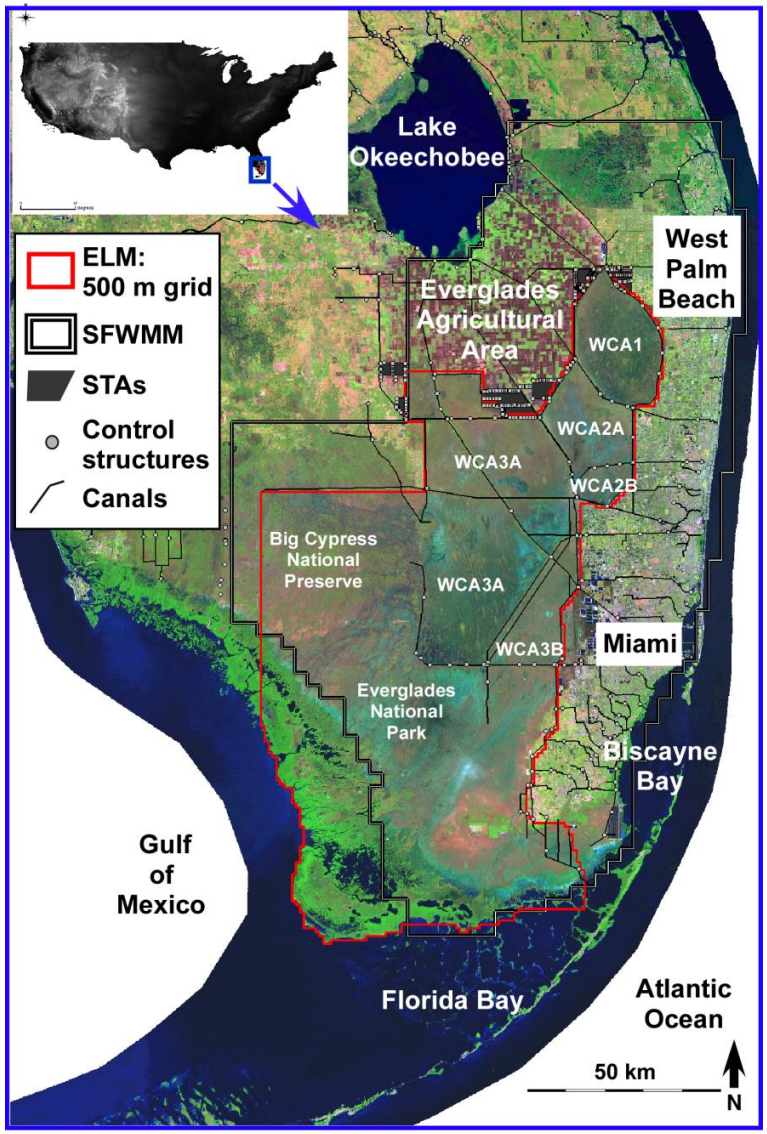
Model analysis of eutrophication constraints on an Everglades restoration project



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Ecological Landscape Models

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FCE LTER

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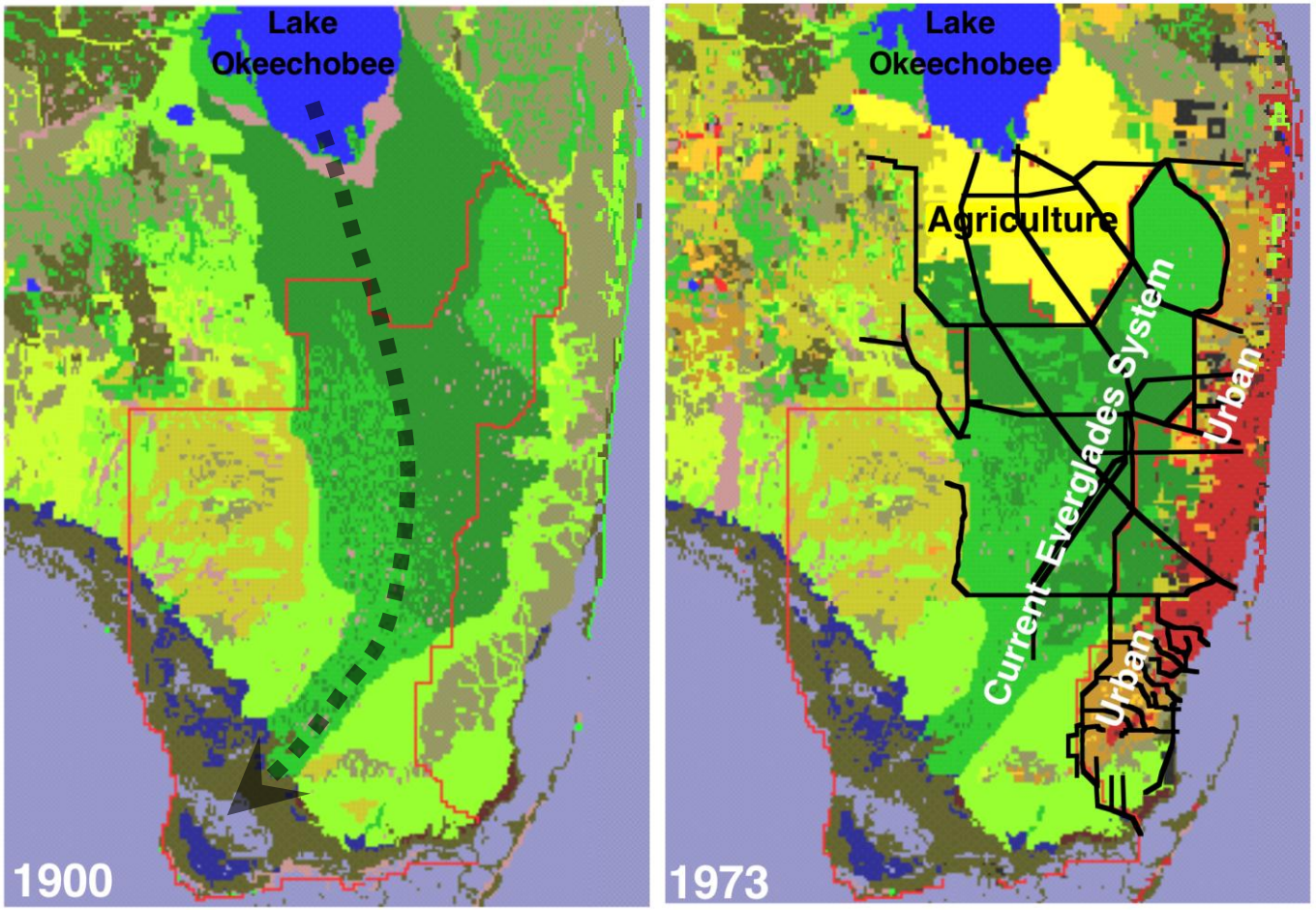
US Army Corps of Engineers ®

Presentation:

- Context – (some) Everglades issues
- Model – design & performance, to address issues
- Model application – Everglades Decompartmentalization
  - ? Modify water flows & loads –> eutrophication concerns ?
  - Answer – no significant concerns for this project

People surrounded the Everglades, which became fragmented by levees and canals, restricting water flows



A River of Grass

A Series of Impoundments

Comprehensive Everglades Restoration Plan (CERP) Goals:

Restore the remaining Everglades

- ✓ Input more water
- ✓ Where it is needed,
- ✓ When it is needed…

- ✓ using CLEAN water

- ✓And multiple other goals….

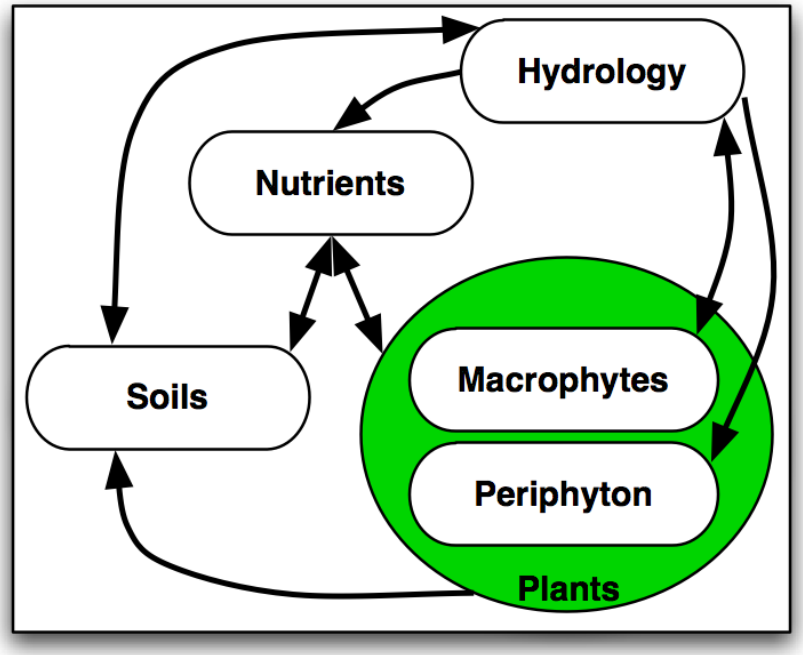
Complex spatio-temporal issues – use of models

- Water management
  - South Florida Water Management Model (SFWMM) - used to design CERP; used to evaluate multiple CERP projects
  - Regional Simulation Model (RSM) – 2nd generation model, now also used to evaluate multiple CERP projects
- Ecology/water quality
  - Everglades Landscape Model (ELM) – used to evaluate ecology/water quality for CERP "DECOMP" project (and other restoration projects)

ELM Design:
Integrating ecological interactions

- Ecosystem model, integrating dynamic processes of hydrology, biogeochemistry, & plant biology

- Arrows denote flows of carbon, water, & phosphorus, and information feedbacks among modules



Model Performance:
1981-2000, 500 m resolution
ELM v2.8.4

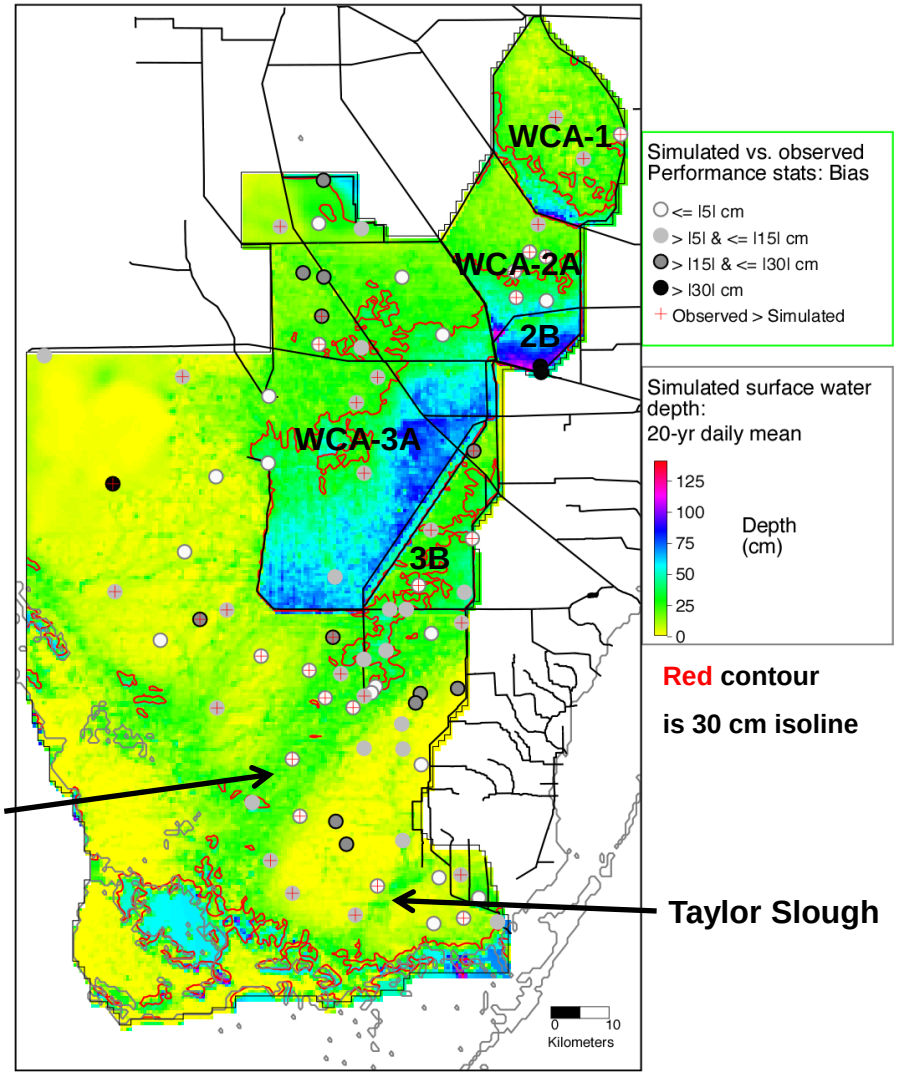
Simulated vs. observed stage:

Median bias = 0 cm

Median NS Efficiency = 0.60

Hydrologic gradients:

- **water ponds in downslope regions of impounded WCAs**
- **deeper regions along Shark & Taylor sloughs, finer-scaled slough features**



ELMreg500m
v2.8.4

ELM review

- National Research Council (2006, 2008, 2010)
  - Stressed overall need for integrated hydrologic, ecological, & water quality models for CERP evaluations
- Mitsch, Band, & Cerco (2007) – internationally-recognized panel, review of ELM for application to CERP
  - Model is "...*robust and will produce a unique contribution, with an integrated ecosystem paradigm, to understand and predict potential outcomes of Everglades restoration projects*..."
- CERP Interagency Modeling Center review of ELM (2008)
  - "... *IMC suggests using ELM as the primary water quality model...*" for DECOMP
- ELM is Open Source, w/ comprehensive, hierarchical documentation
  - Peer-reviewed manuscripts in journals, books

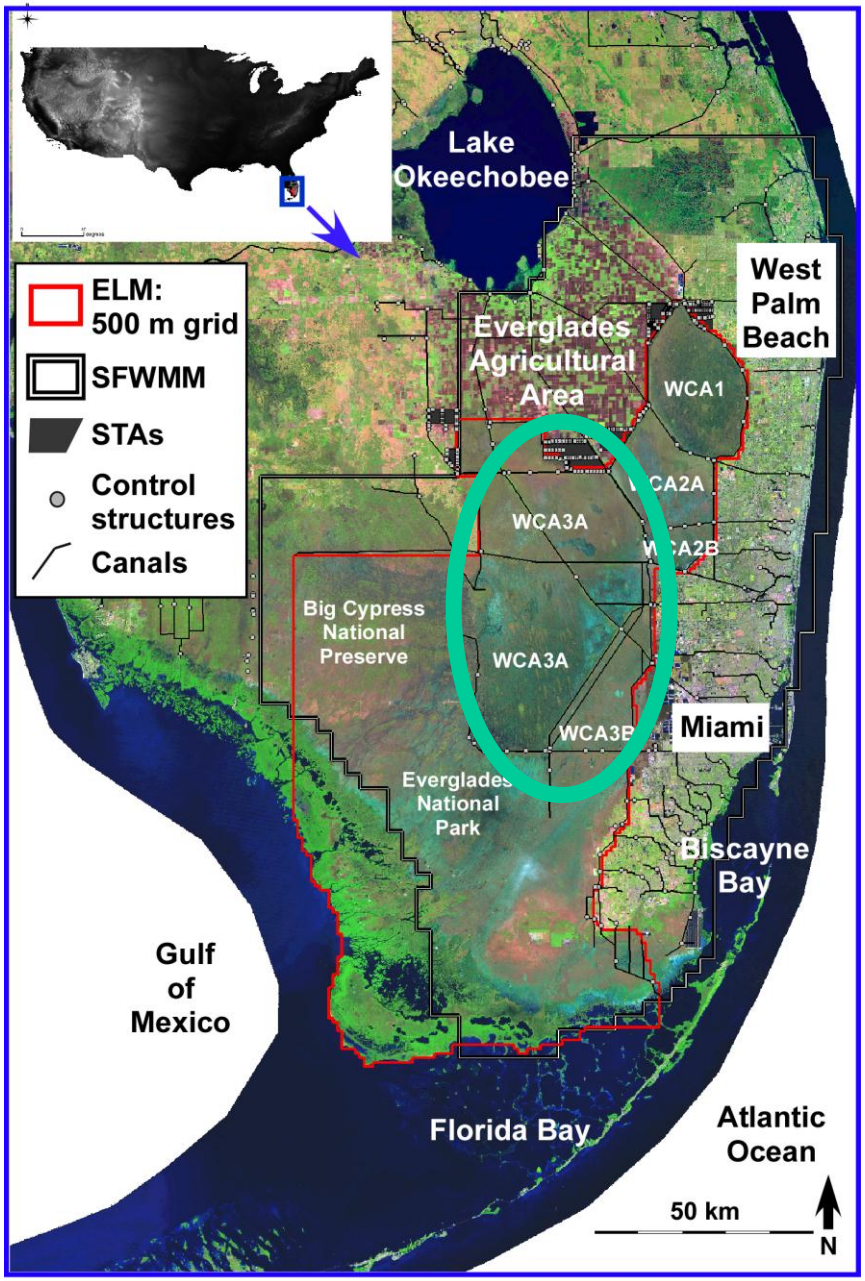
ELM application:

Evaluating CERP WCA-3 Decompartmentalization Project, Phase 1

February 2011 – 2012: Contracted by US Army Corps of Engineers to apply ELM in support of CERP "Decomp" Project, Phase 1

(Related model research publication) **--**

Fitz, H.C., G.A. Kiker, and J.B. Kim. 2011. Integrated ecological modeling and decision analysis within the Everglades landscape. *Critical Reviews in Environmental Science and Technology* 41: 517-547.

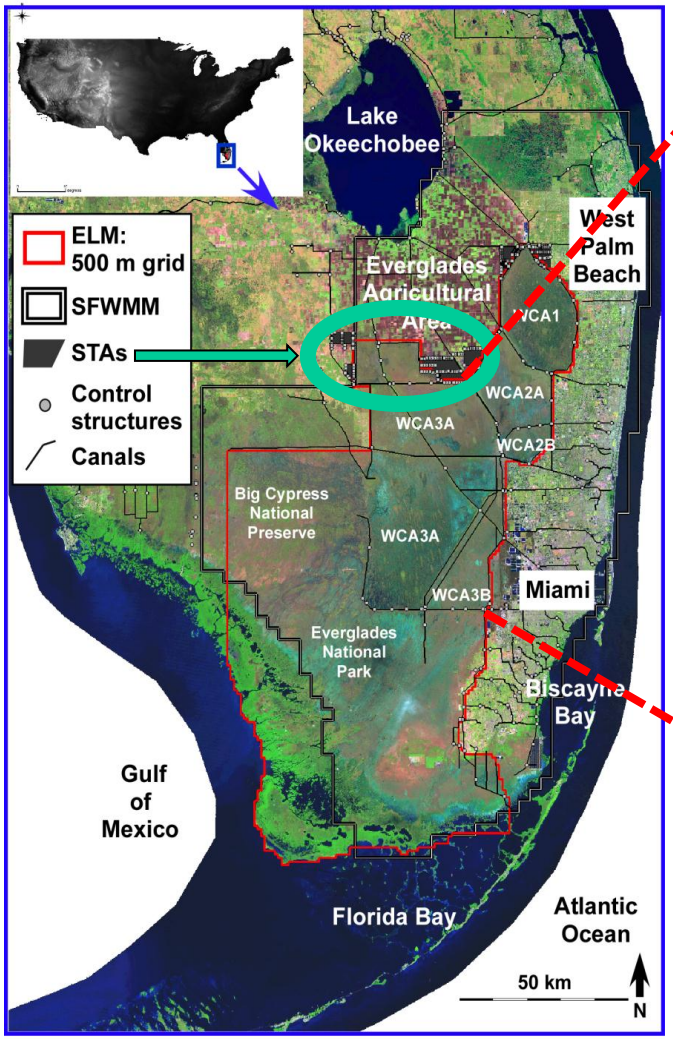


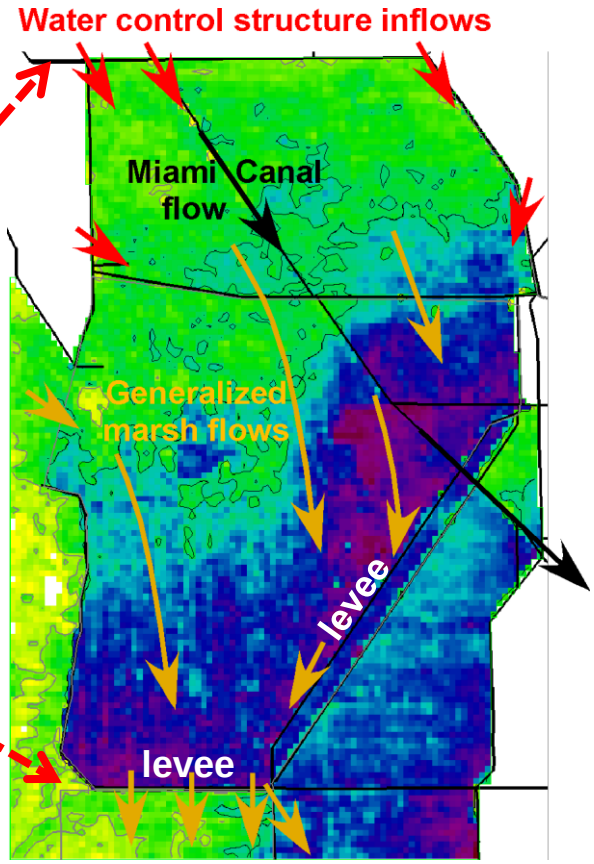
ELM application for CERP Decomp Phase 1 Project

- **Water quality is a formal constraint on Project Objectives**
  - § **Project may not degrade water quality in currently-unimpacted areas**
  - § **Apply integrated hydro-ecological ELM to evaluate that constraint**

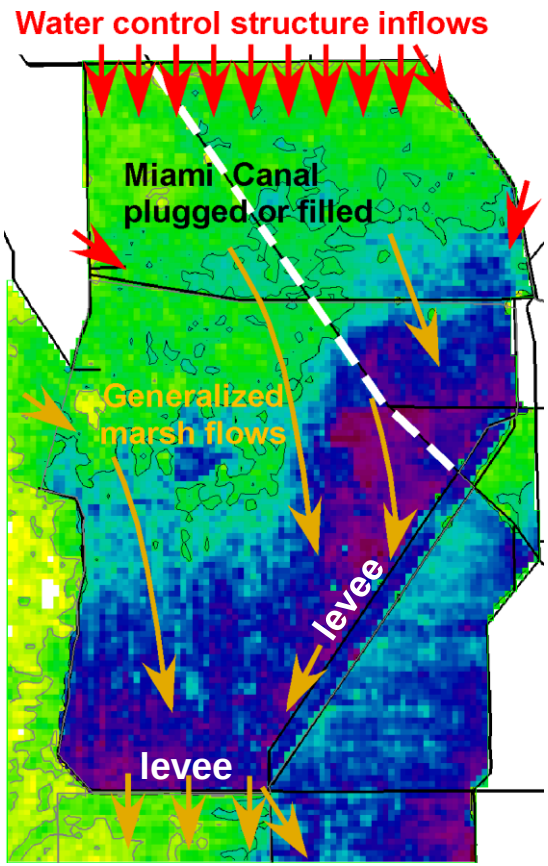
- **Hydrologic water management models drove ELM**
  - § **SFWMM v6.0 (~10 km^2 grid) provided regional flow boundary conditions**
  - § **RSM v2.3.1 (avg ~2 km^2 grid in WCA-3) used SFWMM inflows, applied water management rules to distribute water**
  - § **ELM v2.8.4 (0.25 km^2 grid) was driven by SFWMM and RSM (point) water control structure flows, simulating landscape/canal flows of water and phosphorus**

Decomp Phase 1 Planning Alternatives





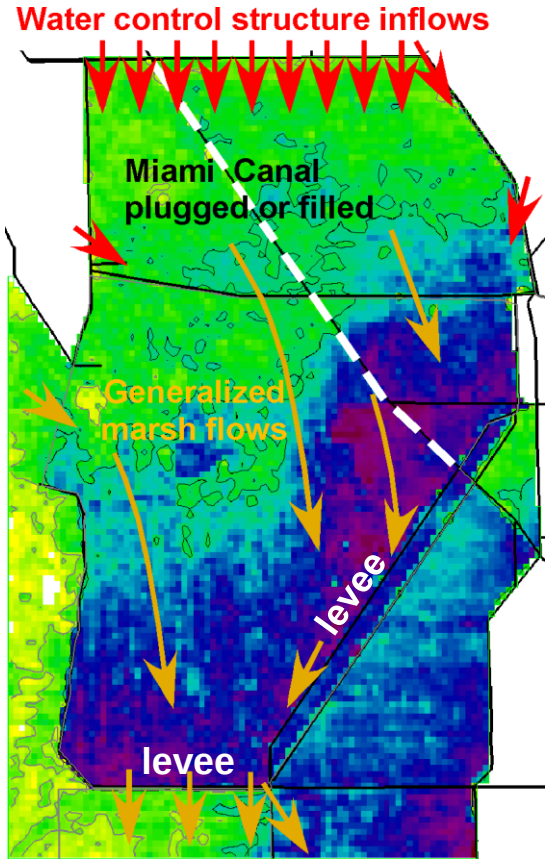
WCA3A water management: Generalized Baseline flows.



WCA3A water management: Generalized Decomp flows.

(Background water depth map same in both diagrams: red=deep)

Decomp Phase 1 Planning Alternatives



Hydropattern restoration– distribute point inflow sources more widely

- Full spread of inflows along north boundary, or
- Combinations of less spread of inflows, or
- No action

Miami Canal modification – presence is flow barrier, and/or accelerates drainage

- Fill – completely, or
- Fill – partial (one or more sections), or
- Plugs – multiple plugs along canal, or
- No action

Future CERP projects will remove levees, input more water... towards restoration

Model setup & assumptions

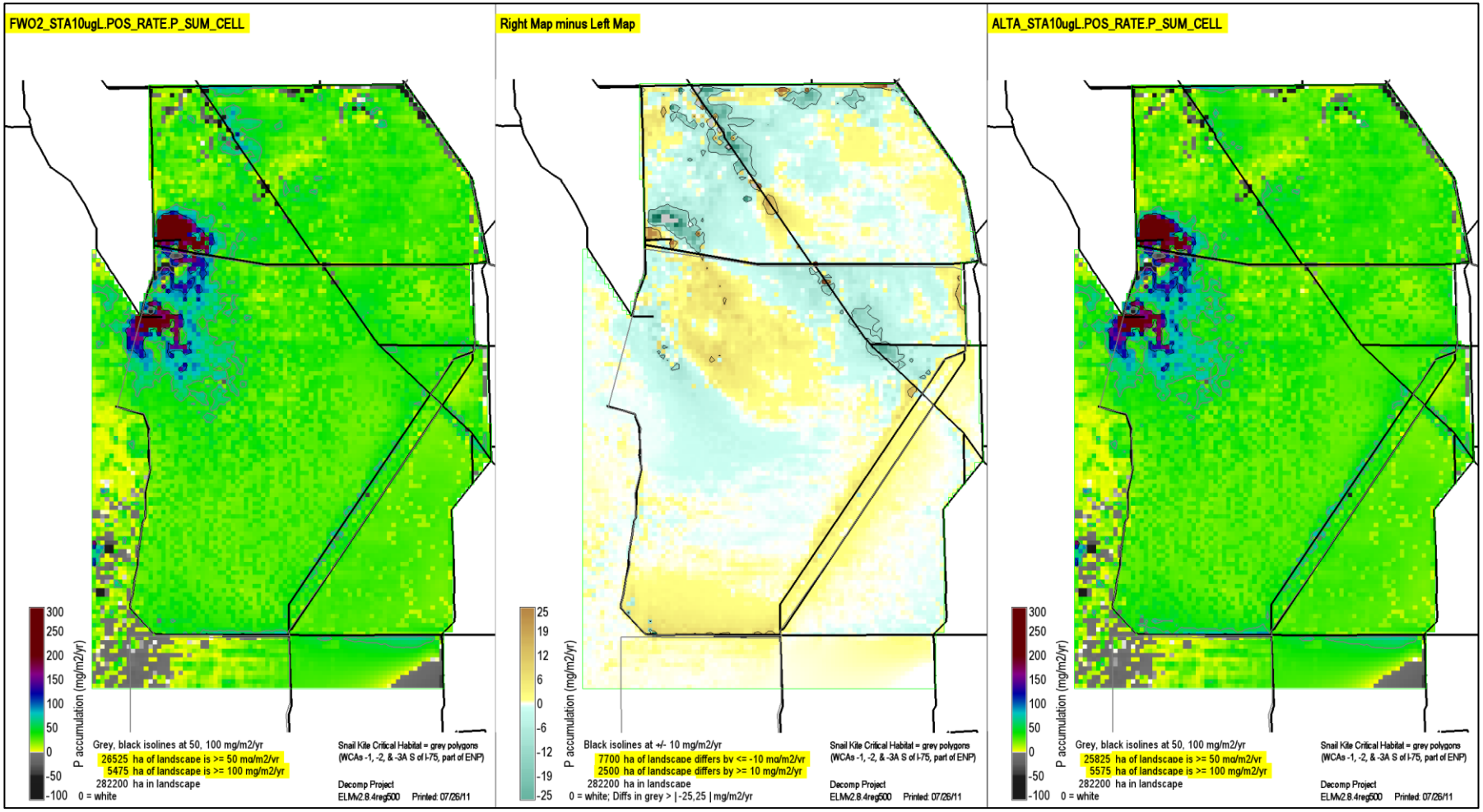
- **Water management**
  - § **7 Alternatives (Alts): "A" – "H"**
  - § **2 Bases: Future WithOut (FWO), Existing Condition Base (ECB)**
  - § ***Common*: All were 36-year future simulations, 1965-2000 climate**
  - § ***Differences*: Infrastructure and operations varied among runs**
- **Water quality**
  - § ***Common*: All but ECB** simulations assumed 10 ug l^{-1} P inflow concentration from STAs (Stormwater Treatment Areas)**
  - § ***Common*: All simulations have same (relatively high) P inflow concentrations from other basin sources**
- **Performance Measures/Indicators**
  - § **RSM: Many metrics used to evaluate hydrologic benefits of Alts relative to FWO base**
  - § **ELM: Eight metrics used to evaluate water quality/ecology of Alts relative to FWO base**

*** unused ECB assumed recent P inflow concentrations from STAs, overall mean 23 ug l^{-1}*

Primary Performance Indicator:

P accumulation rate

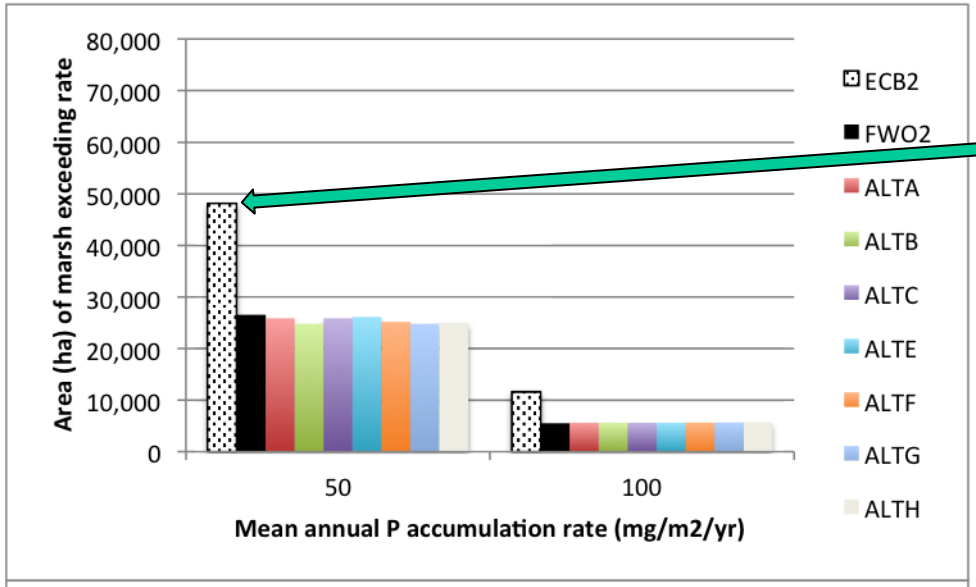
FWO_Base | **AltA – FWO_Base** | **AltA**

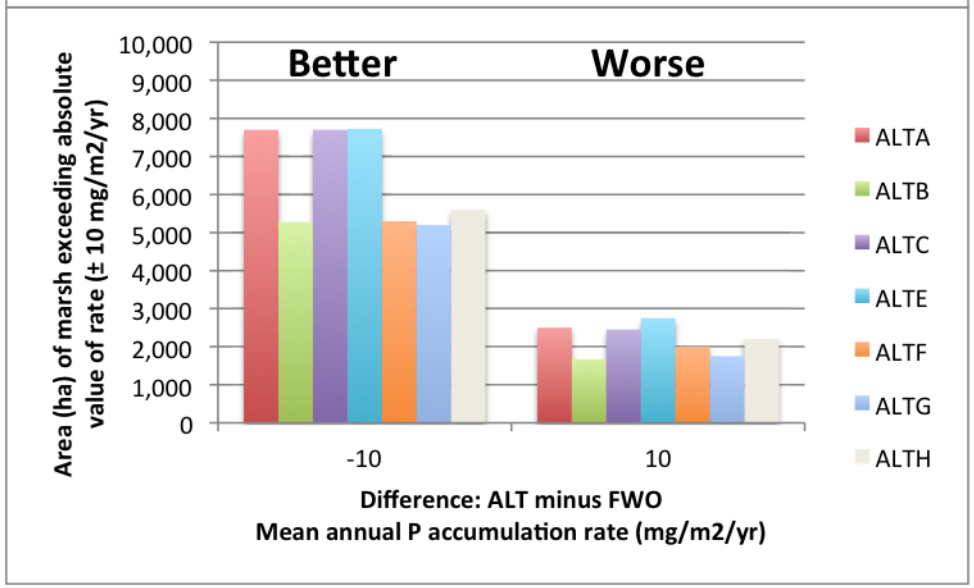


Blue shades in Difference-Map =

AltA less P accumulation than FWO_Base

Simulated P accumulation rate in the Decomp PIR 1 domain considered in ELM. Period of Simulation (POS) mean rate. The total area of that domain is 282,200 ha.





Bases: ECB vs. FWO

-- Relative to FWO, ECB had significantly more marsh area with excessive P accumulation (> 50 mg P m^2 yr^{-1})

Alts vs. FWO

-- None of the Alts (A-H) showed meaningful differences in eutrophication relative to FWO (Base used in planning)

Conclusions

- **Eutrophication risk**
  - Relative to FWO base, no Alternative had meaningful overall differences in future eutrophication risk – but all Alts showed somewhat less risk than FWO
  - Localized spatial differences were found among Alternatives, including benefits of full backfill of Miami Canal (and to some extent, full-plugging of Miami Canal)
  - Hydropattern restoration features distributed ("diluted") P inputs along wide area, tending to reduce localized ecosystem eutrophication (compared to point inflows)
  - Alternative A, with Full Hydropattern restoration and complete backfill of Miami Canal, was one of the, if not the, preferred Alts regarding localized eutrophication risk – but all differences were small
- **Preferred Alternative**
  - RSM showed that most hydrologic benefits occurred in northern WCA-3A, supported by ELM hydro-ecological results
  - Project Development Team used RSM and ELM results to inform the evaluations of best performing plans for Decomp Phase 1
- **http://ecolandmod.ifas.ufl.edu/Projects/**
  - History-matching ELM performance documentation
  - ELM Decomp application assumptions, inputs, and results

Ongoing application/research

- **CERP Aquifer Storage & Recovery (ASR)**

  - Evaluate downstream Everglades sulfate distributions under different ASR configurations/operations

- **Florida Coastal Everglades - LTER**

  - Integrate recent multi-disciplinary research results into ELM

  - Apply ELM as landscape framework for multi-model assessments of climate change & sea level rise

- **Water resource sustainability en España**

  - Develop ecological-economic module to assess land & water management practices in the Segura basin (with N. Guaita, others)