Evaluating the Effects of Changes in Recreation and Electricity Values on Lake Tenkiller Water Levels

Presented by

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OKLAHOMA CLEAN LAKES AND WATERSHEDS
20TH ANNUAL CONFERENCE

Reservoir Management to Maximize Net Benefits

- Reservoir uses/needs may change after construction
- Stakeholders have multiple and possibly conflicting goals
  - Flood Control - Lower levels to contain upstream flood surges
  - Hydropower
    - Releases for power in peak use/price periods
    - High lake levels to increase head over turbines
  - Municipal and Industrial Users
    - Reliable high quality supply of water especially in peak summer months
  - Recreation
    - Desire near normal lake level conditions for aesthetic pleasure and avoidance of mud flats in especially in summer months
  - Downstream uses expect normal flows or releases
- Aging structures may dictate lower levels
- Inflows from upstream are stochastic

Study Area

Tenkiller Ferry Lake in East Central Oklahoma

Completed in 1953

Designated Purpose

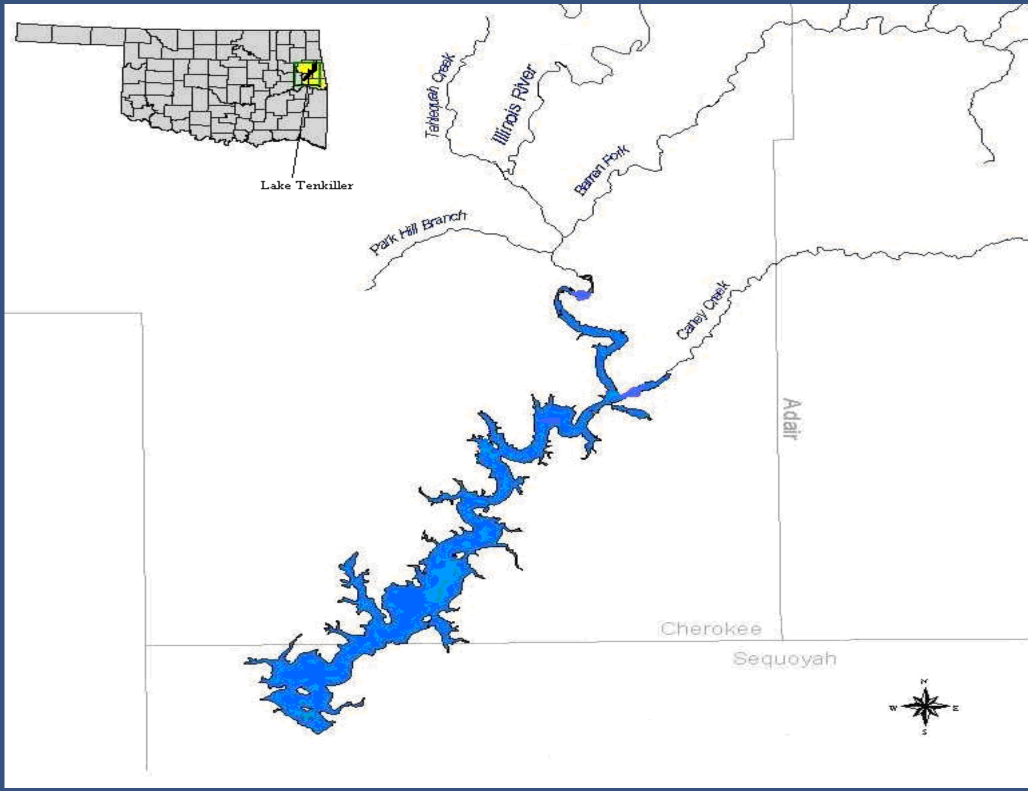
- Flood control
- Hydropower

Lake level: 632 Feet normal pool

Volume: 654,231 Acre Feet

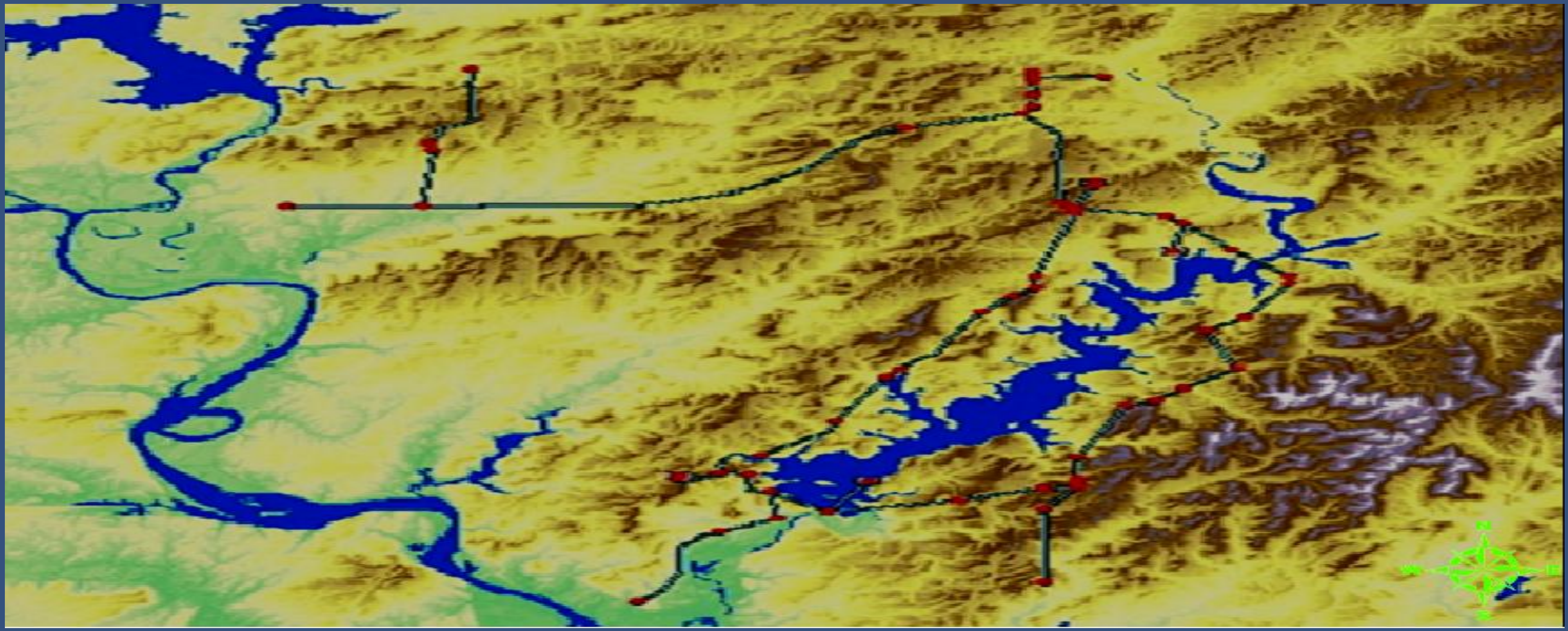
In 2007

- Power Sales $ 2.6 million
- Visitors 2.9 million
- 1.6 million in June -August
  - Increase/year 67,477
  - (2006 to 2007)
- Increasing interest in M&I use

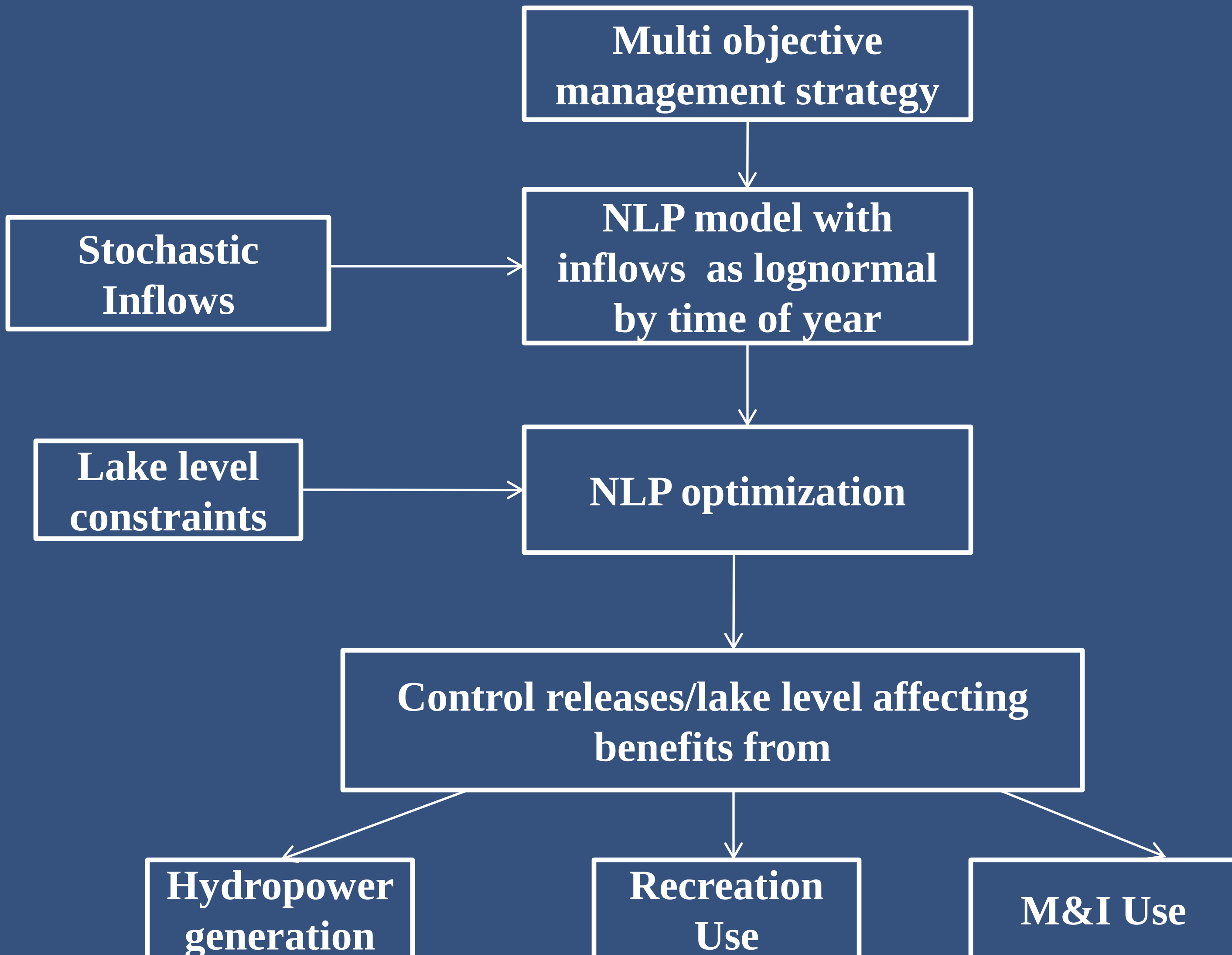


Objective

Determine optimal monthly and/or weekly levels to maximize expected net social benefits derived from recreational, hydropower, M&I uses considering flood control and downstream releases



Multi-objective Stochastic Optimization



Flowchart illustrating the model

Mathematical Model

Maximize: Annual Expected Net Benefits from

Hydropower + Recreation + M&I

$$E(TB) = \sum_{t=1}^{T} \left(E(HB_t) + E(RB_t) + M\&I_t\right)$$

Because of software limitations, Time is monthly for
Jan, Feb, Mar, Apr, May ,
Sep, Oct, Nov, and Dec.
Time is weekly for

June, July, and August .

Subject to

$$V_{t+1} = V_t + E(I_t) - R_t - E_t$$

Volume next period =
Current volume + Inflow (stochastic)
Less Releases, Less Evaporation/seepage

$$V_{min} \leq V_t \leq V_{max}$$

Upper and lower bounds on volume each time period (Flood Control, Dam Safety)

$$R_{min} \leq R_t \leq R_{max}$$

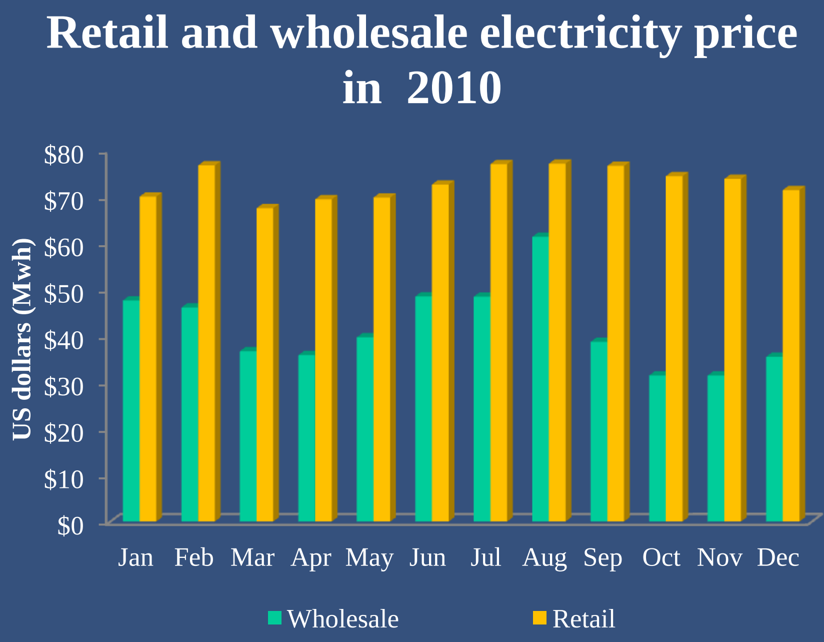
Upper and lower limits on Releases each time period

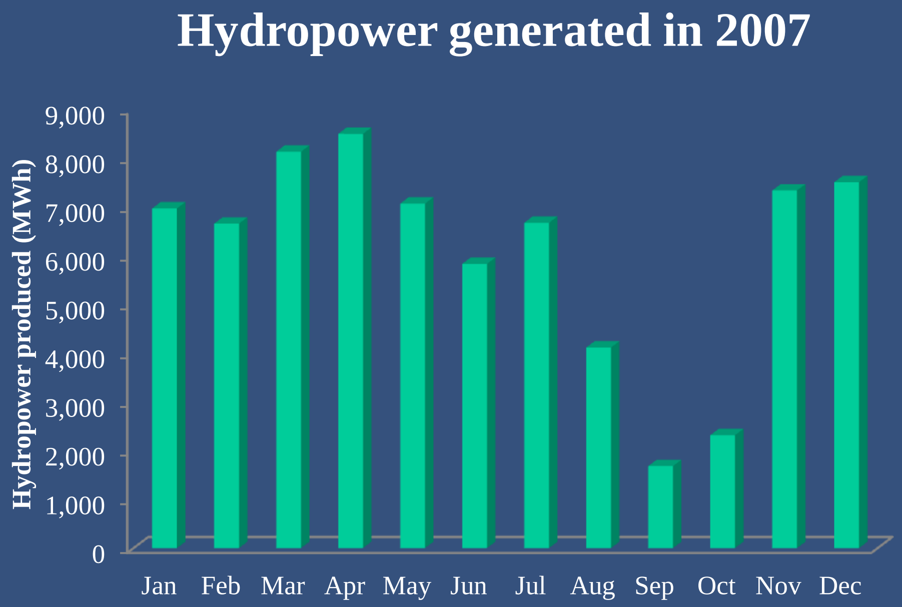
$$V_t, I_t, R_t, E_t \geq 0$$

Hydroelectric power benefits

Hydropower generation equation used
(ReVelle, 1999)

$$Mwh_t = f(Head_t, Qrel_t) \qquad HB_t = P_t * Mwh_t$$





Peak electricity price increased by $0.02/*kwh*

Studies on Values of Lake Recreation

Lake Tenkiller is very Popular

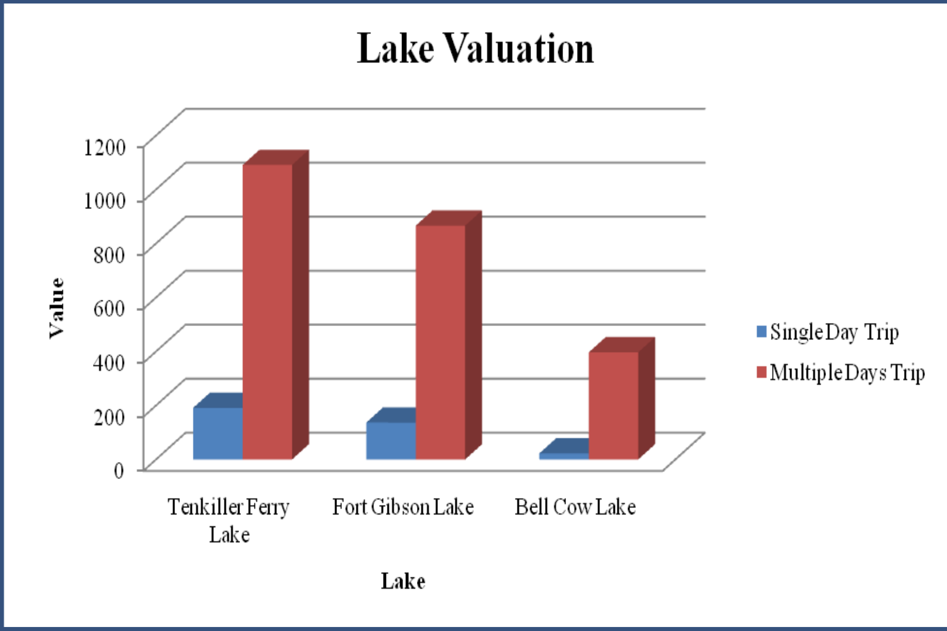
Tenkiller: Warner TCM (1973)
$4.67/day, in 2008 prices= $24/d

Boyer (2008)
TCM study on Oklahoma Lakes

Examples

Lake	WTP/day
Tenkiller	$191
Fort Gibson	$136
Bell Cow	$22

USACE, Economic Guidance Memorandum, value of visitors day $10 by Unit Day Value Method

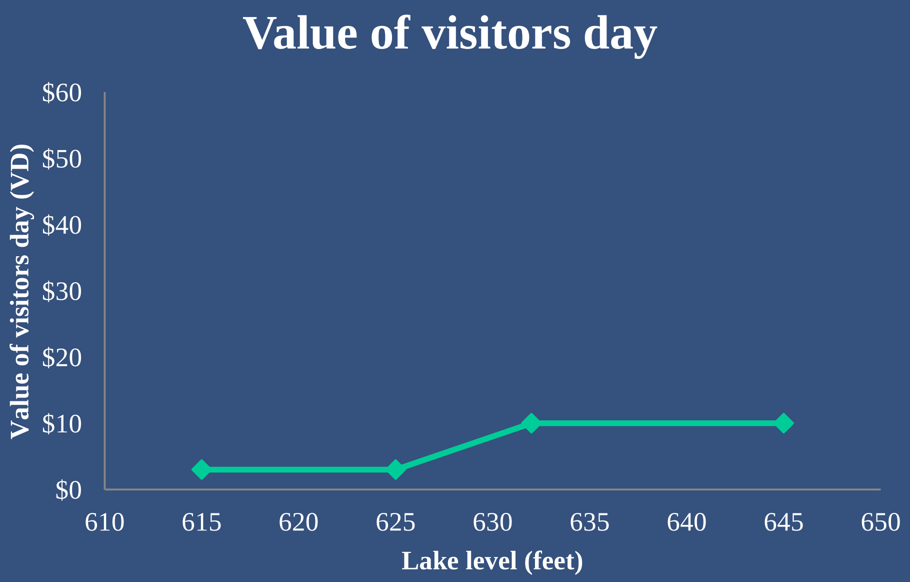


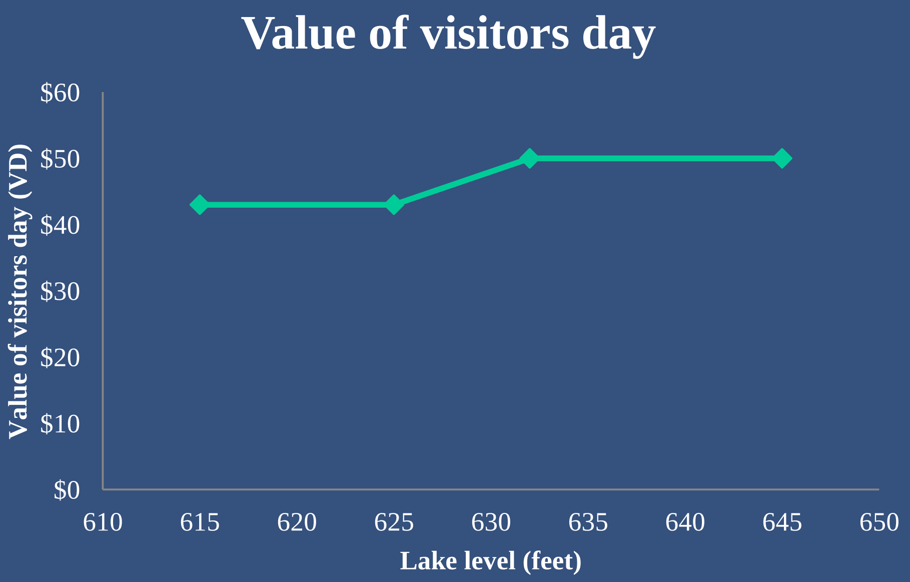
Value of Lake Level on Recreation

Murray et al. (2003) study of TVA Lakes found a WTP to delay September-October drawdown of \$3.12-\$11.30/ft

Roberts, Boyer, Lusk (2008) found WTP for Lake Tenkiller declined \$.82/ft for each foot below normal

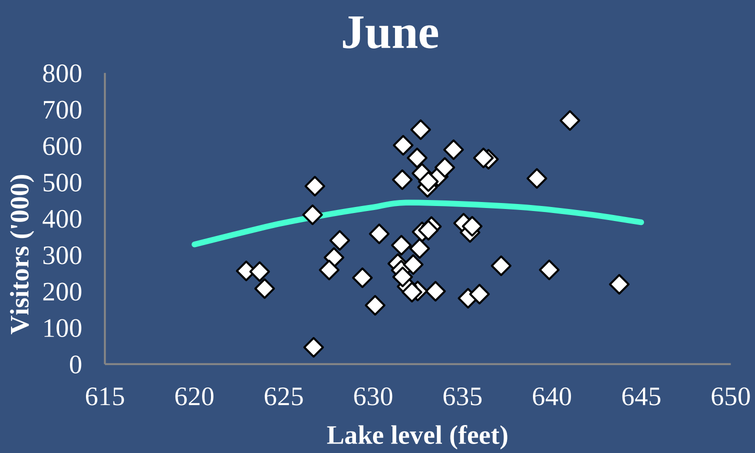
Study Assumptions: Value Tenkiller Visitor Day= \$10 and \$ 50
Value declines by \$.82 for each foot lake below normal
(Both Number of Visits and the WTP depend on Lake Level)

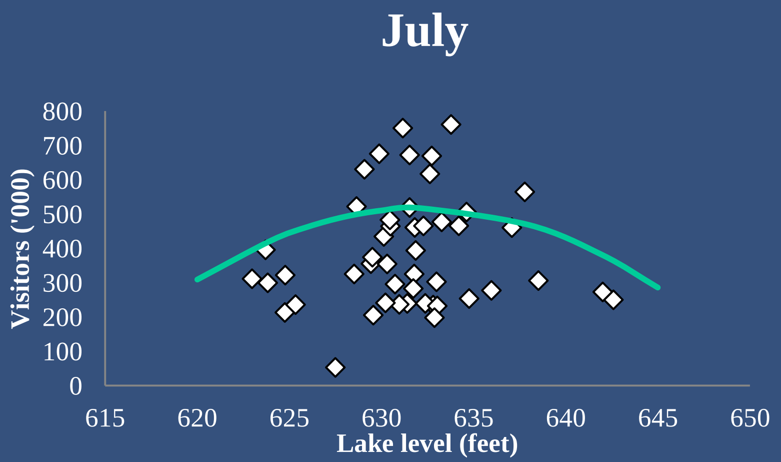


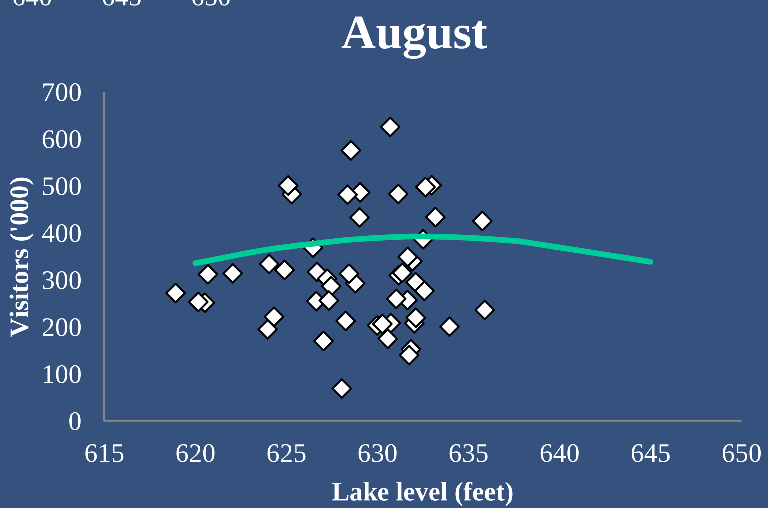


Effect of Lake Levels on Visits

Regressed Monthly Visitors on Lake Level (1955-2010)





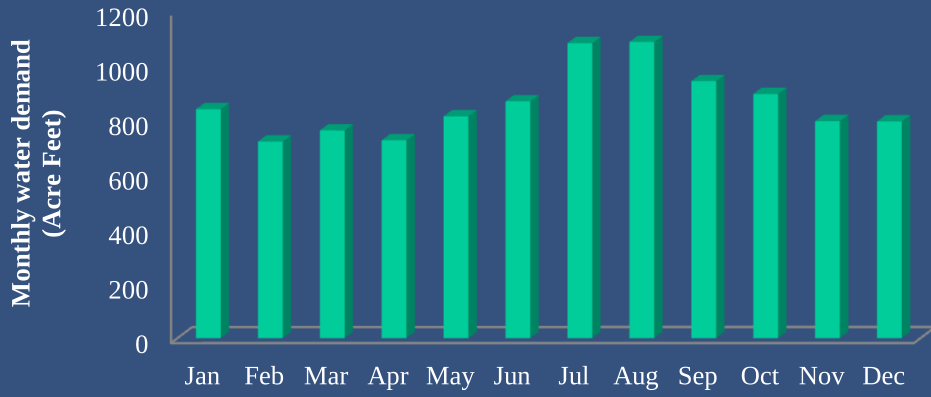


Rural Water Supply Benefits

Rural water supply benefits are calculated as the Net Social Benefits (NSB) derived from the water uses. It is determined as:

$$NSB_t = \text{Consumer Surplus}_t + \text{Producer Surplus}_t$$

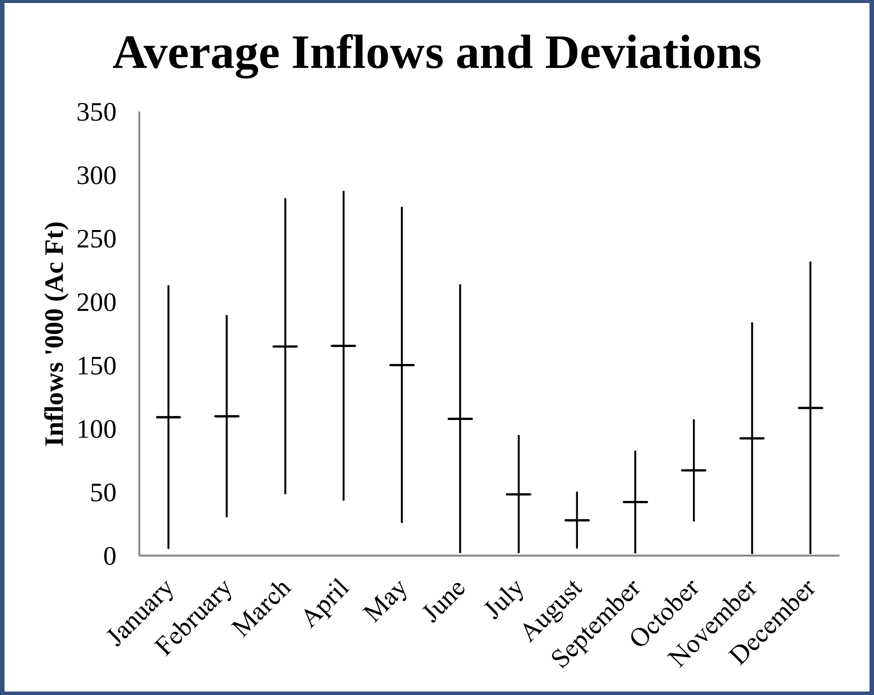
Monthly urban and rural water demand by Lake Tenkiller and its surrounding area

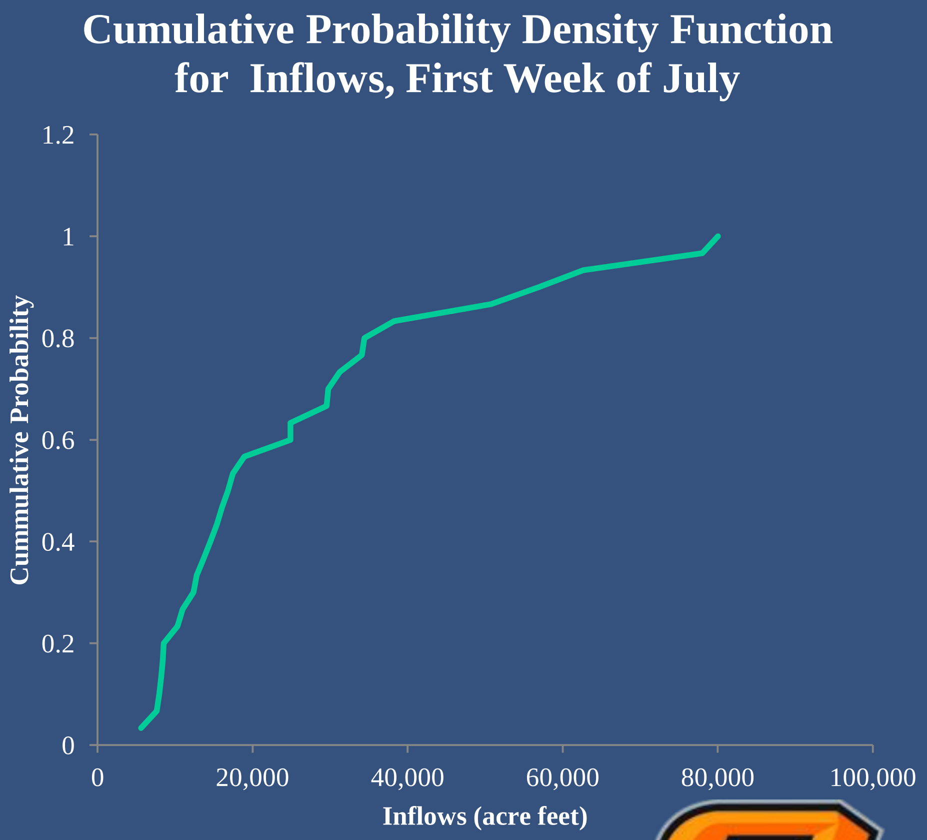


water demand by the 27 water districts in Tahlequah, Gore, Vian, Sequoyah, and Fort Gibson (USACE, 2001)

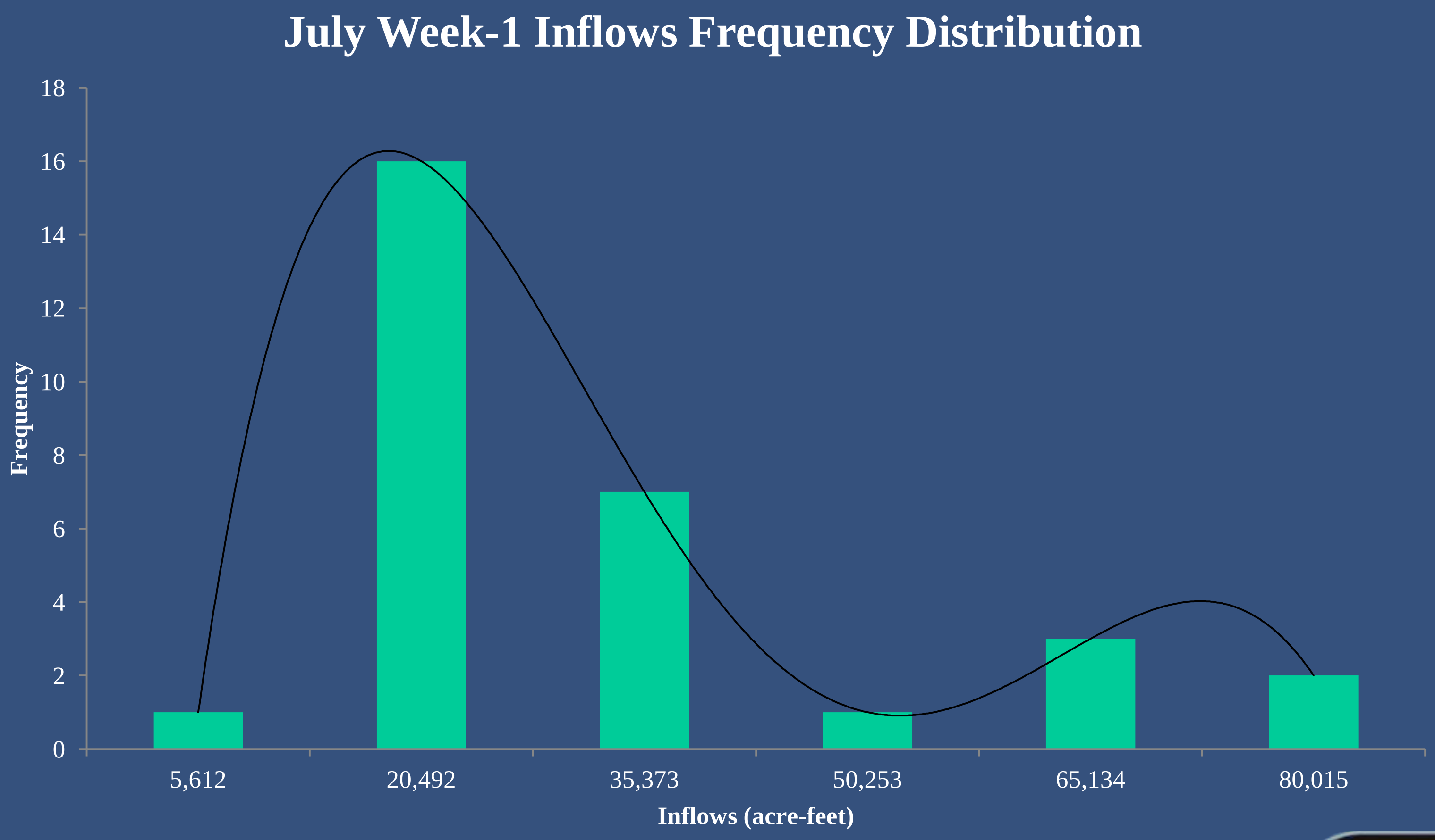
Historical Inflows

- Daily Inflow data from October 1979 through June 2010 were used
- Tenkiller Reservoir receives an average of 1.2 million acre feet of water per year from the Upper Illinois River



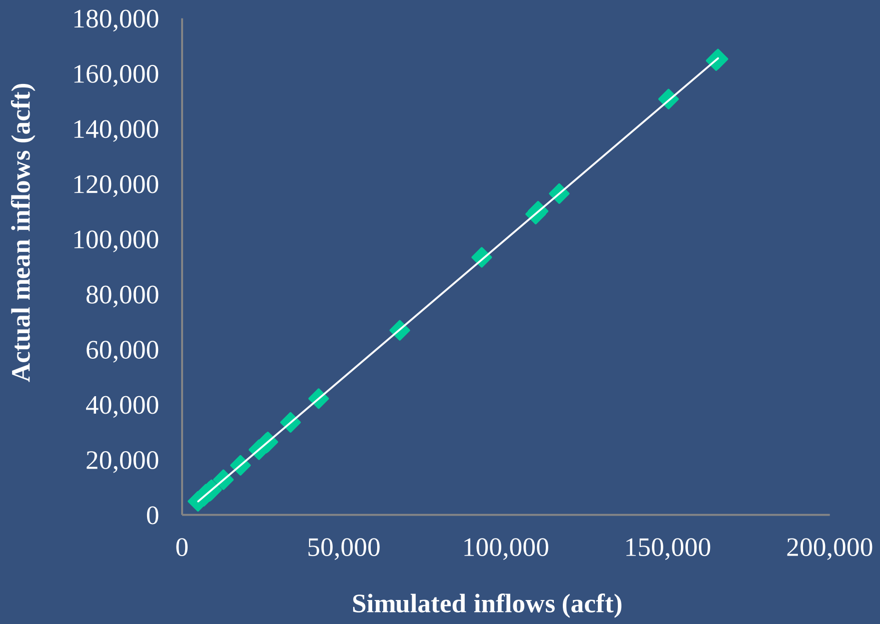


Distribution of Inflows

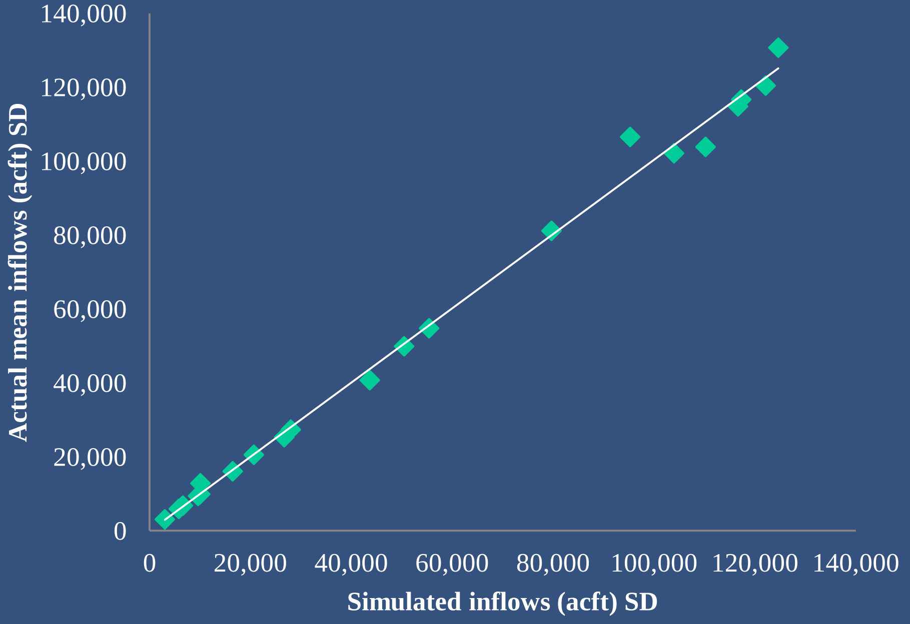


Simulated Inflows Matched Actual

Actual vs simulated mean inflows



Actual vs simulated standard deviations



Optimization Results

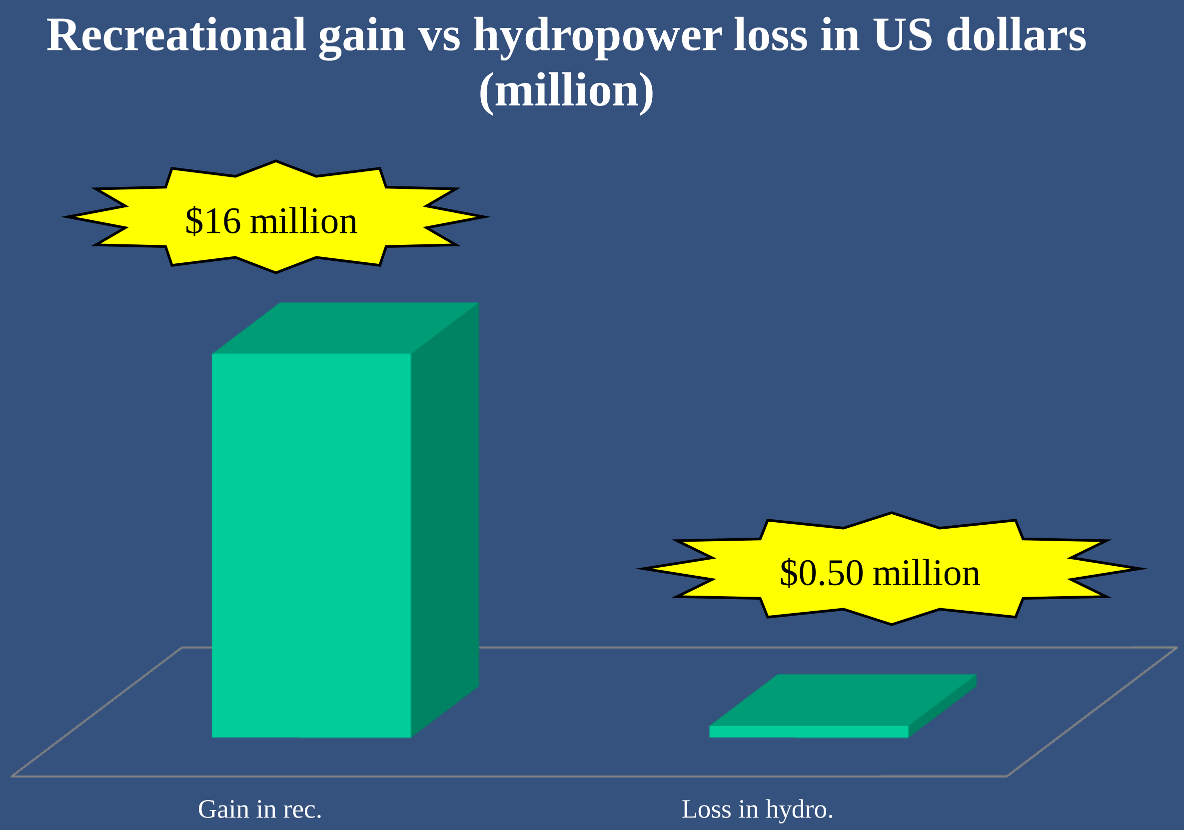
Recreation Valued at $50, Electricity Valued at $0.073/Kwh

Recreational Values in Objective Function*			Recreational Values not in Objective. Function*		
Recreation* Benefit	$	126,392	Recreation* Benefit	$	110,383
Hydropower** Benefit	$	6,890	Hydropower** Benefit	$	7,386
Public Water Supply	$	84,518	Public Water Supply	$	84,518
Total Benefit (with recreation in Objective function)	$	217,770	Total Benefit $ (without recreation in Objective function) $		202,287

Gain Greater NSB by Including Recreation in Objective Function

* (values in thousand dollars)

Tradeoff b/w Recreational Gain and Hydropower Loss When Recreational Values are Included in the Objective Function

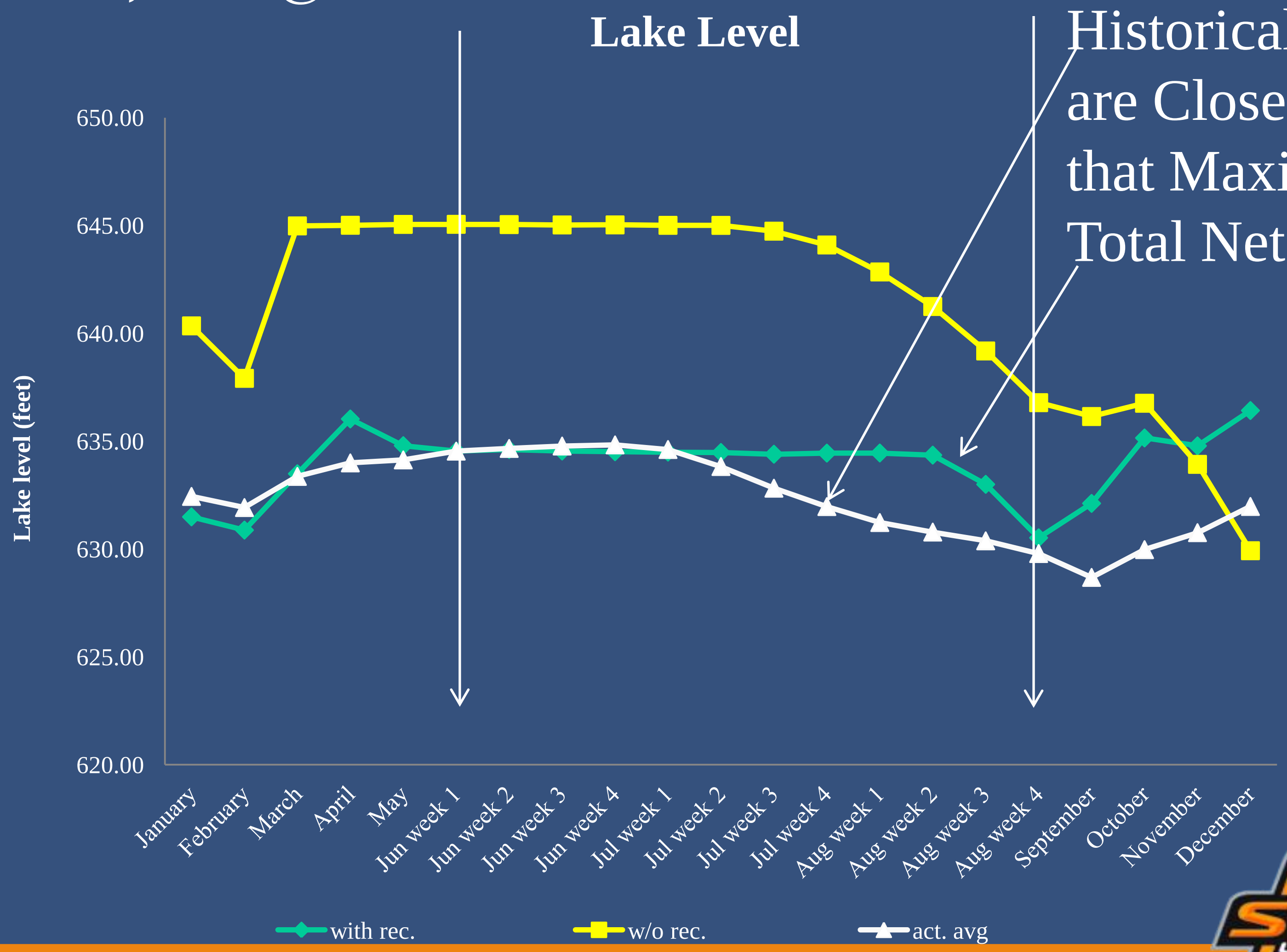


Recreation valued at $50, electricity valued at $0.073/Kwh

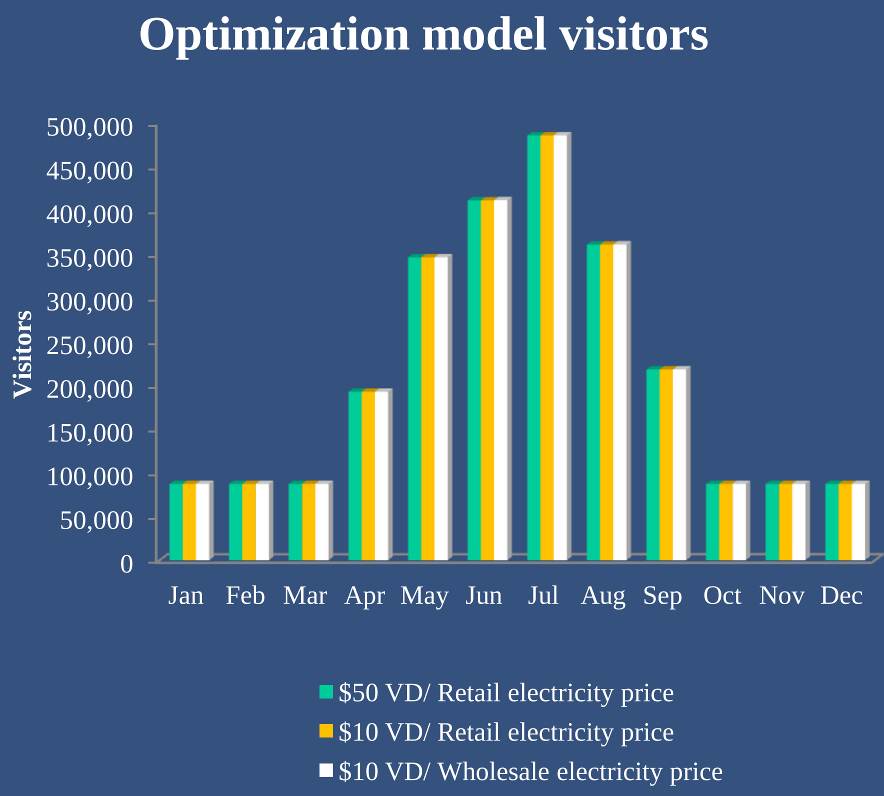
Optimization Results

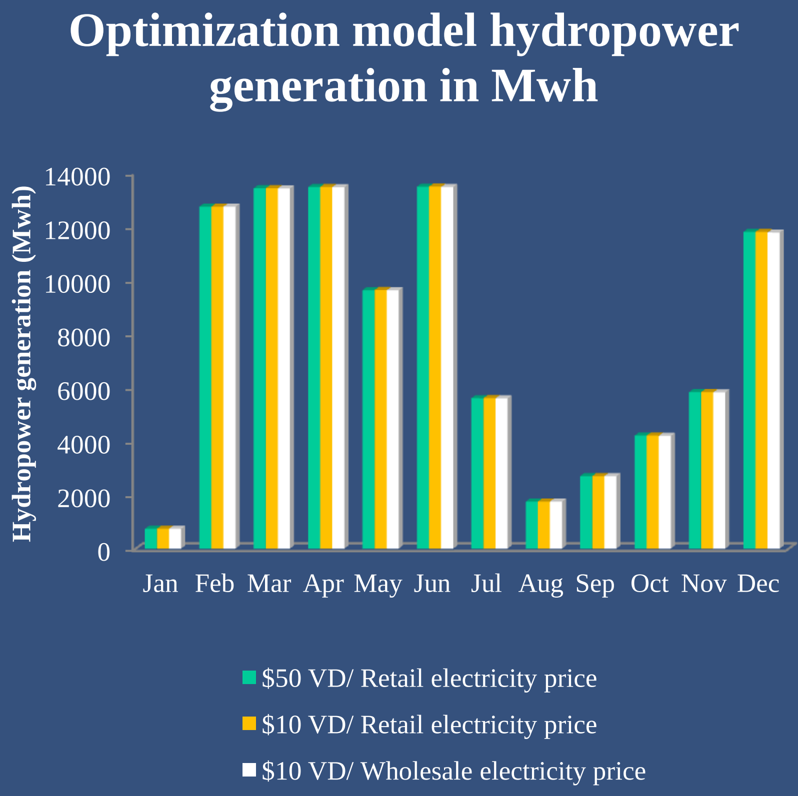
Rec at $50/d, Elec @ $0.073

Except for August, Historical Levels are Close to Those that Maximize Total Net Benefits



Visitation & Hydropower Generation at Three Different Scenarios



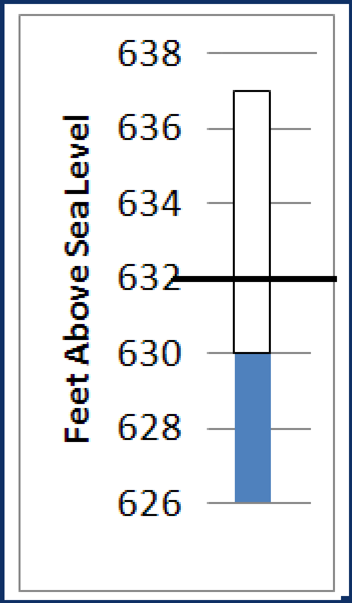


Oklahoma State University

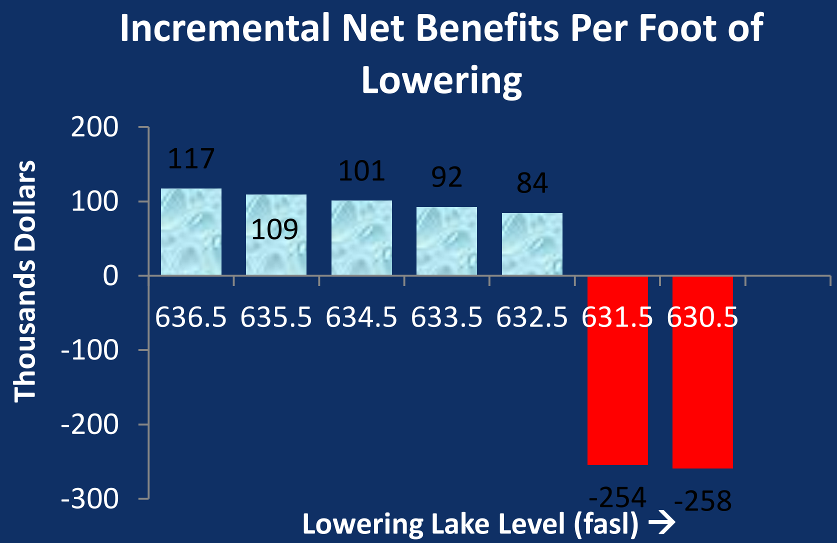
Economics of Tenilker Releases for Hydropower VS Recreation

Consider Effect of Lowering Lake Level on,
Volume Released, Hydropower Generated, Recreation Visits, Value, Net Benefits: Elec @ $.077 /kwh, Rec @$10/day

Lower Lake Level From--> To	Volume of Release acre ft.	Chg. In Elec. Value	Change in Number Visits	Change in Recreational Benefit	Total Change in Net Benefits
	Change per foot of Decline				
637-->636'	13,722	$88,335	2,870	$28,700	$117,035
636-- >635'	13,524	$86,417	2,240	$22,400	$108,817
635-->634'	13,335	$84,571	1,600	$16,000	$100,571
634-->633'	13,153	$82,792	950	$9,500	$92,292
633-->632'	12,979	$81,075	320	$3,200	$84,275
632-->631'	12,811	$79,417	1,240	$333,036	$253,619
631-->630'	12,650	$77,813	1,870	$336,270	$258,456

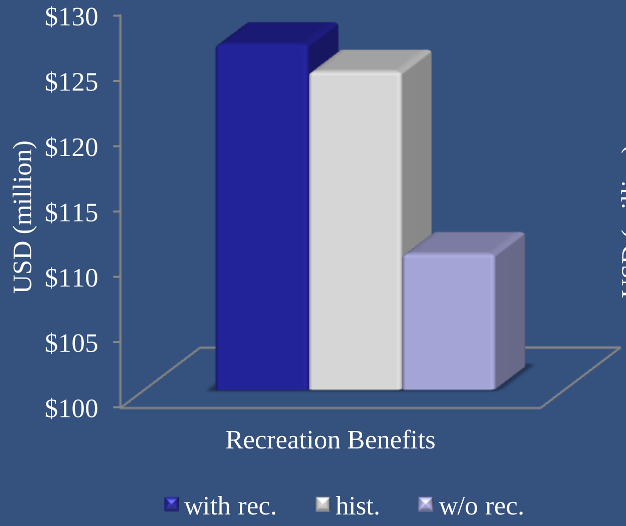


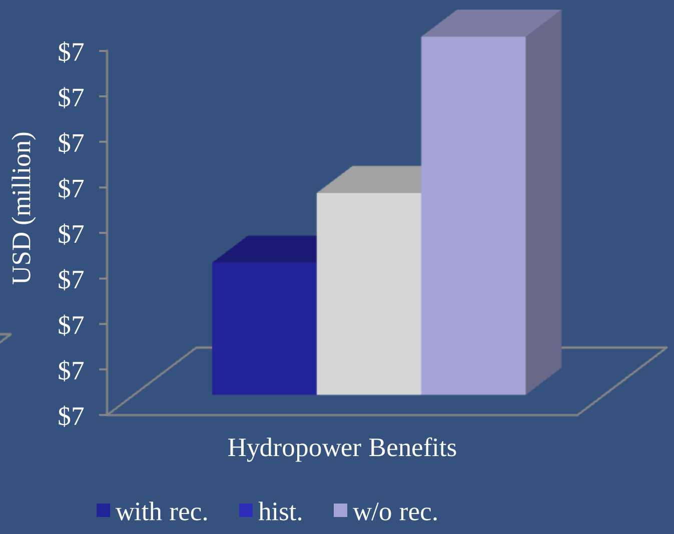
<- Normal Level

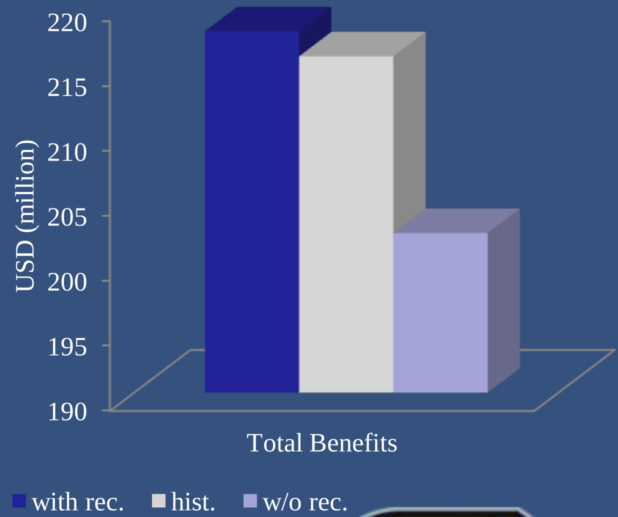


Comparisons b/w Historical and Optimization Models

Recreation, and hydropower generations benefits in US dollars (million)







Recreation valued at $50/day, electricity valued at $0.073/Kwh

Conclusions

- Optimization model (with recreational benefits included in the obj. function) gave higher benefits than average values calculated from historical levels and releases.

- Recreation dominates for Lake Tenkiller. Optimal lake levels remained essentially same whether recreation was valued at \$10 or \$50 per day when hydropower was valued at retail prices.

- Net social benefits can explicitly increased by considering both the market and non-market uses.

- Recreational benefits and rural water supply benefits are higher than the hydropower production benefits.

Conclusions (Contd..)

- During the summer months the visitors are sensitive to the lake levels that are both above and below normal lake level.
- For Lake Tenkiller, additional recreational values are more valuable than additional hydro-electricity generated.
- Only major change in historical levels would be to maintain higher levels through August.
- Maintain lake level near normal level during the summer months and shift the releases for hydropower generation to the other months increasing overall benefits.

Thank you !

Questions Comment or Suggestions

Different Research Components Funded by :
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