**1 Introduction**

Bluff Lake in the Sam D. Hamilton Noxubee National Wildlife Refuge provides important habitat for migratory birds and sport fish. Additionally, controlled releases from Bluff Lake support the movement of paddle fish (P. spathula). However, different ecological objectives require different lake levels. Migratory bird habitat for waterfowl and wood stork require lowered water levels. Sport fish requires maintenance of a sizable deep water lake area. Controlled releases to support paddle fish, deplete water levels. Furthermore, declines in lake level can increase the amount of floating vegetation.

The existing lake level management plan was established decades ago and was not explicitly developed to account for the competing ecological objectives. This paper details recent efforts to develop a decision support model that quantifies controls on the lake water balance, quantifies linkages between lake level and specific ecological objectives, and develops a framework for making adaptive management decisions on the optimal approach to maintaining lake water level.

While lake and reservoir management models have been used for decades to make decisions about releases, such models have often been applied in systems with well-defined competing uses (e.g. hydroelectric vs. recreation vs. water supply), not the less certain controls on ecological function. Furthermore, such models have often been implemented in highly regulated systems with well-established hydrologic monitoring. In the case of Bluff Lake - and other wildlife refuges – a small staff is tasked with a number of responsibilities, of which adjusting and managing lake level is just one. Additionally, there are no direct measurements of inflow or a long-term record of lake water level.

Therefore, a key goal of the model is to account for uncertainty in both hydrology and well as ecology in order to develop a framework to support logical decision-making on releases but to also inform future monitoring needs.

**2.1 Bluff Lake Water Balance Model**

A water balance model was constructed to allow simulation of lake stage and releases. Inflows to Bluff Lake are estimated from the USGS gage on the Noxubee River at Macon, MS. Because the Bluff Lake watershed is only a fraction of the total Noxubee at Macon watershed (220 mi2/768 mi2=0.29 ), the gage flow must be scaled downward to approximate the inflow into Bluff Lake. Exact scaling between the measured flow at Macon and the Bluff Lake inflow was determined by calibrating the lake water balance model to one year of Bluff Lake stage measurements.

Outflows from Bluff Lake were a function of water stage in the lake and were calculated based on standard hydraulic equations. The primary outflow structure from Bluff Lake consists of 14, 5-ft width bays with movable boards. In eight of the bays, a tainter gate is positioned behind the boards. If the gate is left in the closed position (the typical position), the gate eliminates outflow even if the boards are overtopped. In most cases, outflow is regulated by adjusting board heights. Flow over the boards was modeled as a sharp-crested weir:

(<https://www.engineeringtoolbox.com/weirs-flow-rate-d_592.html>) where head is the difference between the board elevation and the water height, width is dependent on the number of 5-ft wide bays with boards set at the lowest level, and *g* is the gravitational acceleration constant (32 ft s-2). The lowest possible elevation of a board is \_\_\_\_ ft mean sea level (msl) while the highest possible elevation is \_\_\_\_\_\_ ft m.s.l. The standard setting is to maintain \_\_ bays with the board set at elevation \_\_\_\_\_.

A secondary spillway provides outflow when lake water levels exceed an elevation of \_\_\_\_ ft m.s.l. The secondary spillway consists of a 73-foot wide concrete apron. Flow through this spillway was modeled as a broad-crested weir:

where C~2.7 (Tracy 1957), width is approximately 73 feet, and head is water depth above the \_\_\_\_ ft m.s.l. spillway base.

**2.2 Prior Discharge-Stage Relationship**

Using the 70+ year historical discharge record in conjunction with the Bluff Lake water balance model, one can construct the conditional relationship between the prior month’s streamflow and the current month’s water level. Once established, this can provide an ability to forecast the likelihood of future lake water level. Due to the seasonal dependency in each relationship, the probabilistic relationship between stream discharge and lake level is developed for each month.

The relationship between discharge and stage was also evaluated for modified lake level management strategies. This entailed changing the timing and degree to which boards were adjusted.

**Relevant Literature**

Nichol, S., B. Griffith, J. Austin, and C.M. Hunter. 2014. Optimal water depth management on river-fed National Wildlife Refuges in a changing climate. Climatic Change. 124(1-2): 271-284. <https://link.springer.com/article/10.1007/s10584-013-1033-8>

Stoffels, R.J., N.R. Bond, S. Nicol. 2018. Science to Support the Management of Riverine Flow. Freshwater Biology, <https://onlinelibrary.wiley.com/doi/abs/10.1111/fwb.13061>

Tracy, H.J. 1957. Discharge characteristics of broad-crested weirs. USGS Circular 397. Dept. of Interior. Washington, DC. <https://pubs.usgs.gov/circ/1957/0397/report.pdf>

Bluff Lake Model Needs:

* Bathymetry
* Watershed area and fraction into Bluff Lake
* Assessment of inflows via historical stage data
* Elevation of boards
* Outflow for different board elevations vs water elevations
* DEM of area around lake (LiDAR processing)
* Inflow control structure near Griffin Slough