turning knowledge into practice

Predicting Change in Nitrogen Deposition & Loading to Escambia Bay due to Additional Emissions Controls on Plant Crist

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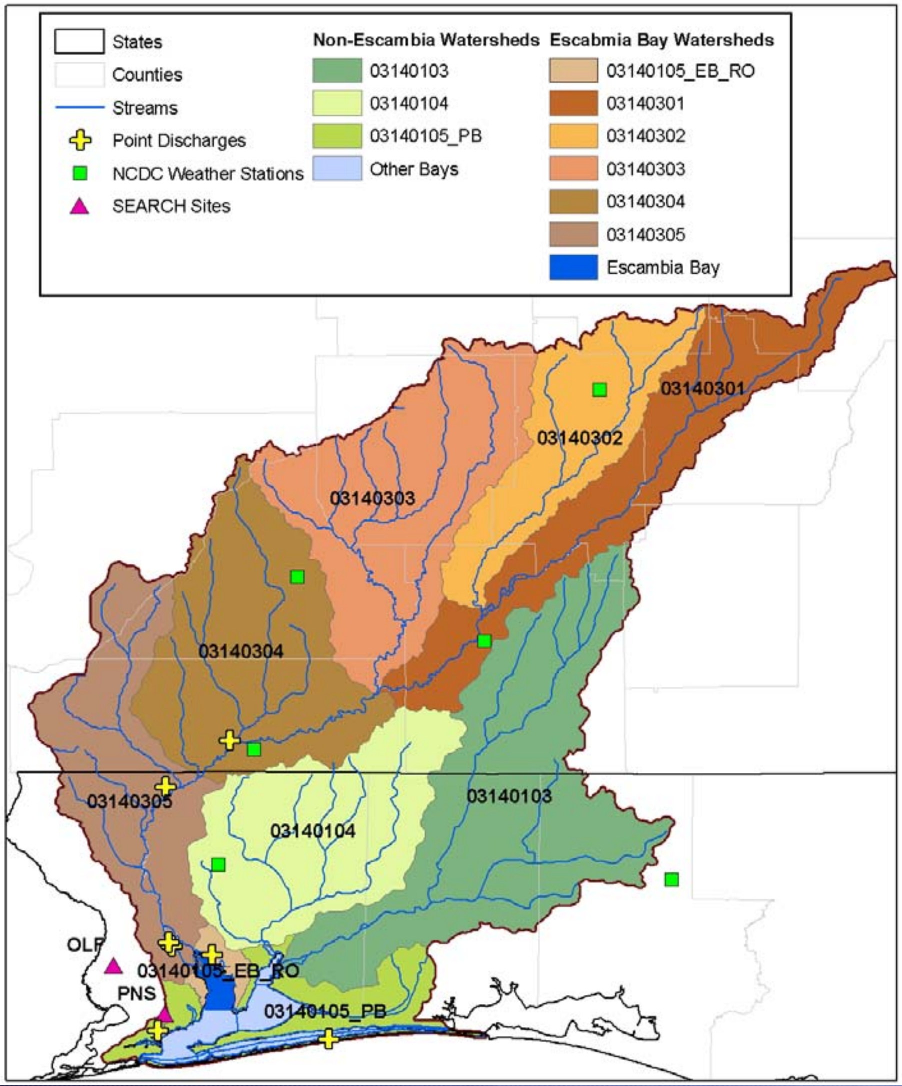
Study Objectives

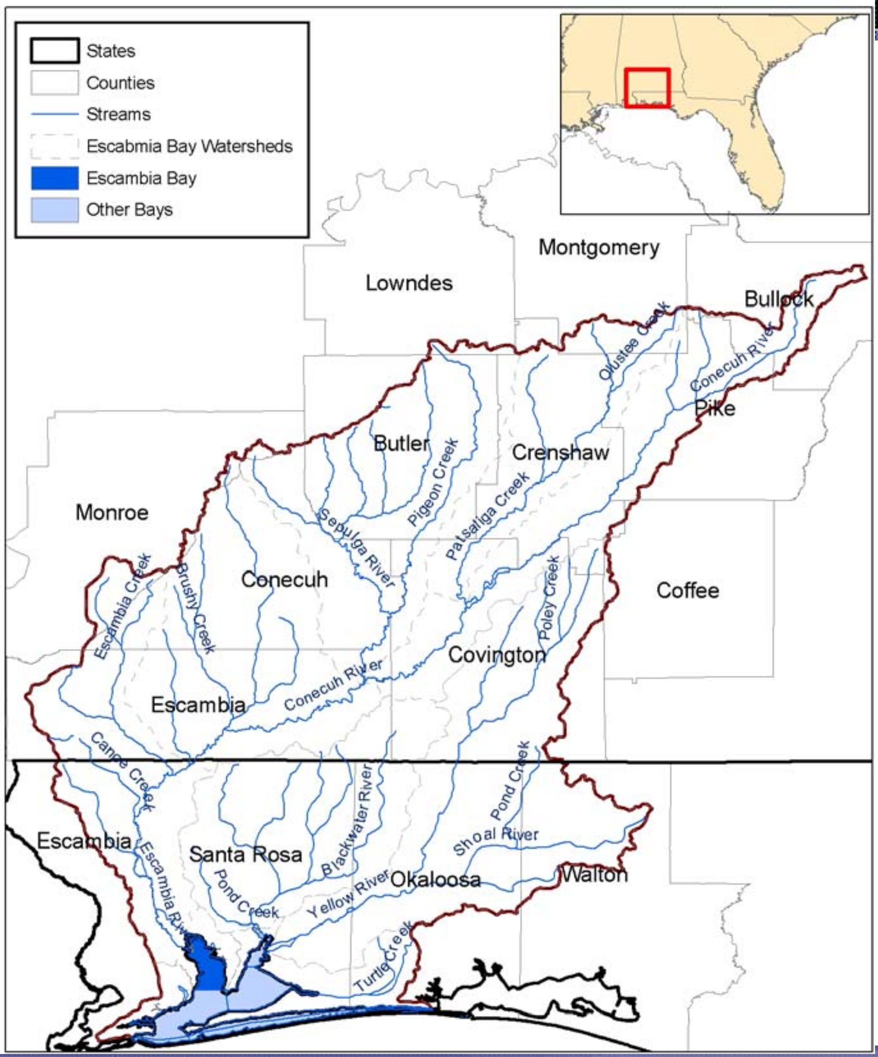
- The objective of this modeling study was to estimate the difference in total nitrogen loading to Escambia Bay between two scenarios:
  - Current conditions (“no controls” scenario)
  - After installation of additional emission controls for NO_x and SO_2 at Plant Crist (“controls” scenario)

Presentation Outline

- Description of study area
- Atmospheric modeling component
- Watershed modeling component
  - Criteria for models used
  - Screening and intermediate level models chosen
  - Model parameterization
  - Modeling methodology
- Characterization of nitrogen fate and transport
- Results
- Findings and recommendations for next steps

Area of Interest





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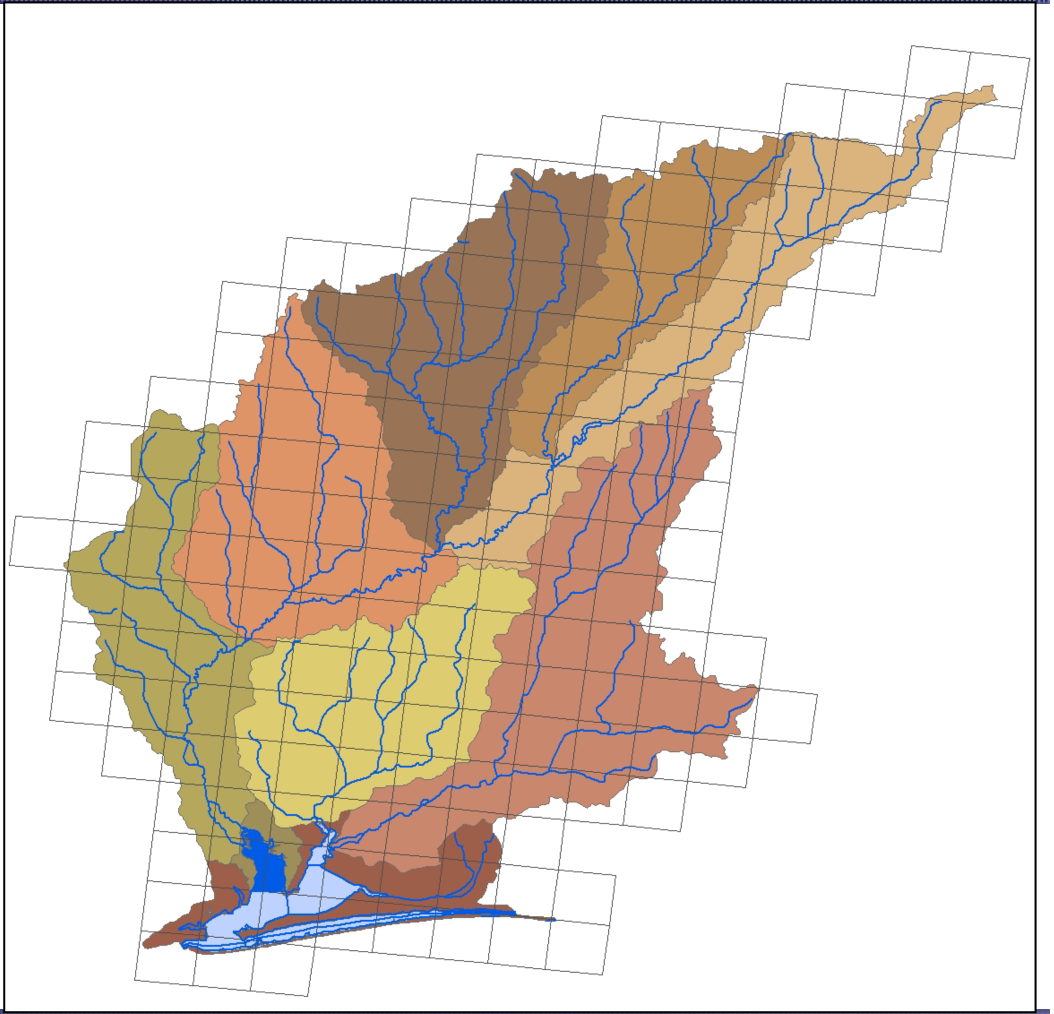
Atmospheric Models

- To investigate the effect of different models reflecting evolving science, several atmospheric models were used:
  - CMAQ-VISTAS
    - CMAQ v4.5.1 with SOA modifications by VISTAS RPO
    - Does not include coarse sea-salt/nitrate interactions
  - CMAQ-MADRID
    - CMAQ v4.5.1 with Model of Aerosol Dynamics, Reaction, Ionization, and Dissolution (MADRID) aerosol treatment
    - Includes full sea-salt/HNO_3 chemistry and heterogeneous NO_3 chemistry
  - CMAQ-MADRID-APT
    - CMAQ-MADRID with plume-in-grid advanced plume treatment (APT)
  - CMAQ-VISTAS + CALPUFF
    - Combines Eulerian grid model (background) with single source puff model

Atmospheric & Watershed Model Linkages

- Time Step
  - Hourly vs. Daily & Yearly
- Space
  - Grid cells vs. Land Use & Watershed
- Species
  - Chemical mechanism vs. Total Nitrogen



Watershed Model Selection

- Key Considerations
  - **Ability of the watershed model to use the air quality modeling output**
  - Data requirements
  - Availability of model
  - Effort and time required to set up, calibrate, and run the model
  - Geographic applicability
  - Inclusion of nitrogen speciation
  - Simulation of groundwater interactions, biological processes, and aquatic chemistry
  - Time required for implementation vs. project schedule

Watershed Models Chosen

Model	Export Coefficient	ReNuMa
Level	Screening	Intermediate
Basis	Export coefficients & Pass through rates; PLOAD	GWLF[1] model, NANI[2] accounting system
Timestep	Yearly	Daily inputs, Monthly outputs
Hydrologically Driven		**X**
Includes Point Sources	**X**	**X**
Specific N Sources[3]		**X**
Considers Land Use	**X**	**X**
Denitrification		**X**
Particulate & Dissolved N		**X**
Calibration Procedures		**X**

1 Generalized Watershed Loading Functions

2 Net Anthropogenic Nitrogen Input

3 Including fertilizer, manure applications, & septic systems

Model Parameterization

- Export Coefficient Method (EC)
  - Literature search for geographically relevant export coefficients and pass-through rates
- ReNuMa (Regional Nutrient Management Model)
  - *Literature search:* fertilizer & manure application rates, SCS curve numbers, sediment and groundwater nitrogen concentrations
  - *EPA Systems:* point source loads & calibration data
  - *GIS:* populations served by septic systems
  - *Calibration:* denitrification rates, erosivity coefficients, hydrologic parameters
- Applied instream loss terms to watershed loads that do not directly enter the bay

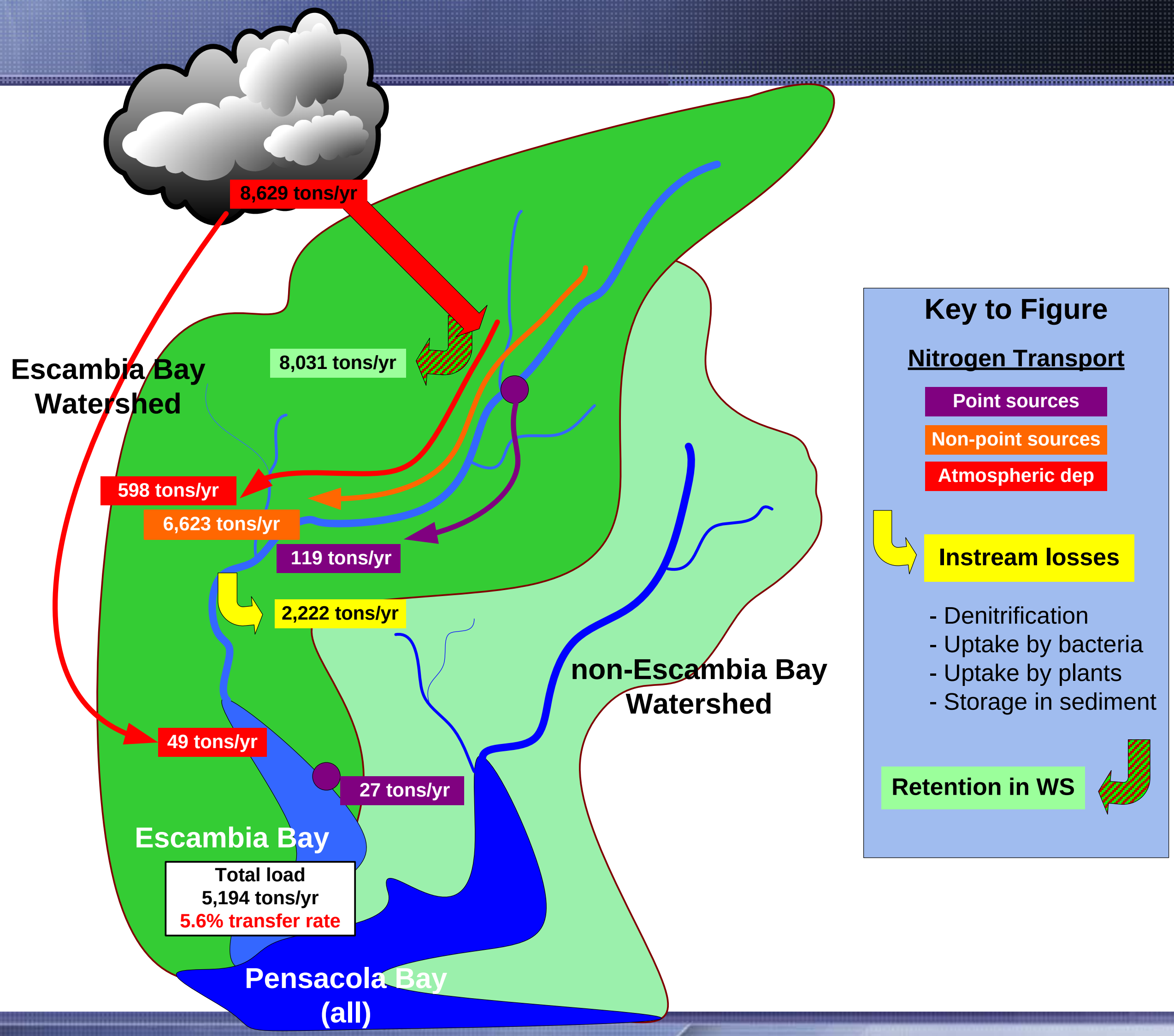
Methodology

- Change between no control and control scenarios based on difference between initial loads and loads entering the bay
  - EC method: only a delta in atmospheric load
  - ReNuMa: a delta in both the atmospheric load and the NPS load due to simulation of watershed retention processes
- Transfer rates determined as load reaching the bay divided by initial load deposited

$$\text{Transfer Rate} = \frac{\text{Mass to Bay}^{*}{}_{\text{NC}} - \text{Mass to Bay}^{*}{}_{\text{Controls}}}{\text{Atmos Depo}_{\text{NC}} - \text{Atmos Depo}_{\text{Controls}}} \times 100$$

Note: Change in “Mass to Bay” calculated differently for EC method and ReNuMa

Characterization of Nitrogen Flow



Results of Watershed Modeling

Watershed	Scenario	Export Coefficient Method			ReNuMa		
		Atmospheric Deposition Input (tons/yr)	Atmospheric Deposition Load to the Bay (tons/yr)	Transfer Rate	Atmospheric Deposition Input (tons/yr)	Atmospheric Deposition Load to the Bay (tons/yr)	Transfer Rate
Escambia Bay Watersheds							
Indirect Deposition Over Individual Watersheds	No Controls	105-2,156	27 - 285		101 - 2,155	12 - 138	
	Controls	100-2,146	26 - 278	13	97 - 2,146	11 - 137	6
Direct Deposition Over Escambia Bay	No Controls	50 - 52			50 - 52		
	Controls	49 - 50		100	49 - 50		100
Totals for Escambia Bay System	No Controls	8,796 - 9,088	980 - 1,017		8,780 - 9,085	497 - 511	
	Controls	8,689 - 8,996	966 - 1,003	11	8,678 - 8,995	490 - 504	6
Non-Escambia Bay Watersheds							
Indirect Deposition Over Individual Watersheds	No Controls	545 - 2,580	27 - 285		544 - 2,580	57 - 99	
	Controls	535 - 2,563	26 - 278	18	534 - 2,562	56 - 98	6
Direct Deposition Over Non-Escambia Bay	No Controls	218 - 227			218 - 227		
	Controls	215 - 224		100	215 - 224		100
Totals for Non-Escambia Bay System	No Controls	4,805 - 5,039	940 - 984		4,799 - 5,038	433 - 451	
	Controls	4,729 - 4,975	925 - 971	20	4,723 - 4,974	426 - 446	9
Entire Pensacola Bay System							
Totals for Pensacola Bay System	No Controls	13,601 - 14,127	1,920 - 2,001		13,579 - 14,123	930 - 962	
	Controls	13,429 - 13,971	1,892 - 1,974	14	13,401 - 13,969	916 - 950	7

Results of Implementing Controls

$$\text{Transfer Rate} = \frac{\text{Mass to Bay}^{*}{}_{\text{NC}} - \text{Mass to Bay}^{*}{}_{\text{Controls}}}{\text{Atmos Depo}_{\text{NC}} - \text{Atmos Depo}_{\text{Controls}}} \times 100$$

* Change in “Mass to Bay” is due only to change in Atmospheric Deposition load to the bay for the ECM but due to both Atmospheric Deposition and Non-Point Source load changes for ReNuMa

- ReNuMa predicts a smaller decrease in load due to controls compared to the ECM
- Reductions for the Escambia Bay WS and Non-Escambia Bay WS similar between the models
- Higher transfer rate for Non-Escambia Bay system (~18%) compared to Escambia Bay system (~13%)

Final Results for Escambia Bay Watershed

Atmospheric Model	Watershed Model	Change in Atmospheric Nitrogen to Watershed/Bay (tons)	Change in Nitrogen Load to Bay (tons)	Fraction of Nitrogen to Bay from Atmospheric Deposition	Transfer Rate
CMAQ VISTAS	Export Coefficient	-92	-14	22	15
	ReNuMa	-90	-11	9.7	12
CMAQ MADRID APT	Export Coefficient	-107	-14	21	13
	ReNuMa	-108	-11	9.6	10
CMAQ MADRID	Export Coefficient	-100	-18	21	18
	ReNuMa	-102	-12	9.5	12

Findings and Limitations

- Transfer rates vary by watershed and system, hence results are not transferable to other watersheds
- Reductions in atmospheric deposition cause non-linear reductions in loads transferred from the watersheds due to watershed processes
- Difference in nitrogen loads to the bay between controls and no controls is VERY small for all of the scenarios
- Examination of fate and transport of different species of nitrogen not completed but atmospheric results suggest this is an important consideration
- Significant advantages to the methodology that we developed with regard to data requirements and efficient run time
- A maximum load 18 tons of N to Escambia Bay can be offset through planned reductions in emissions from Plant Crist

Recommended Next Steps

- Further calibration of current formulation with ReNuMa
- Run current analysis for more than one year to remove meteorological bias
- Use a process-based model in place of empirically based model with mass balances
- Expand analysis to use watershed model which includes nitrogen speciation
- Compare results of this analysis to those of a more comprehensive analysis with a more extensive watershed model to determine if intermediate level analyses can produce corresponding results

Questions?