# A SIMULATION MODEL FOR THE APALACHICOLA-CHATTAHOOCHEE-FLINT (ACF) RIVER SYSTEM

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**Abstract.** The Apalachicola-Chattahoochee-Flint (ACF) River System supports a diverse array of instream and out-of-stream uses and values, including ecological support, recreation, power generation, municipal water supply, and maintenance of water quality. A simulation model program has been developed to better understand both the sensitivity of each water demand to the system-wide demands as well as the sensitivity to uncertain model inputs such as inflows and evaporation.

The ACF simulation model is written in Visual Basic for Applications (VBA) programming language so that the sensitivity of each modeling parameter can be tested through varying the model parameters for multiple automated model runs The model's ability to test the effects of different modeling parameters and inputs help provide a way in which the most effective tradeoffs can be developed. The possible applications of such a simulation tool include the evaluation of peaking power requirements during reservoir operation, identifying the most effective reservoir balancing alternatives, and evaluation of the effects of conservation on reservoir levels.

## INTRODUCTION

A number of water balance and reservoir operations models have been developed over the past 20 years to address water conflicts and water management in the ACF system. The models currently used by the Environmental Protection Division (EPD) include the Army Corps' HEC-5 and HEC-ResSim ACF Model and a Stella Model originally developed by the University of Washington using Stella software (The Univ. of Washington, 1995). While these models already contain much details and data from years of use and improvements, they are all three modeling platforms for which the source code is not available and therefore can only be modified within the limits of the existing platform. Therefore in order to run multiple iterative model simulations an ACF reservoir operations model was developed in VBA. This paper serves as description of the ongoing development and use of this new model.

## BACKGROUND

Many of the most complex questions about water management in the ACF require integrated modeling in which all demands and modeling parameters can be tested for sensitivity with one another. As stakeholders consider various alternatives to managing the ACF river basin, commonly asked but complex questions must be clearly answered such as:

1. How much do increases or decreases in water use affect lake elevations?
2. How much do increases or decreases in water use affect downstream flows?
3. What type of water management would best serve lake elevations and downstream flows

Only after such relationships of water use, lake levels, and low flows are understood can the question of best water management be answered. This paper seeks to demonstrate the relationship between water use, remaining storage (lake levels), and power generation under the current operation plan. This paper will further demonstrate how the probabilistic uncertainty of hydrologic data and operation data could be considered during operation by using forecasted inflows.

## COMPARISON WITH HEC-5 RESULTS

The VBA ACF model was compared with HEC-5 during the process of development and in order to validate its comparability in terms of mass balance and operations. Using equal inflows, demands, operation rules, and flow targets the VBA ACF model produced very similar results, as shown in Figure 1 and Figure 2. The operation rules used were the Army Corps currently in place Revised Interim Operation Plan (RIOP) finalized in 2008. Differences in results can be attributed to energy requirements and balancing mechanism of the reservoir system. Comparisons are being undertaken to compare the VBA ACF model results with the HEC-ResSim ACF Model and the Stella Model.

Additionally the model will be compared with historic conditions from 2008 until present when the RIOP has been in place to see how well the model replicates actual operations.

## ACF PARAMETER SENSITIVITY

In order to determine the effects of each water need on the system wide performance requires require performance measures such as minimum lake elevations and frequency of low flows. For the purpose of this study the lake levels performance will be measured as the minimum conservation storage remaining in the upper three reservoirs of Buford, West Point, and Walter F. George using the historic hydrology from 1939-2007. Downstream flow performance will be measured as the Woodruff Simulated flows divided by natural flow for various frequencies of low flow.

Of the many parameters that could be tested in the IOP formula this paper considers the required usage of flow to generate electricity or energy requirements. The energy requirements for the IOP are a complex formula which sets a number of hours of power generation that must take place depending on the amount of storage available. As more storage is available, higher requirements for energy production are mandated. Often energy requirements are met without any extra storage release because releases for downstream flow requirement are greater than those for energy requirements. Sometimes however, the energy requirement flows require additional storage to be used.

To test how energy requirements affect available storage during critical periods, a series of 80 model runs were made with energy requirements ranging from 0% to 200% using current demands. The resulting minimum storage remaining during the most critical droughts were plotted against the percentage of energy requirements that were met (Figure 3). The results show that as the energy requirements increase to 100%, the minimum storage level gets lower. There is an overall 60,000 acre-feet difference between zero energy requirements and 100% energy requirements. There also appears to be an optimal energy factor where 80% of energy requirements can be met with only a storage loss of 10,000 acre-feet. As energy requirements are increased to 200%, lake levels reach low levels that do not require significant power releases so the minimum storage begins to flatten. The resulting Woodruff outflows as a percentage of natural flows were similarly plotted against the percentage of energy requirements that were met (Figure 4). As power generation requirements are increased Woodruff outflows generally become closer to natural flows. However, not all flow frequency show higher outflows as power generation requirements are increased. This is because as energy requirements are increased lake elevations are lowered which cause lower flow targets. This analysis however, only tested the energy requirements of the whole system and did not test the sensitivity of the timing or location of energy requirements. Further studies should be done to determine whether some reservoirs or seasons are more sensitive to energy demands.

The next parameter to be tested in the ACF model under the IOP formula is the consumptive water use demands. These demands include agricultural, industrial, municipal, and power plant demands. Again 80 Simulations were run while varying water demands from 0% to 200%. The resulting minimum storage remaining during the most critical droughts were plotted against the percentage of demands met (Figure 5). As demands increase to the current level of 100% a drawdown of 240,000 additional acre-feet is needed beyond the drawdown with 0% of demands. Also noted is that as demands increase the storage needed to meet these demands increases at a faster rate. Therefore the doubling of our current demand would result in drawdown of 390,000 additional acre-feet instead of the 240,000 acre-feet resulting from our current water use. The resulting Woodruff outflows as a percentage of natural flows were plotted against the percentage of demands met (Figure 6). The results show that as demands increase the low flow frequencies are affected the most. The 95$^{th}$ and 90$^{th}$ percentile flow frequencies appear to decrease from above natural flow levels under 0% of demands to 91% of natural inflows under current demands. The 99$^{th}$ percentile flow frequencies are consistently above natural inflows due to the floors of 4,500 cfs and 5,000 cfs which are mandated in the RIOP.

## ACF MODEL FORECASTING RESULTS

One possible solution to optimizing the river basin management performance of is the use of forecasted inflows to determine the expected future conditions of the river system. This paper does not test any possible operation strategies using forecasts, but rather describes how lake levels can be forecasted in the VBA ACF model. Inflows were forecasted for the next 12 months using 1,000 random Monte Carlos simulations using the historic unimpaired inflows from 1939-2007. The inflow forecasts are normally distributed with a bivariate correlation to the previous month’s inflow. In other words flows during May will be forecasted randomly but with a correlation to consider the previous month of April’s inflows. If April inflows are lower than normal then May’s inflows will most likely be forecasted as lower than normal. These 1,000 flow forecasts were then simulated using the VBA model to produce 1,000 potential lake elevations for the next 12 months.

The resulting forecasts with January 2011 as a starting point are below in Figure 7, 8 and 9. Figure 7 shows the expected probability of exceedance for the 12 next months. Figure 8 and 9 show the probability density function for the expected lake level elevation by February 1 and March 1 of 2011. The results forecast a 70% chance that Lanier will be at full pool by February 1. While these results may be very crude forecasts, as they do not consider regional and global climatic forecasts, they offer the right type of uncertain expected conditions that should be considered in policy formulation.

## CONCLUSION

The VBA ACF model sufficiently models the river basin as a flexible modeling platform capable of multiple automated sensitivity tests. The testing of the sensitivity of each stakeholder's demand provides a means to determine where tradeoffs are most effective and most fair. Such demonstration of each stakeholder's effect on others promotes stakeholders to develop integrated fair solutions to address complex problems.

## REFERENCES

GAEPD, 2003, Georgia Drought Management Plan. March 2003.

The University of Washington, 1995. A Stella Model for ACF River Basin.

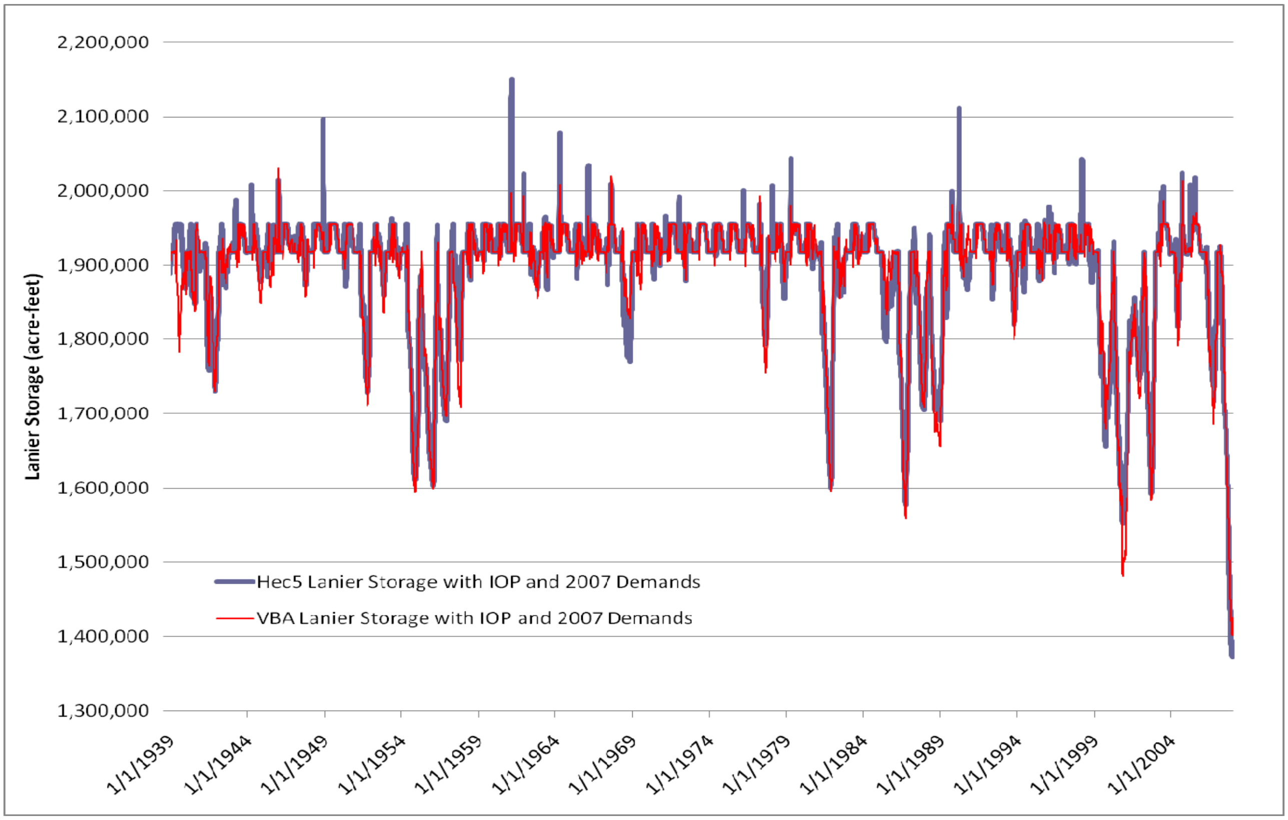


**Figure 1. Comparison of VBA ACF modeling results with HEC-5 Results for 1939-2007 under IOP conditions with 2007 Demands**

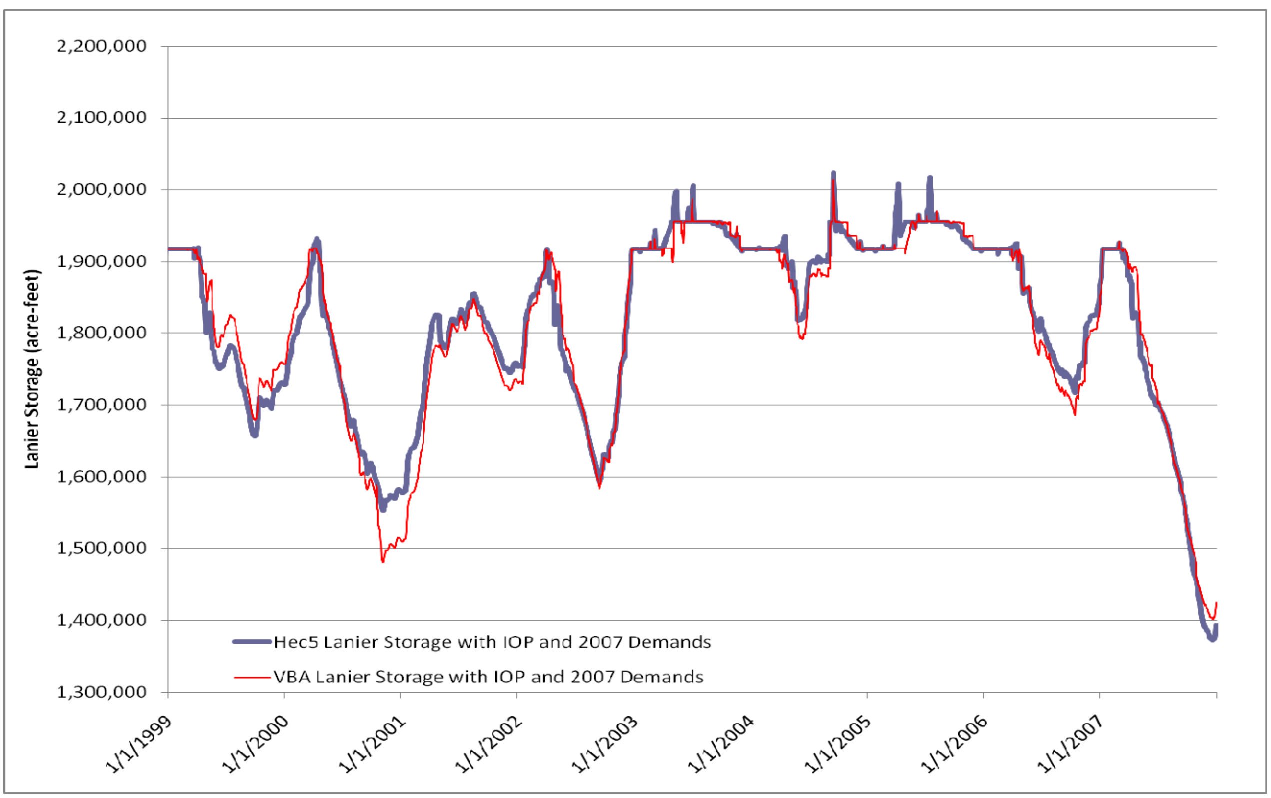


**Figure 2. Comparison of VBA ACF modeling results with HEC-5 Results for 1999-2007 under IOP conditions with 2007 Demands**

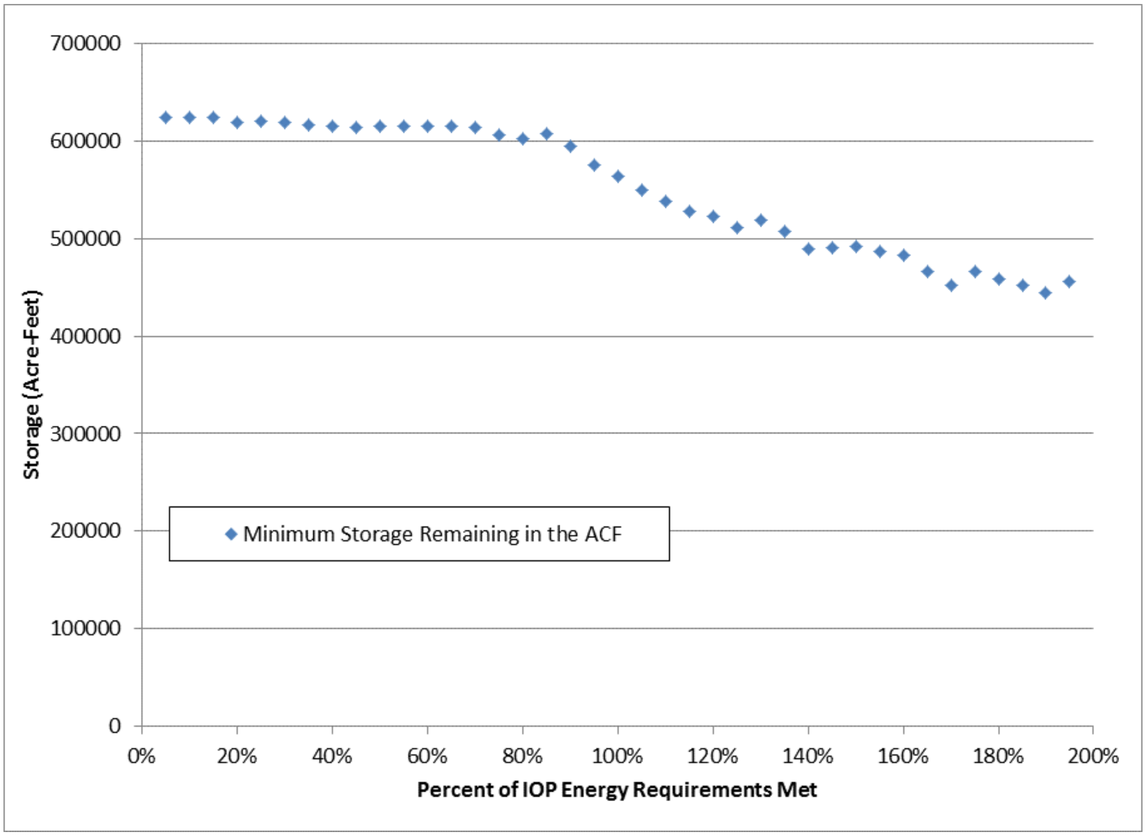


**Figure 3. Sensitivity of Energy requirements to the minimum amount of storage remaining in the ACF reservoirs**

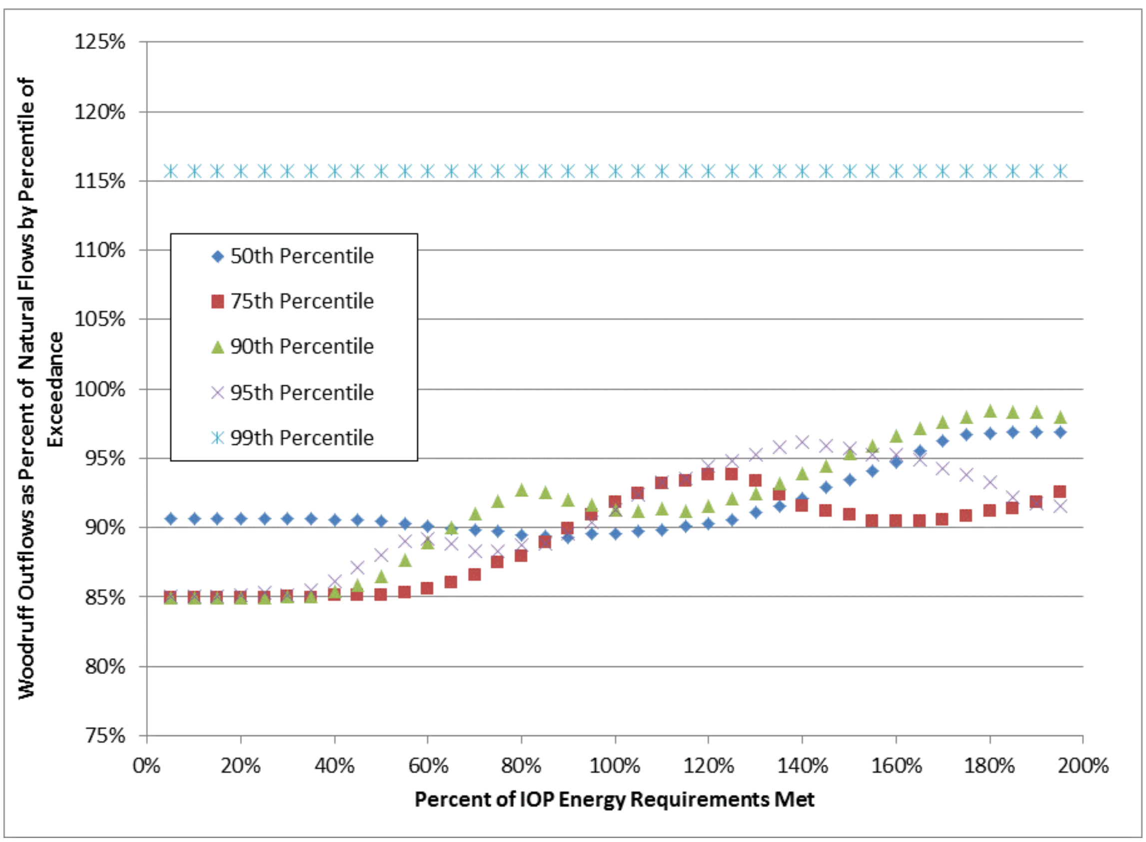


**Figure 4. Sensitivity of Energy requirements to the Woodruff outflows as a percent of natural flow**

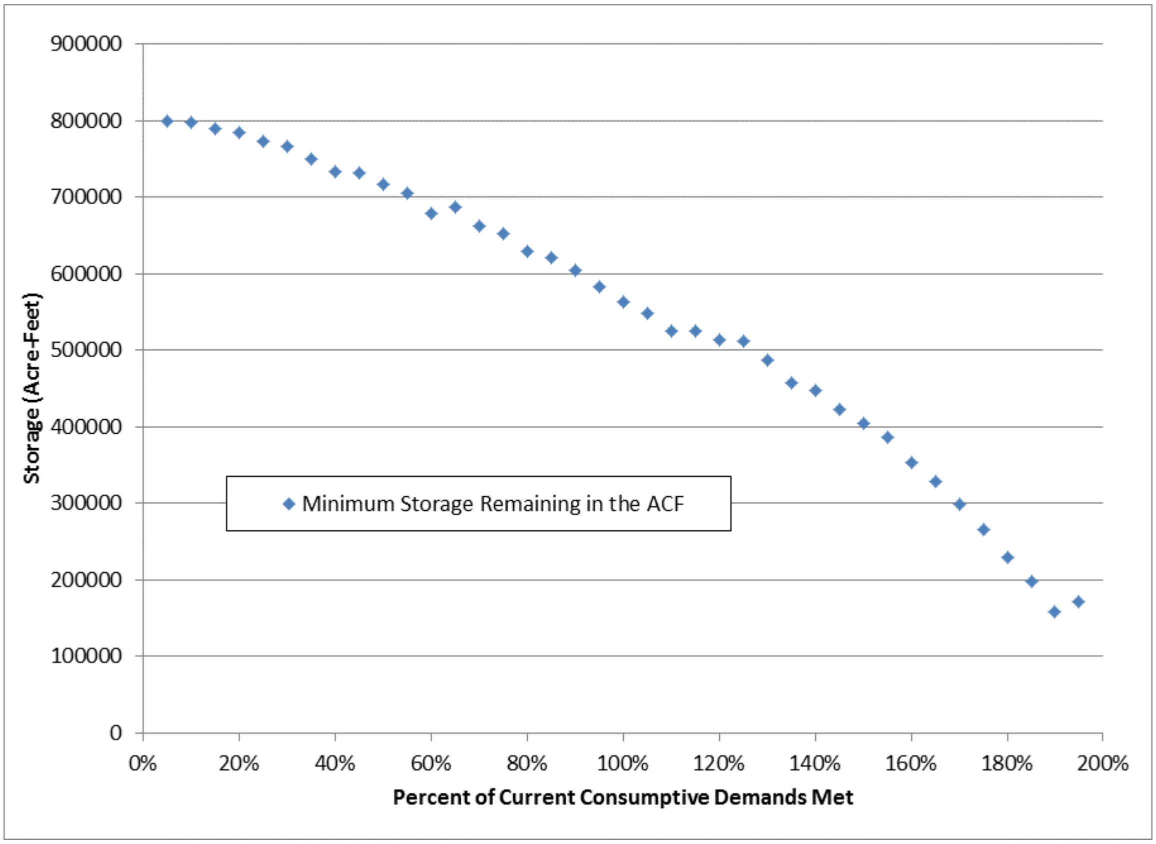


**Figure 5. Sensitivity of water use requirements to the minimum amount of storage remaining in the ACF reservoirs**

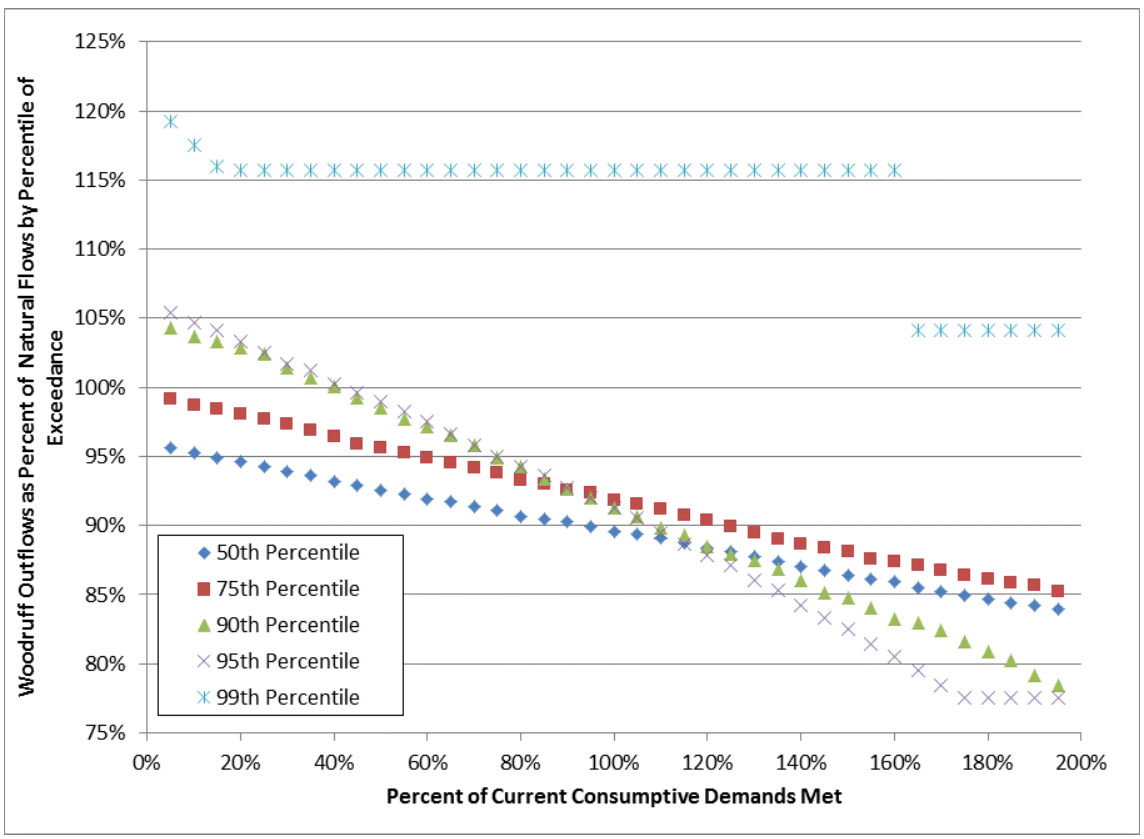


**Figure 6. Sensitivity of water use requirements to the Woodruff outflows as a percent of natural flow**

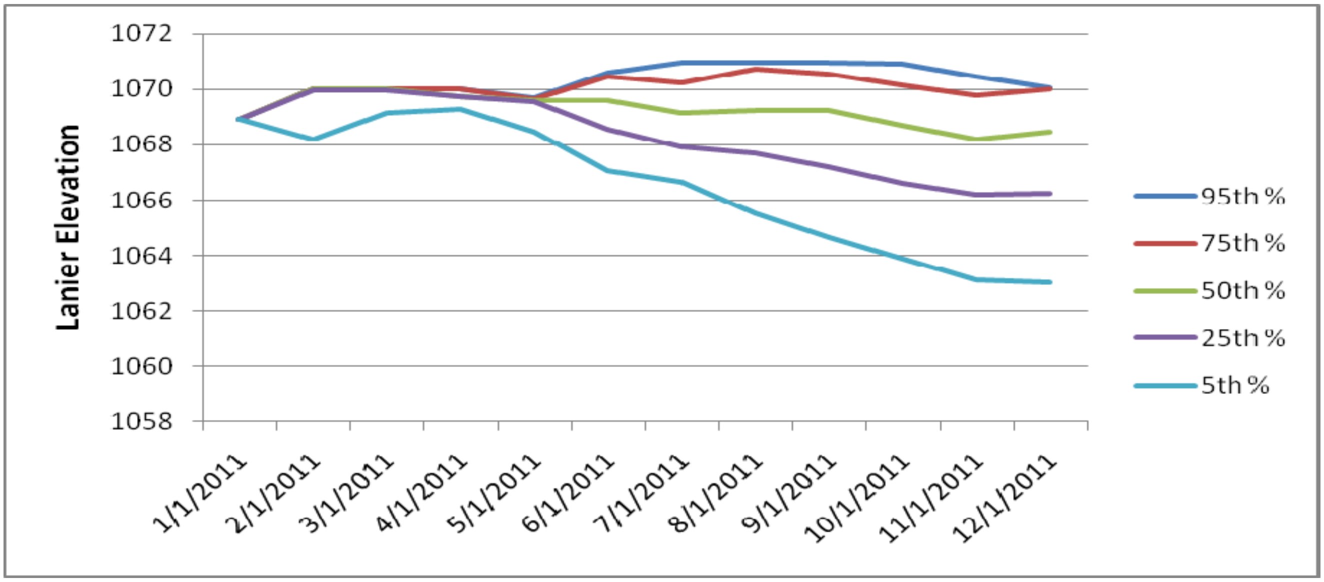


**Figure 7. Forecasted Percentiles of Lake Lanier elevation for the next 12 months**

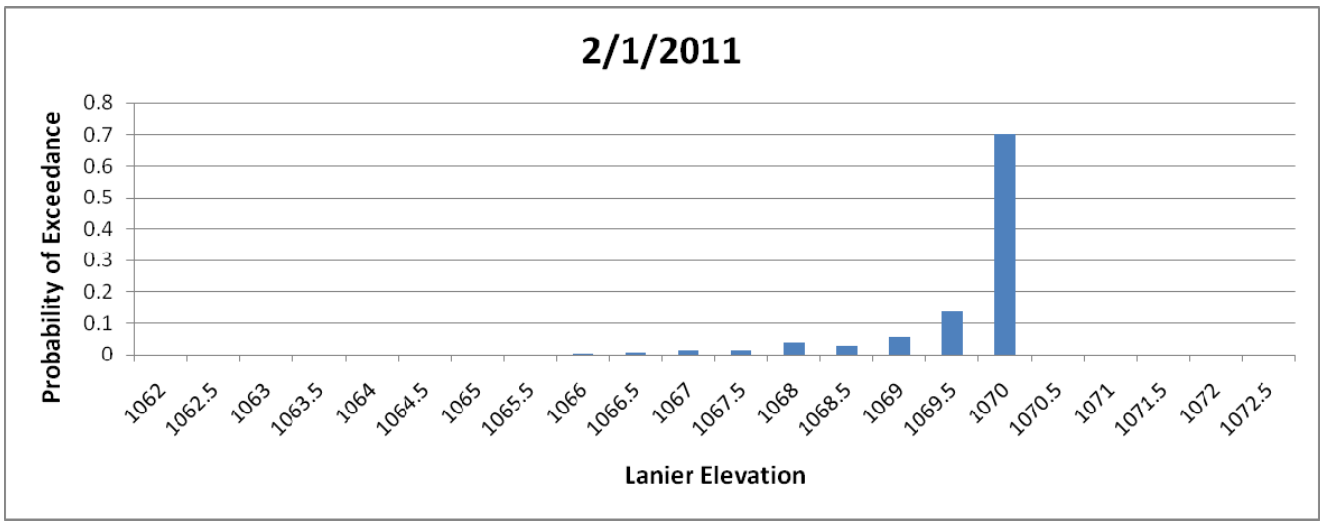


**Figure 8. Forecasted probability of Lake Lanier elevation for the beginning of February 2011**

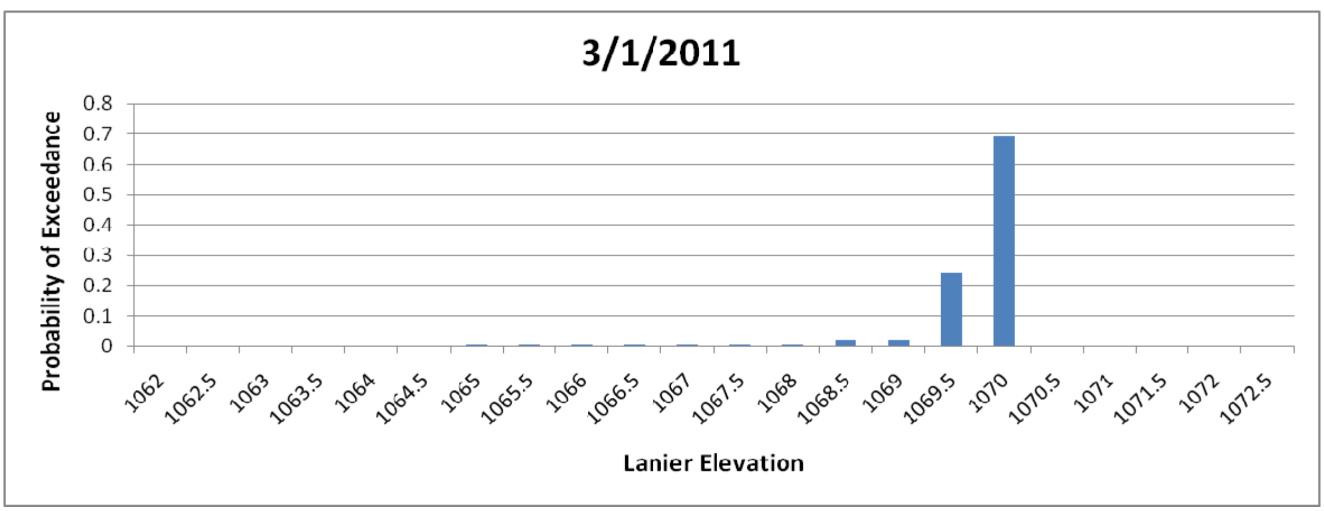


**Figure 9. Forecasted probability of Lake Lanier elevation for the beginning of March 2011.**