Multi-objective management of Lake Okeechobee (Lake O) has been a “wicked problem” for the Army Corps of Engineers for nearly 100 years. The need to maintain in-lake storage capacity for flood protection while also meeting water quality requirements for flows to the Everglades has led to frequent, deleterious discharges to the Caloosahatchee and St. Lucie estuaries. Depending on discharge timing, Lake O can contribute large nutrient and cyanobacteria loads to the coast. While Lake O discharges have been associated with the occurrence of both freshwater and marine harmful algal blooms (HABs), the specific connections among managed discharges, watershed-derived nutrient loads, phytoplankton dynamics, and coastal hydrodynamics have not been adequately resolved.

**Goal and Objectives:** The overarching goal of this project is to develop data- and model-driven guidance for Lake Okeechobee releases and Caloosahatchee River watershed management based on an improved understanding of the interactive effects of engineered discharges, watershed flow and nutrient deliveries, phytoplankton community dynamics, and river/near-shore hydrodynamics. Based on this goal, the project team is pursuing four linked objectives: 1) adapting and coupling Lake Okeechobee, Caloosahatchee River watershed, and estuarine circulation models for the region spanning from Lake Okeechobee to the estuary; 2) augmenting existing water quality data with additional real-time, monthly, and event-driven sampling and source-tracking methods; 3) quantifying spatial and temporal variation in estuarine residence times, organic and inorganic nutrient concentrations, dissolved oxygen, salinity, and phytoplankton community composition/abundance in relation to environmental drivers; and 4) applying model and data synthesis to identify optimal conditions for Lake O discharge across an array of scenarios that broadly characterize management needs.

**Figure 1:** Schematic depiction of model coupling. The Lake O Optimization of Nutrient Exports (LOONE) model, Lake O Delft-3D model, and Caloosahatchee River (C-43) watershed model will deliver discharge and nutrient loads to the Charlotte Harbor COAWST model encompassing the Caloosahatchee River and Estuary and greater Charlotte Harbor (Source for C-43 map: TetraTech 2017).
KEY YEAR 1 OUTCOMES AND FINDINGS:

Lake Okeechobee Nutrient and Phytoplankton Loading Modeling: A simple modeling tool (LOONE) has demonstrated improved capability to simulate discharge and phosphorus exports from Lake O. The tool was used to determine that implementation of the Lake Okeechobee System Operating Manual (LOSOM) could decrease phosphorous (P) loads into the St. Lucie Canal by 40% but increase P loads into the Caloosahatchee River by 33% and double P loads to the south due to increased flow volumes. This computationally efficient model can be used to further optimize operation schedule alternatives and to support forecasting.

Caloosahatchee River Watershed Modeling: A Soil and Water Assessment Tool (SWAT) model domain for the Caloosahatchee River watershed has been developed, data sources for calibration have been identified, and an initial model calibration has been completed. Once calibrated, the SWAT model will serve as a scenario intercomparison tool for long-term flow and nutrient load hindcasts or projections. Simultaneously, transformer neural network models for river flow and nitrate concentration have been developed, providing a tool for short-term forecasts.

Caloosahatchee River Estuary Hydrodynamic Modeling: A Regional Ocean Modeling System (ROMS) model has been applied to the Caloosahatchee River Estuary (CRE) and successfully calibrated and verified for water level and salinity during wet and dry seasons. The verified model has been applied to understand the effects of river discharge (including Lake O releases) on estuarine salinity gradients, 3-dimensional circulation, and residence times across the CRE and the broader Charlotte Harbor Estuary.

Water Quality Monitoring and Analysis: Initial source-tracking analyses indicate local sources of inorganic nutrients in the upper and middle Estuary that do not come from the C-43 canal. Stable isotope analyses indicate that particulate organic matter (POM) from the C-43 canal can be distinguished from POM from the estuary. There were no ‘major’ freshwater or marine blooms during the current reporting period (October 2021 – September 2022), however HAB taxa present included the potentially toxic freshwater cyanobacteria Limnothrix, Raphidiopsis, Dolichospermum, and Microcystis, and the marine taxa Prorocentrum, Peridinium, and Pseudo-nitzschia. Specifically, potentially toxic species of cyanobacteria were observed in the C-43 Canal and upper Caloosahatchee Estuary, including M. aeruginosa, but not at ‘major’ bloom levels.

Figure 2: One of two continuous monitoring site were established in the C-43 canal just below the S77 structure in August 2022. The probes measure temperature, salinity, dissolved oxygen, chlorophyll, FDOM, turbidity, and phycocyanin reported hourly (https://recon.sccf.org/sites/moore-haven).
Statistical Water Quality Modeling: Freshwater inflow dynamics and dominant flow sources to the Caloosahatchee Estuary were characterized from historical data to better understand the role of Lake O management on downstream water chemistry. Concentration-Discharge (C-Q) patterns at the S-79 were analyzed to identify functional linkages between biogeochemistry and watershed hydrology. Results revealed that different nutrient forms had distinct C-Q relationships, with implications for understanding phytoplankton community composition responses on sub-annual timescales. Additionally, Bayesian models for phytoplankton taxa were created and coded to support the integration of newly collected data and predictors as the project continues.

**Year 2 Research Priorities**

**Lake Okeechobee Nutrient and Phytoplankton Loading Modeling:**
- Fine tune evaluation of LOONE+Delft3D model alternatives
- Develop nitrogen and phytoplankton modules in LOONE

**Caloosahatchee River Watershed Modeling:**
- Add septic and wastewater treatment plant discharge data into SWAT model
- Include modelled atmospheric forcings
- Calibrate and validate the hydrologic model using observed/simulated data
- Incorporate forecasted variables into transformer neural network
- Advance neural network to create an integrated modeling framework

**Caloosahatchee River Estuary Hydrodynamic Modeling:**
- Perform additional numerical experiments to characterize estuary residence time behavior
- Couple and verify the estuarine model with the watershed model
- Apply and verify the coupled model in forecast mode
- Include nutrient sources in the model and verify it with observations

**Water Quality Monitoring and Analysis**
- Continue monthly sampling through April 2023 (and extend if feasible)
- Implement event-driven sampling responding to a treated/untreated bloom
- Install additional continuous sensors at location CLEW04
- Review literature and create a bloom species environmental matrix

**Statistical Water Quality Modeling:**
- Submit a manuscript summarizing the C-Q analysis for S-79 and S-77
- Improve Bayesian model for phytoplankton community by integrated additional variables

**Scenario Development and Analysis:**
- Stakeholder workshops in 2023, potentially coordinated with the newly awarded St. Lucie Estuary project, will focus on developing management-relevant scenarios

**Project Team:** David Kaplan¹, Mauricio Arias², Eric Milbrandt³, Elise Morrison¹, Natalie Nelson⁴, Maitane Olabarrieta³, Edward Philips⁵, Susan Badyak⁵, Sierra Greene³, Vyaktha H. Hewageegananda¹, Shin Ah Lee¹, Lise Montefiore⁴, Jose Maria Gonzalez Onlna¹, Enrique Orozco-Lopez³, Luming Shi¹, Ben Stelling⁶, Osama Tarabih²

---

¹ University of Florida, Engineering School of Sustainable Infrastructure and Environment,
² University of South Florida, Department of Civil and Environmental Engineering,
³ Sanibel Captiva Conservation Foundation Marine Laboratory,
⁴ North Carolina State University, Biological and Agricultural Engineering Department,
⁵ University of Florida School of Forest, Fisheries, and Geomatics Sciences