independent estimates from Darcy-based calculations using observed head gradients and reasonable ranges of vertical hydraulic conductivity. The match across independent lines of evidence – stable isotopes, water level lags, and water budget residuals – strongly supports swamp-to-aquifer recharge.

4. Discussion

Our analyses reveal that the Okefenokee Swamp is not hydraulically isolated from the Upper Floridan Aquifer, as long presumed. Instead, water stable isotope data (Figure 2A–F) and hydraulic time series (Figure 3A–C) both demonstrate vertical connectivity through the intervening Hawthorne Group. Together, these independent lines of evidence show that the swamp and aquifer exchange water and transmit pressure signals across a nominally confining system, over distances of tens of kilometers and time lags of about one month. This overturns long-held assumptions in the region's hydrogeologic conceptual model and has implications for water budgets, ecological dynamics, and groundwater management.

4.1 The confining layer permits vertical flux

Isotopic enrichment in aquifer samples beneath the swamp (δ^2H, $\delta^{18}O$) points to mixing with evaporatively enriched swamp water (Figure 2A–B). Modeled swamp contributions reach 27-95% (Figure 2D), far exceeding what would be expected under an impermeable boundary. These values align with residual water budget estimates (130–220 mm/yr;Rykiel, 1977) and reinforce a view of substantial vertical drainage. Moreover, the aquifer's hydraulic response to swamp-level changes follows a smooth, cumulative function that is well-fit by a leaky aquitard model (Figure 3C), with an estimated diffusivity of 291 m^2/d. This value implies that pressure perturbations cross the confining layer within a month—consistent with the observed lag in aquifer levels and with Kitchens & Rasmussen (1995)'s early observations.

Taken together, the isotope data quantify the flux, and the hydraulic response quantifies the transmissivity. The combined interpretation is clear: the Hawthorne Group, while impeding flow, does not prevent it. Its behavior is more consistent with a semi-confining system that allows significant distributed leakage, rather than an intact seal.

Figure 4 illustrates this conceptual framework, showing the vertical and lateral fluxes that govern the Okefenokee–Floridan system. The persistent head difference of up to 21 meters between swamp surface and aquifer potentiometric levels, combined with residual water budget imbalances (~130–220 mm/yr), provides a sustained downward driving force. The schematic also highlights the dominance of evapotranspiration, the influence of Trail Ridge, and the relative positions of key stratigraphic units and monitoring wells. While simplified, this cross-section captures the essential structure