Improved Drought Management of Falls Lake Reservoir:
Role of Multimodel Streamflow Forecasts in Setting up Restrictions

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Presentation Outline

- Background and Purpose
- Current Operational Constraints
- Falls Lake Management Model
- Analysis
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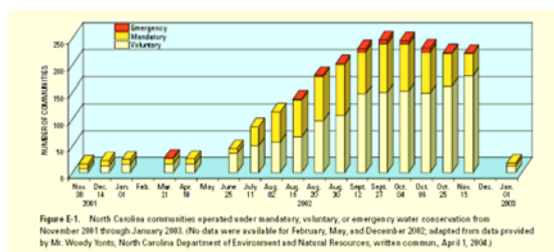
Recent multi-year Droughts

Recent drought conditions from 1998 -2002 forced authorities to institute both voluntary and mandatory restrictions on domestic water supply in the Triangle Area

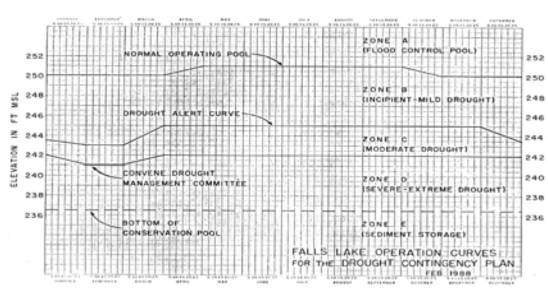


FALLS LAKE PURPOSE

- Constructed to serve five purposes:
  - Flood control
  - Water supply
  - Water quality
  - Recreation
  - Fish and Wildlife

- Provides Raleigh with up to 100 million gallons of water a day

Falls Lake Rule Curves



Source: US Army Corps of Engineers, *Falls Lake Neuse River Basin, NC, Drought Contingency Plan*

Purpose of the Study

- To use season ahead probabilistic streamflow forecasts with the reservoir model.
  - single model forecasts.
  - Multimodel forecasts.
- Determine the probabilities of satisfying target storage, water quality and water supply constraints for Falls Lake.

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Operational Constraints

- Rule Curves
  - Maintain a year-round normal pool elevation of 251.5’
- Conservation Pool Management
  - 39% devoted to Water Supply and 61% devoted to Water Quality Purposes
  - Water Quality Minimum Discharge Requirements
    - 100 cfs (April to October)
    - 60 cfs (November to March)
  - Water Supply to Raleigh & surrounding municipalities
    - Maximum instantaneous withdraw 100 MGD (155 cfs)
    - Increasing demand of a finite resource

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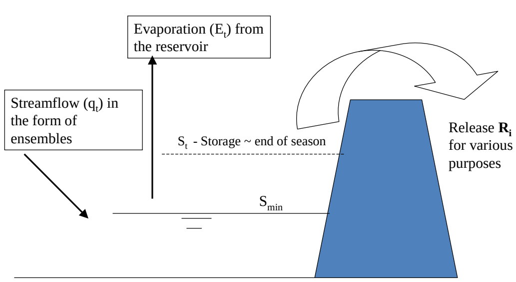

$$S_t = S_{t-1} + q_t - E_t - \sum_{i=1}^{n} R_{ti}$$

Reservoir Simulation

(for each ensemble ‘k’)

- Inflow Forecast: q_{tk}; t=1…,T; k=1,…,N
- Continuity Equation: t=1,2, …, T

$$S_t = S_{t-1} + q_t - E_t - \sum_{i=1}^{n} R_{ti}$$

- R_{ti} (Target Release for each user)
- Evaporation: $E_t = \psi_t \delta_1 ((S_t + S_{t-1})/2)^{\delta_2}$
- Accounts the Deficit by enforcing restrictions

Specify

water supply releases $\mathbf{R_1}$ and $\mathbf{R_2}$

To Estimate

- $P(S_T \leq S_{T*})$ **End of the Year Storage Constraint**

For S_{T*} = 131,519 ac-ft

- $P(W_i \leq W_i^*)$ - **Contract Level Constraint**

W_{i*} Max Restriction that could be enforced for each user.

Model Setup

- **Inputs:**
  - Inflow Data: Forecast Ensembles (500 ensembles)or Climatologic Data
  - Stage-Storage Relationship
  - Water Supply Demands
  - Water Quality Demands (either actual releases or min. WQ)
  - Evaporation Rate
  - Initial Storage
  - Target Storage: Storage available at normal pool elevation 251.5' (Storage volume: 131,519 ac-ft)
- **Outputs:**
  - Probabilities
    - Failure to meet target storage
    - Failure to meet water supply demands
    - Failure to meet water quality demands
  - End of season storage volume

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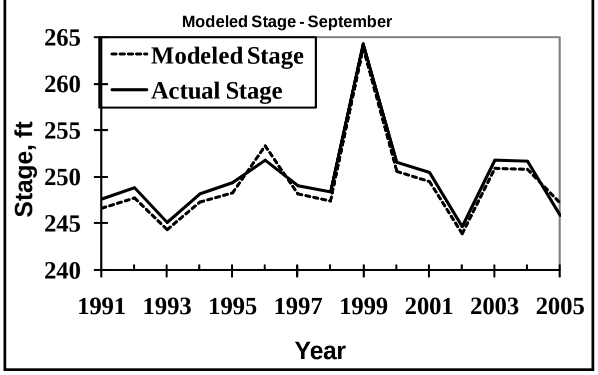
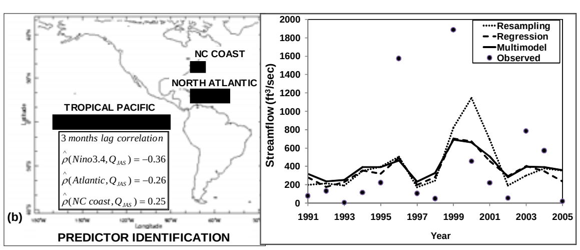
Reservoir Model Verification

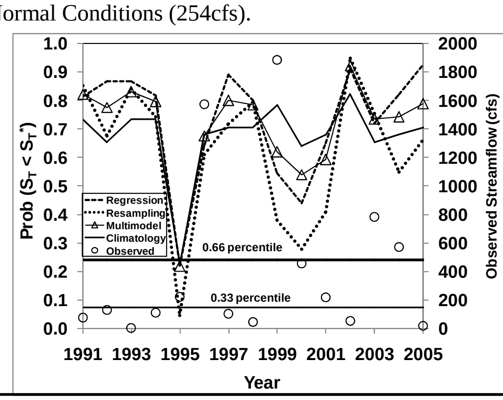


Streamflow Forecasting Models (Devineni et al., 2008)

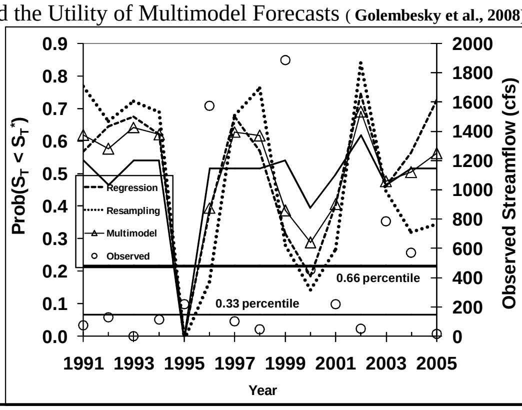


Streamflow forecasts and Initial Storages – Inputs to the Management Model

Meeting Target Storage With Forecast Models during Normal Conditions (254cfs).



Meeting Target Storage during Drought Conditions (100cfs) and the Utility of Multimodel Forecasts (**Golembesky et al., 2008**)



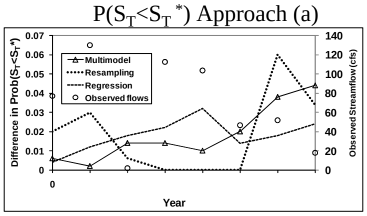
Enforcing Restrictions based on the Estimates of $P(S_T<S_T^*)$

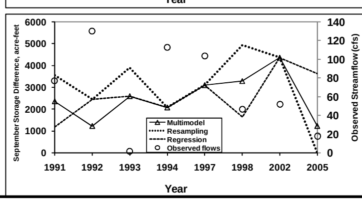
Two approaches suggested to invoke restrictions

a) Specify the restriction percent to quantify the reduced risk of not meeting the target storage.

b) Specify the desired reduction in the risk of not meeting the target storage to obtain the corresponding restriction percent.

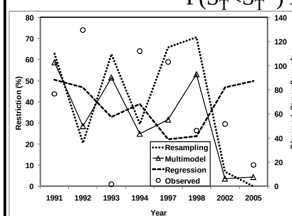
Enforcing Restrictions based on the Estimates of $P(S_T<S_T^*)$ Approach (a)



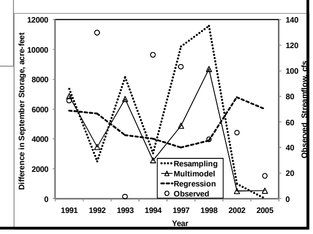


0.5 – 0.6 – 10%
0.6 – 0.7 – 20%
0.7 - 0.8 – 30%

Enforcing Restrictions based on the Estimates of $P(S_T<S_T^*)$ Approach (b)



5% reduction in the estimate



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Summary and Conclusions

- A reservoir simulation model is presented, validated and applied for allocating water during the summer season from the Falls Lake Reservoir.
- The model was analyzed using seasonal streamflow forecasts (JAS) from three models: *regression, resampling and multimodel forecasts (obtained from the former two models).*
- The performance of these models in estimating $Prob(S_T < S_T^*)$ was evaluated by comparing with the estimates of $Prob(S_T < S_T^*)$from climatological ensembles.

Summary and Conclusions

- The study suggested two different approaches of invoking restrictions on water supply releases to improve the end of September storage conditions.
- Among the three streamflow forecasting models, multimodel streamflow forecasts seem to better predict the change in streamflow potential, thus resulting in reduced false alarms and missed targets in predicting below-normal storage conditions at the end of September.

References

- Devineni, N., A. Sankarasubramanian, and S. Ghosh (2008), **Multimodel ensembles of streamflow forecasts: Role of predictor state in developing optimal combinations**, Water Resour. Res., 44, W09404, doi:10.1029/2006WR005855.
- Golembesky, K., A.Sankarasubramanian and N. Devineni (2008),**Improved Drought Management of Falls Lake Reservoir: Role of Multimodel Streamflow Forecasts in Setting up Restrictions,** *Journal of Water Resources Planning and Management*, in press.

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