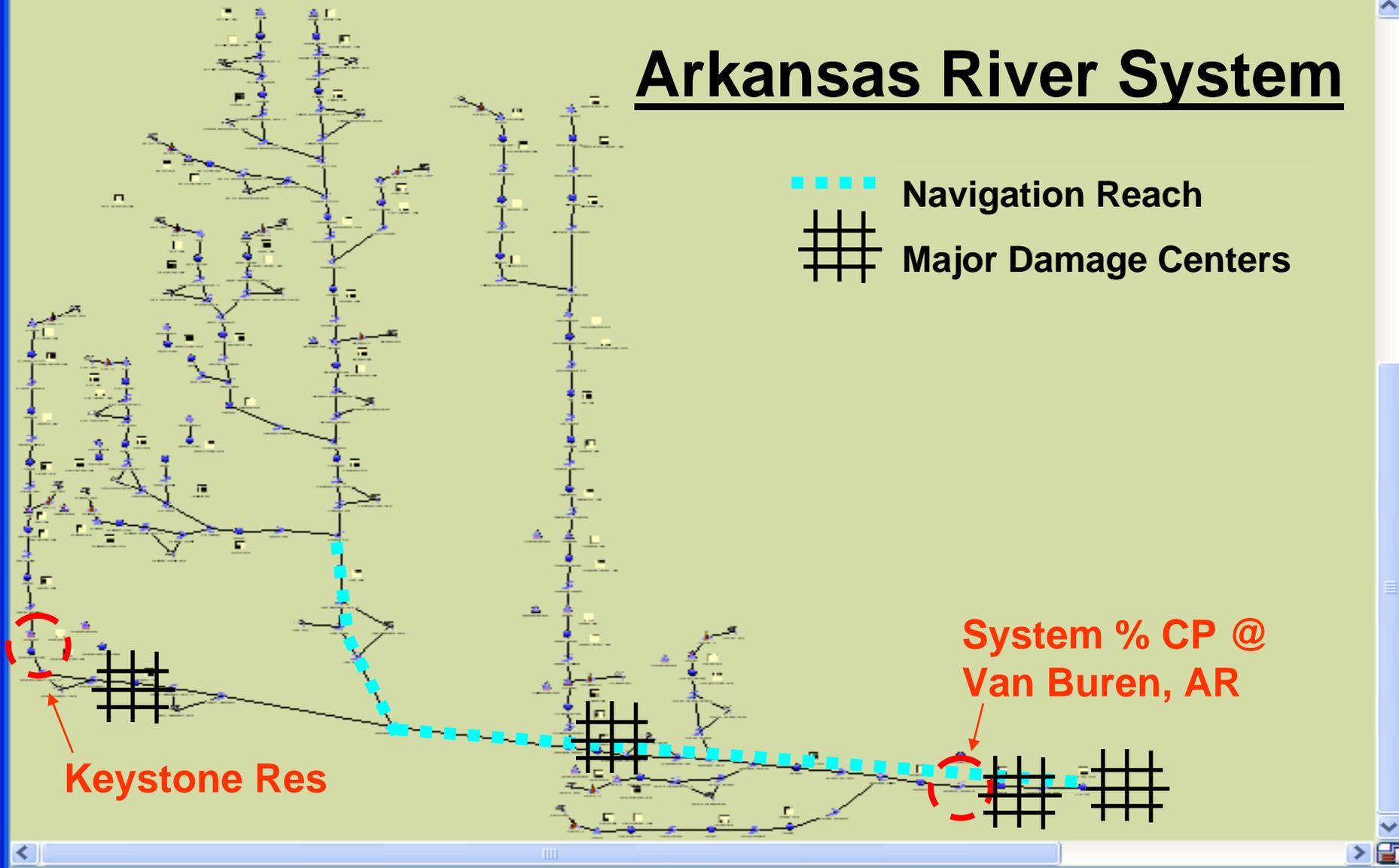
7 Hydropower

48 CP's



# Arkansas River System

-  Navigation Reach
-  Major Damage Centers



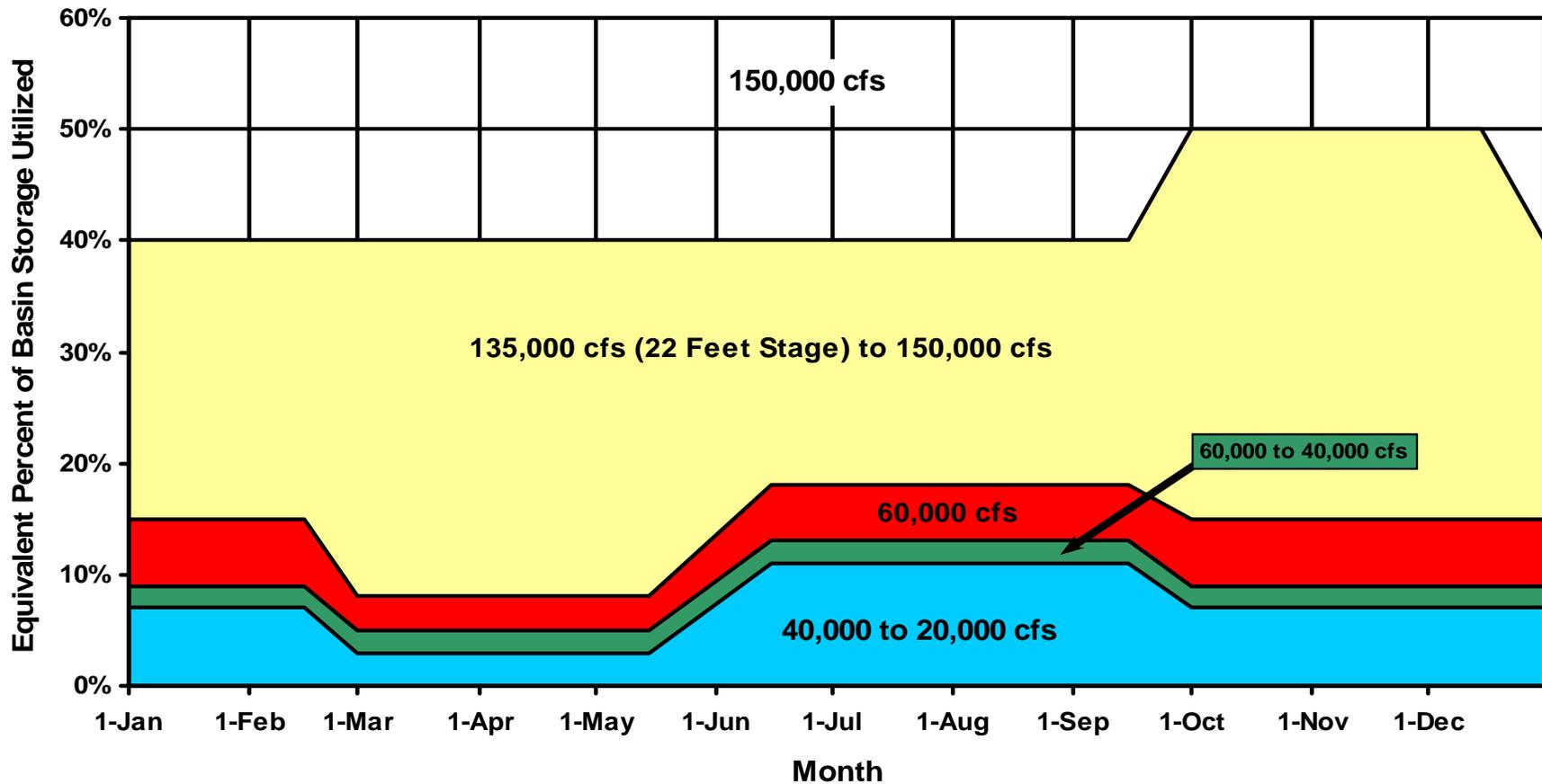
# STUDY APPROACH WITH RIVERWARE:

- **Rules Simulation**
- **CoE – SWD Flood Control Methods**
- **Jan 1940 – Dec 2000 Daily Timestep**
- **Base Condition Run**
- **Alternative Run**
- **Post Processing for Evaluation**

# CoE-SWD METHODS IN RIVERWARE:

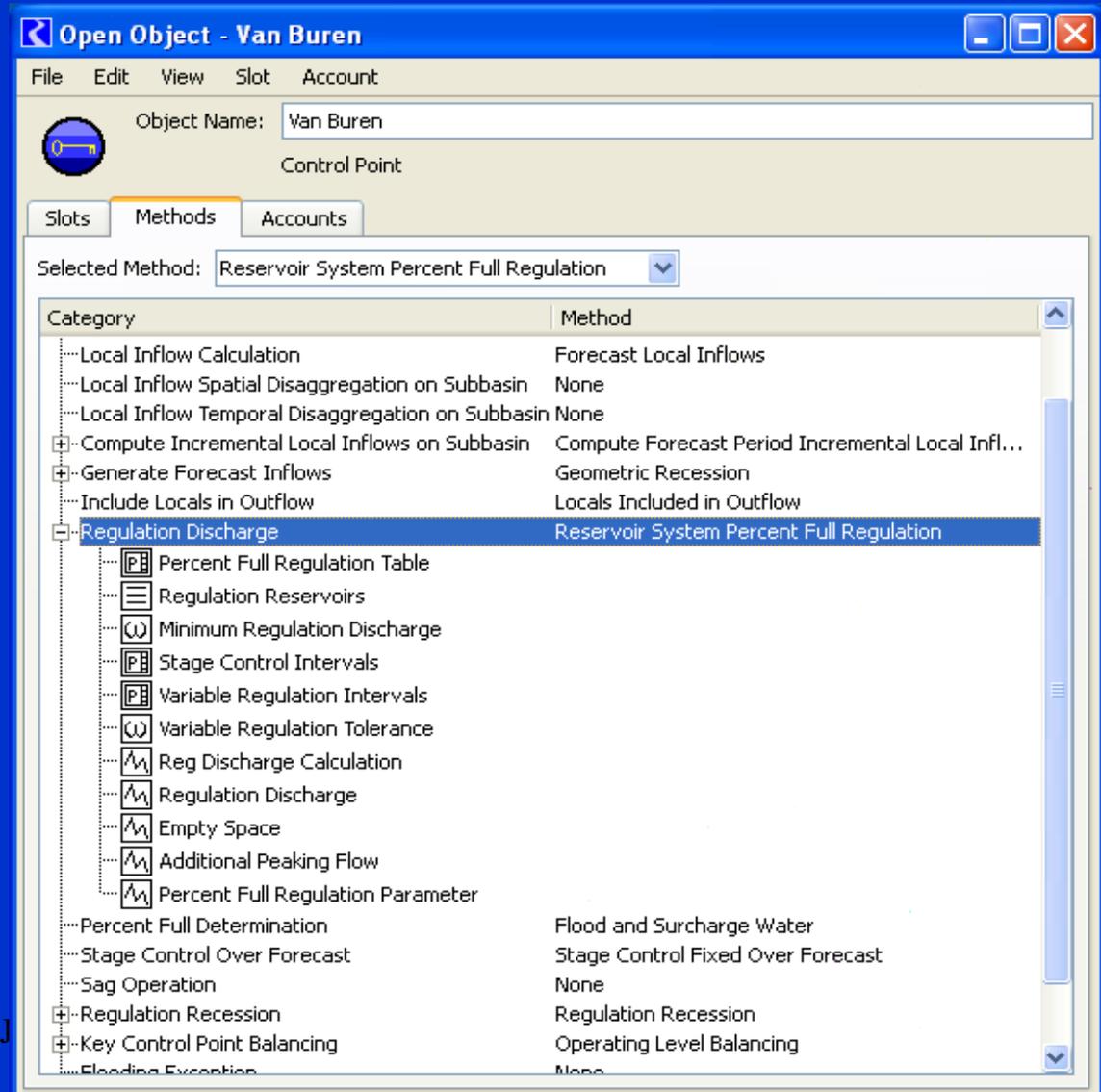
- **Local Flow**
- **Surcharge Routine**
- **Control Point Determination**
- **Reservoir Release Determination**

# Van Buren Control Point:



Van Buren Guide Curve

# CoE SWD Method: Control Point Determination



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# CoE SWD Method: Control Point Determination

The image shows two overlapping software windows from a water resources modeling application.

**Van Buren.Key Control Point Reserv...** (Left Window):

- Menu: File, Edit
- Toolbar: Includes icons for list, edit, undo, redo, and delete.
- Icon: A blue circle with a white key.
- Text: Van Buren.Key Control Point Reservoirs
- Section: Reservoir List
- List:
 

1	▲	Pensacola
2	▲	Hudson
3	▲	Ft Gibson
4	▲	Oologah
5	▲	Hulah
6	▲	Copan
7	▲	Birch
8	▲	Skiatook
9	▲	Kaw
10	▲	Keystone
11	▲	Tenkiller
12	▲	Eufaula
13	▲	Wister
- Buttons: OK, Apply, Reset, Cancel

**Open Object - Van Buren** (Right Window):

- Menu: File, Edit, View, Slot, Account
- Object Name: Van Buren
- Control Point: (Empty)
- Methods: Accounts
- Method: Reservoir System Percent Full Regulation
- Table:
 

Method	Method
Forecast Local Inflows	Forecast Local Inflows
None	None
None	None
Compute Forecast Period Incremental Local Inflows	Compute Forecast Period Incremental Local Inflows
Geometric Recession	Geometric Recession
Locals Included in Outflow	Locals Included in Outflow
Reservoir System Percent Full Regulation	Reservoir System Percent Full Regulation
Percent Full Regulation Table	Percent Full Regulation Table
Regulation Reservoirs	Regulation Reservoirs
Minimum Regulation Discharge	Minimum Regulation Discharge
Stage Control Intervals	Stage Control Intervals
Variable Regulation Intervals	Variable Regulation Intervals
Variable Regulation Tolerance	Variable Regulation Tolerance
Reg Discharge Calculation	Reg Discharge Calculation
Regulation Discharge	Regulation Discharge
Empty Space	Empty Space
Additional Peaking Flow	Additional Peaking Flow
Percent Full Regulation Parameter	Percent Full Regulation Parameter
Flood and Surge Water	Flood and Surge Water
Stage Control Fixed Over Forecast	Stage Control Fixed Over Forecast
None	None
Regulation Recession	Regulation Recession
Operating Level Balancing	Operating Level Balancing
None	None

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# CoE SWD Method: Control Point Determination

**Open Object - Van Buren**

**Van Buren.Percent Full Regulation Table**

File Edit Row Column View Adjust

Value: 0.09 NONE

	20000.00 cfs	40000.00 cfs	60000.00 cfs	60000.01 cfs	150000.00 cfs	150000.00 cfs	150000.00 cfs	150000.00 cfs	
	---	---	---	---	---	---	---	---	
	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	
0:00 Jan 2	0.00	0.07	0.09	0.15	0.16	0.40	0.40	1.00	
<b>0:00 Feb 16</b>	0.00	0.07	<b>0.09</b>	0.15	0.16	0.40	0.40	1.00	
0:00 Mar 2	0.00	0.03	0.05	0.08	0.09	0.40	0.40	1.00	
0:00 May 16	0.00	0.03	0.05	0.08	0.09	0.40	0.40	1.00	
0:00 Jun 16	0.00	0.11	0.13	0.18	0.19	0.40	0.40	1.00	
0:00 Sep 16	0.00	0.11	0.13	0.18	0.19	0.40	0.40	1.00	
0:00 Oct 2	0.00	0.07	0.09	0.15	0.16	0.50	0.50	1.00	
0:00 Nov 2	0.00	0.07	0.09	0.15	0.16	0.50	0.50	1.00	
0:00 Dec 2	0.00	0.07	0.09	0.15	0.16	0.50	0.50	1.00	
0:00 Dec 16	0.00	0.07	0.09	0.15	0.16	0.40	0.40	1.00	

Interpolate  Lookup

Annual Period, Irregular Interval

**Van Buren.Key**

File Edit

Reservoir List

- 1 Pensacola
- 2 Hudson
- 3 Ft Gibson
- 4 Oologah
- 5 Hulah
- 6 Copan
- 7 Birch
- 8 Skiatook
- 9 Kaw
- 10 Keystone
- 11 Tenkiller
- 12 Eufaula
- 13 Wister

OK

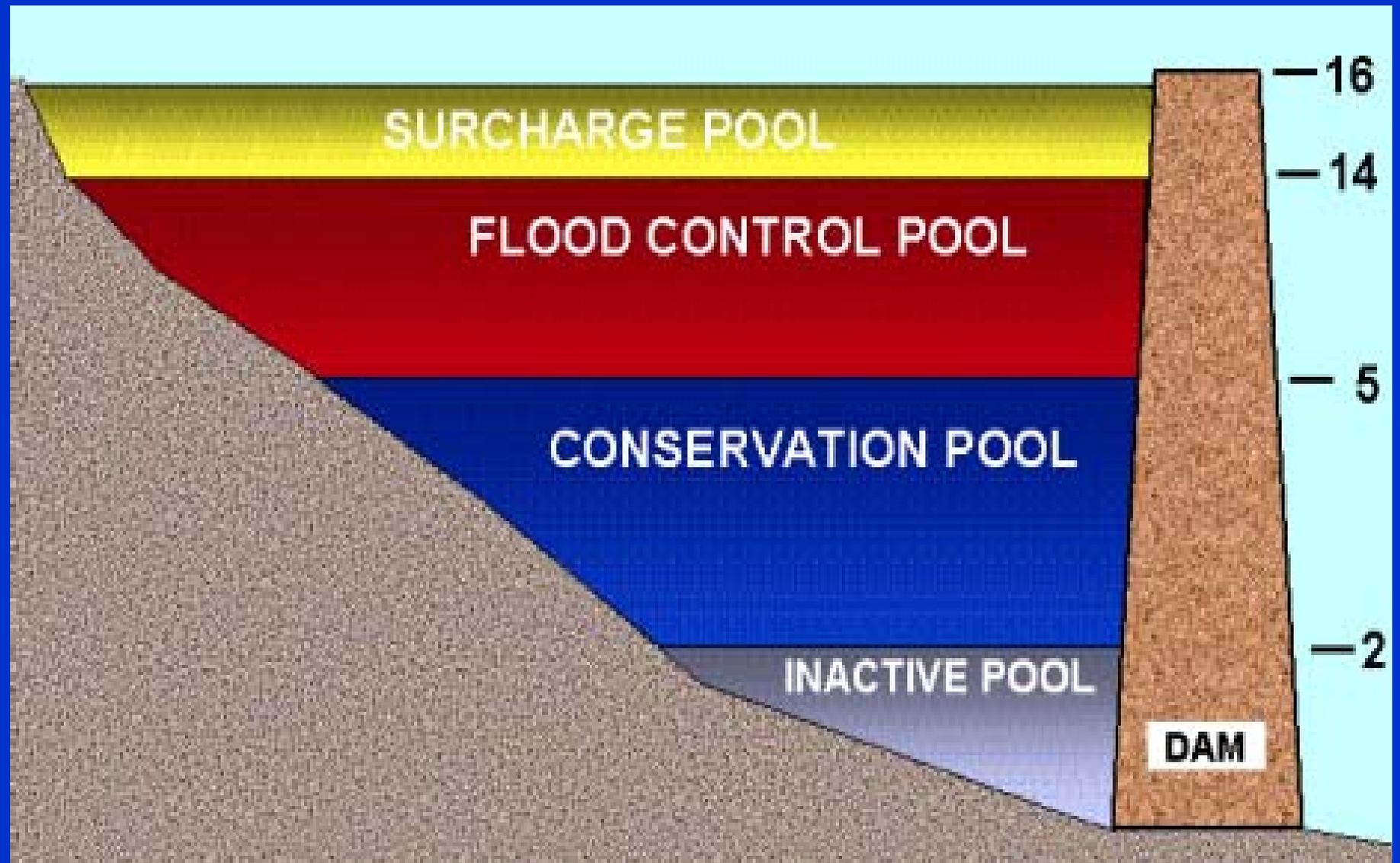
Sag Operation None

Regulation Recession Regulation Recession

Key Control Point Balancing Operating Level Balancing

Flooding Exception None

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**USACE storage divisions and balance levels**

Open Object - KeysExistingCond

Object Name: KeysExistingCond

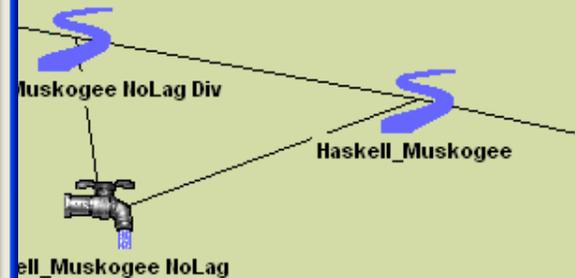
Level Power Reservoir Object

Slots Methods Accounts

December 31, 1939

Slot Name	Value	Units	
Maximum Release Variation	3000.00	crs/day	
Minimum Mandatory Release	NaN	cfs	[I]
Minimum Power Elevation			[I]
Monthly Load	NaN	GWH	[I]
Net Head vs Generator Capacity			[I]
Net Head vs Plant Efficiency			[I]
Off Peak Spill	NaN	cfs	[I]
Operating Head	NaN	ft	[I]
Operating Level	5.00	NONE	[I]
Operating Level Table		ft	[I]
Operation Factor	NaN	decimal	[I]
Outflow	200.00	cfs	[I]
Peak Release	NaN	cfs	[I]
Peak Spill	NaN	cfs	[I]
Peak Time	NaN	hour	[I]
Period of Perfect Knowledge	1.00	NONE	[I]
Pool Elevation	723.00	ft	[I]
Power	NaN	MW	[I]
Precipitation Rate	0.0000	in/day	[I]
Precipitation Volume	NaN	acre-ft	[I]
Rating Curves			[I]
Recession Factor	0.50	NONE	[I]
Regulated Spill	NaN	cfs	[I]
Regulated Spill Capacity Fraction	NaN	decimal	[I]

# CoE SWD Flood Control Method:



Simulat...

Objects

- Altoor
- Altoor
- Altoor
- Altoor
- Ameri
- Ameri
- Arkan
- August
- August
- August
- Avant
- Bartle
- Bartle
- Bartle
- Bartle
- Big Hil
- Bio Hil

Open Object - KeysExistingCond

Object Name: KeysExistingCond  
Level Power Reservoir Object

Slots Methods Accounts

December 31, 1939

Slot Name	Value	Units
Maximum Release Variation	3000.00	crsday
Minimum Mandatory Release	NaN	cfs
Minimum Power Elevation		
Monthly Load	NaN	GWH
Net Head vs Generator Capacity		
Net Head vs Plant Efficiency		

# CoE SWD Flood Control Method:

KeysExistingCond.Operating Level Table

Operating Level Table

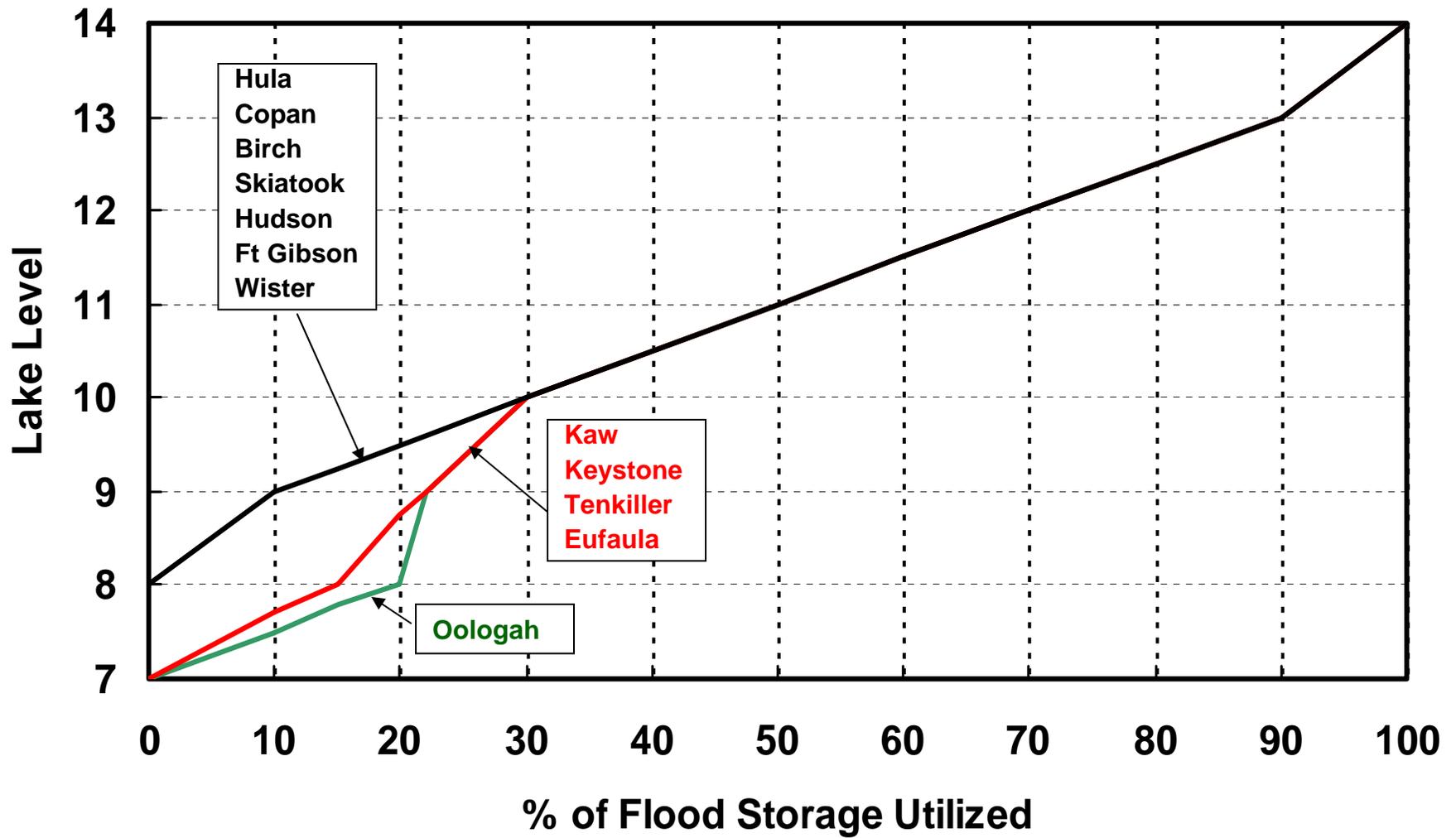
Value: 660 ft

	1.00 NONE ft	2.00 NONE ft	3.00 NONE ft	4.00 NONE ft	5.00 NONE ft	6.00 NONE ft	7.00 NONE ft	8.00 NONE ft	9.00 NONE ft	10.00 NONE ft	11.00 NONE ft	12.00 NONE ft	13.00 NONE ft	14.00 NONE ft	15.00 NONE ft	16.00 NONE ft
0:00 Jan 1	660.00	706.00	706.00	715.40	723.00	723.00	723.00	730.18	732.83	735.61	741.73	747.04	751.78	754.00	757.00	760.00

Interpolate  Lookup

Annual Period, Irregular Interval

# SYSTEM FLOOD STORAGE



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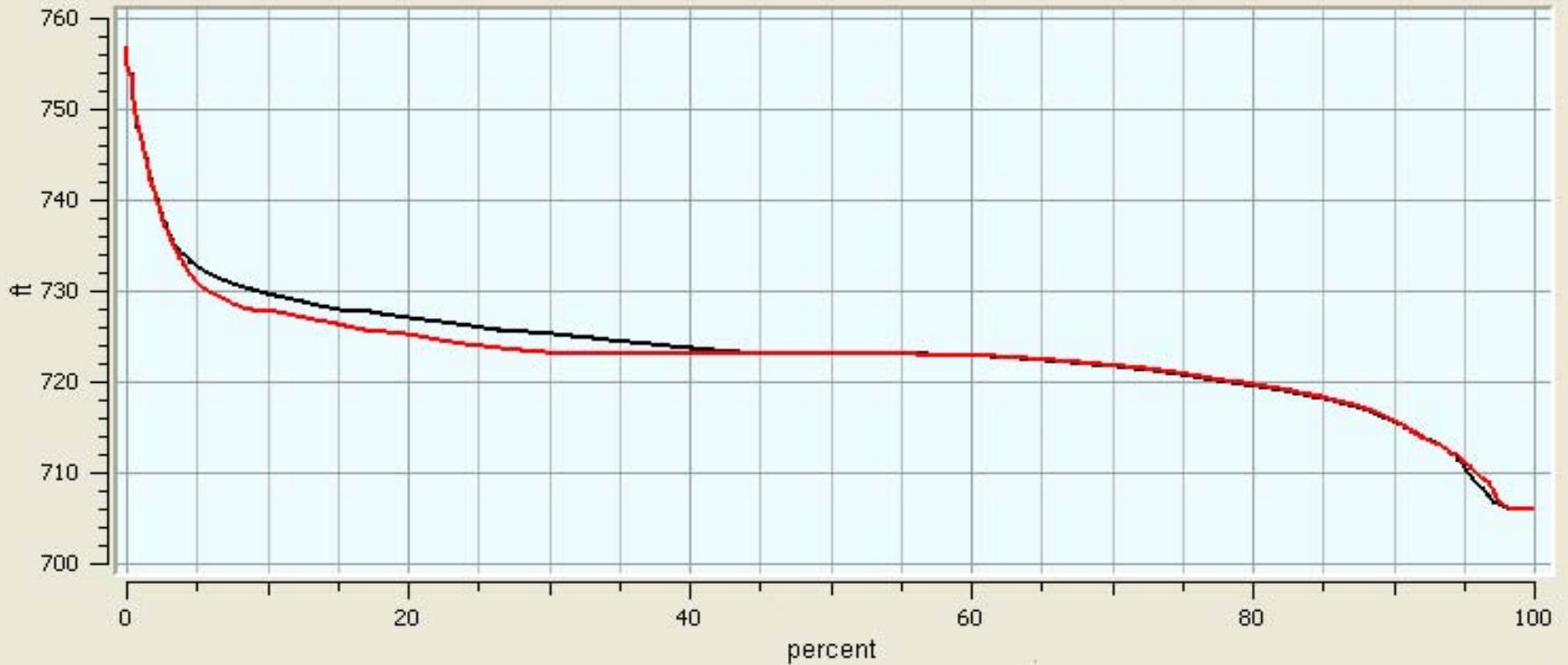


Plot

File Edit Graph Data Window

Dec 31, 1939

### KEYSTONE RESERVOIR: EXISTING & MODIFIED ELEVATION - DURATION



— Keystone Data.Keys\_Elev\_Duration\_Existing (Percent of time equaled or exceeded x Pool Elevation)  
— Keystone Data.Keys\_Elev\_Duration\_Modified(Percent of time equaled or exceeded x Pool Elevation)

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Plot

File Edit Graph Data Window

Dec 31, 1939

### KEYSTONE RESERVOIR: EXISTING & MODIFIED ELEVATION - MAX FREQUENCY



— Keystone Data.KEYS\_Elev\_MaxFreq\_Existing (Max exceedence frequency in percent of years x Pool Elevation)  
— Keystone Data.KEYS\_Elev\_MaxFreq\_Modified(Max exceedence frequency in percent of years x Pool Elevation)

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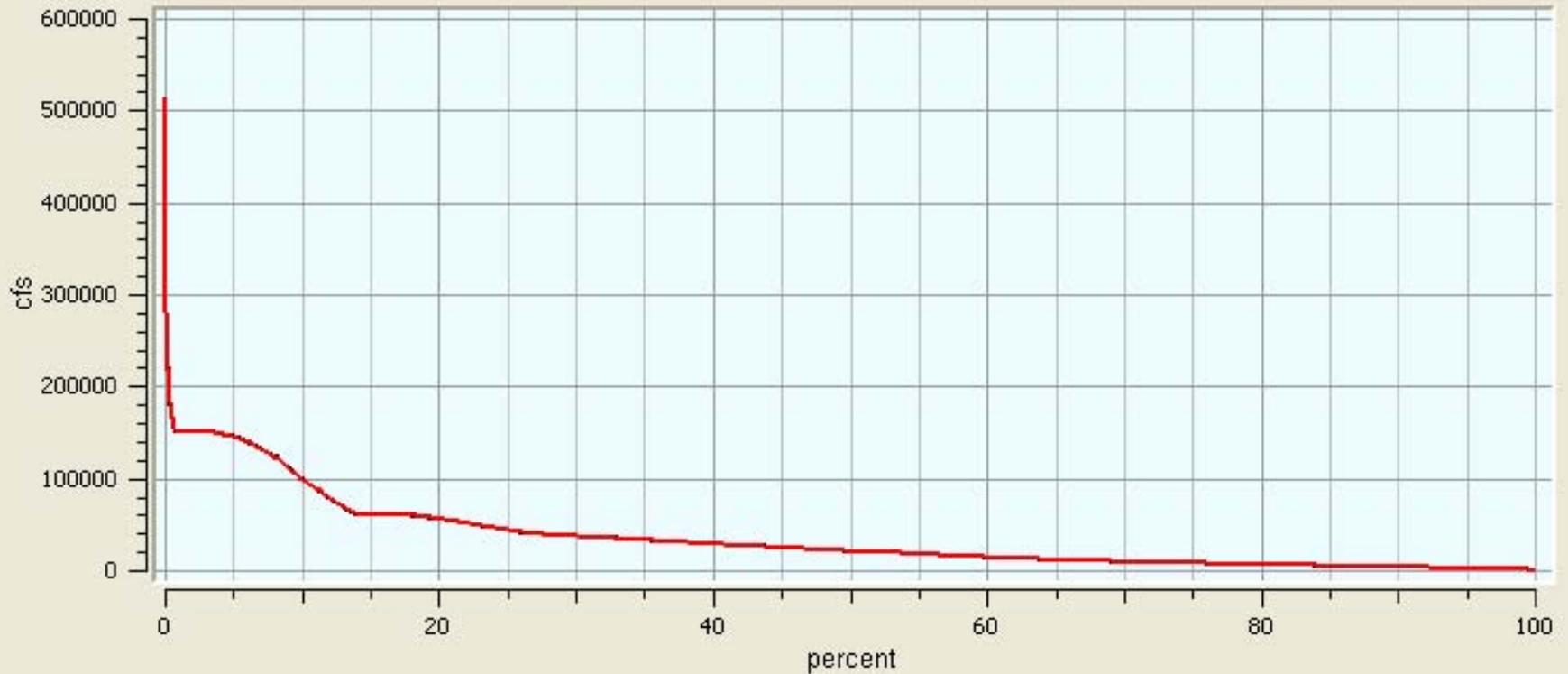
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Plot

File Edit Graph Data Window

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### ARKANSAS RIVER AT VAN BUREN: EXISTING & MODIFIED FLOW - DURATION



— VanBuren\_Data.FlowDurationExistCond (Percent of time equaled or exceeded x Outflow)  
— VanBuren\_Data.FlowDurationModCond(Percent of time equaled or exceeded x Outflow)

X, Y = (2.78207, 611278)

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Plot

File Edit Graph Data Window

Dec 31, 1939

### ARKANSAS RIVER AT VAN BUREN: EXISTING & MODIFIED FLOW - DURATION



— VanBuren\_Data.FlowDurationExistCond (Percent of time equaled or exceeded x Outflow)  
— VanBuren\_Data.FlowDurationModCond(Percent of time equaled or exceeded x Outflow)

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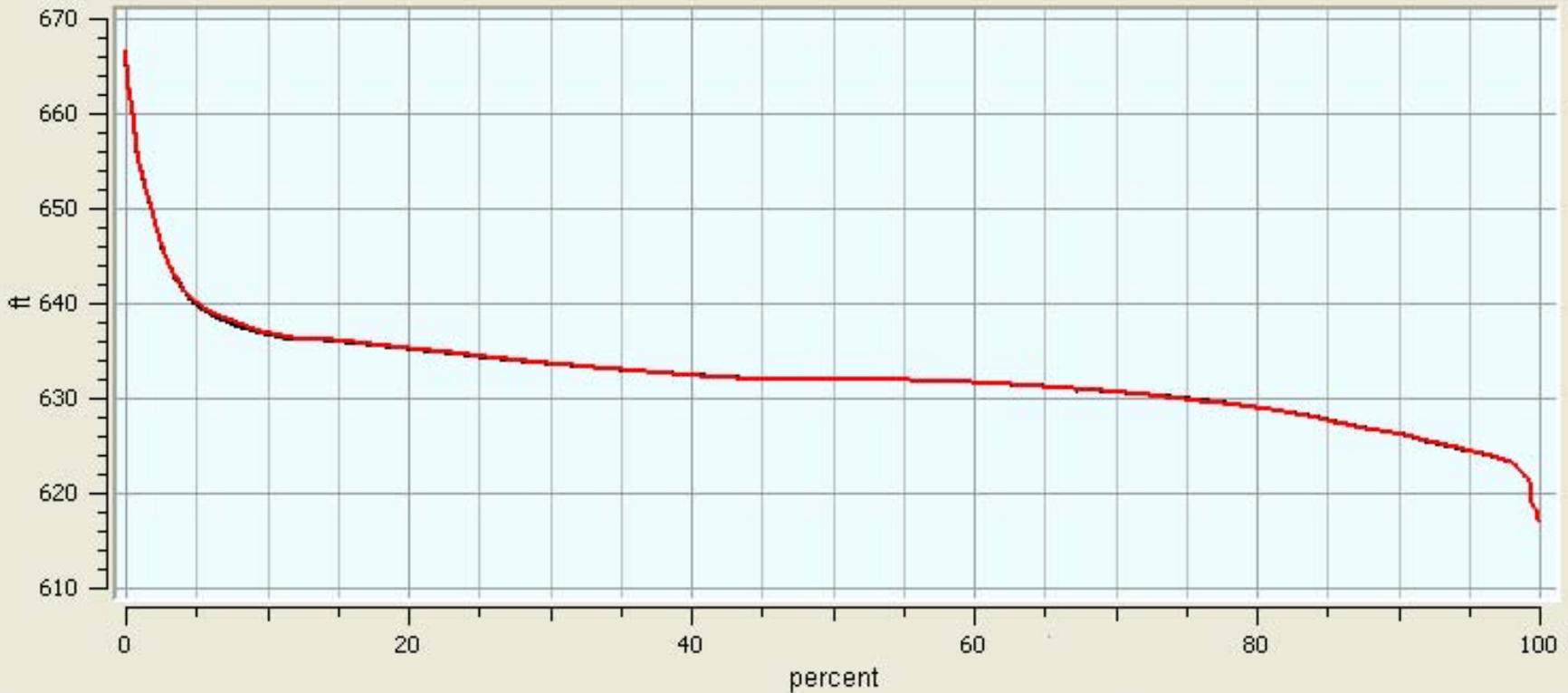
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Plot

File Edit Graph Data Window

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### TENKILLER RESERVOIR: EXISTING & MODIFIED ELEVATION - DURATION



— Tenkiller Data.Tenk\_Elev\_Duration\_Existing (Percent of time equaled or exceeded x Pool Elevation)  
— Tenkiller Data.Tenk\_Elev\_Duration\_Modified(Percent of time equaled or exceeded x Pool Elevation)

X, Y = (16.8421, 671.111)

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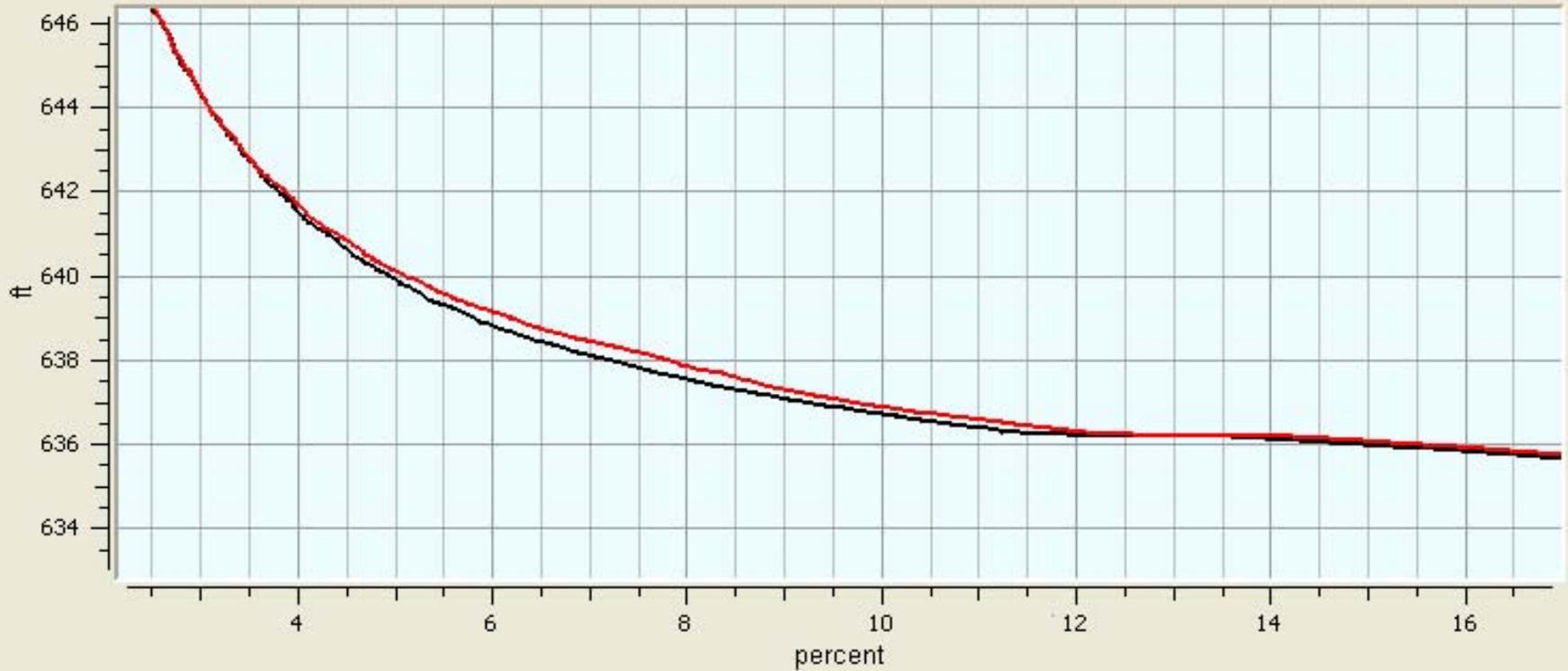
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Plot

File Edit Graph Data Window

Dec 31, 1939

### TENKILLER RESERVOIR: EXISTING & MODIFIED ELEVATION - DURATION



- Tenkiller Data.Tenk\_Elev\_Duration\_Existing (Percent of time equaled or exceeded x Pool Elevation)
- Tenkiller Data.Tenk\_Elev\_Duration\_Modified(Percent of time equaled or exceeded x Pool Elevation)

X, Y = (4.44008, 646.341)

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# TOTAL SYSTEM ENERGY PRODUCED

	Existing Conditions	Modified Conditions	Diff
	GWH's	GWH's	GWH's
Kaw Res.	5,917.18	6,009.69	92.51
<b>Keystone Res.</b>	<b>14,827.04</b>	<b>16,119.19</b>	<b>1,292.15</b>
Pensacola Res.	22,692.86	22,729.03	36.17
Hudson Res.	13,758.00	13,761.49	3.49
Ft Gibson Res.	11,751.22	11,746.45	-4.77
Tenkiller Res.	6,786.76	6,767.51	-19.25
Eufaula Res.	15,921.70	15,928.08	6.38
<b>Sums:</b>	<b>91,654.76</b>	<b>93,061.44</b>	<b>1,406.68</b>

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# Keystone Dam

## Questions?



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