Exploring the Management Value of a Machine Learning-Based Model that Predicts Chlorophyll-α Using Multi-Media Modeling Environmental Predictors

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20th ANNUAL CMAS Conference
Nov 1-5 | Virtual

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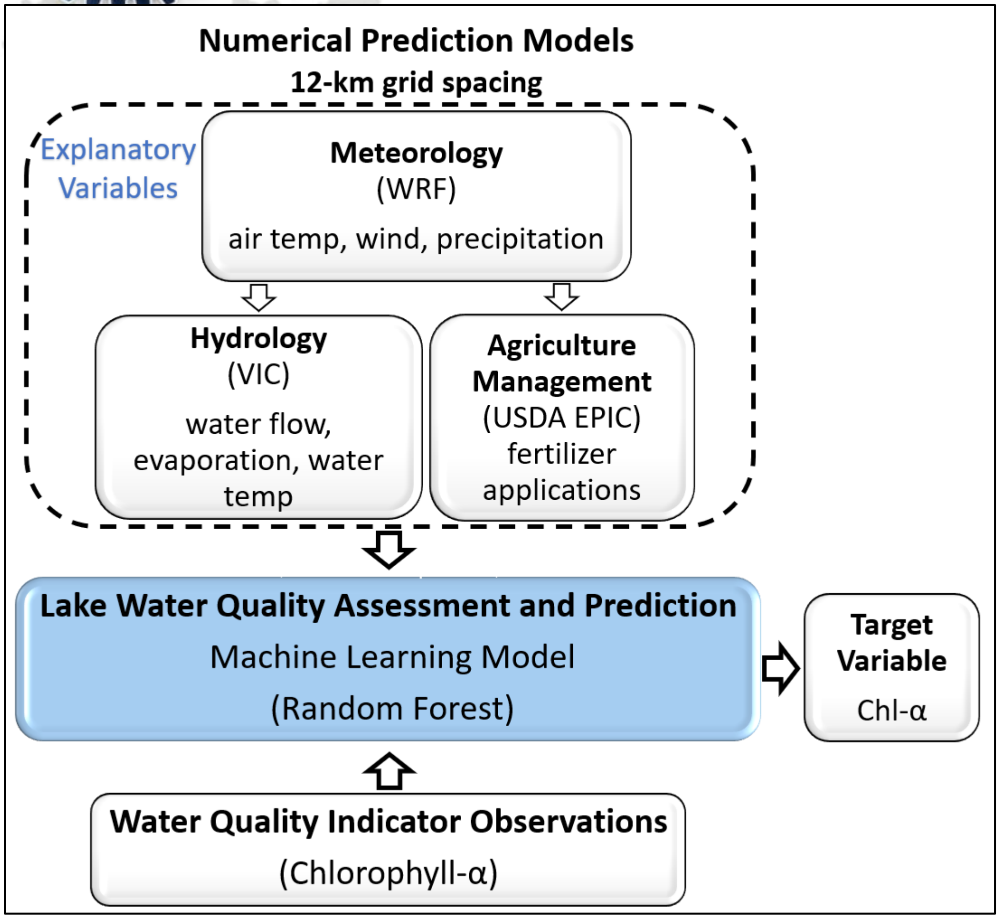
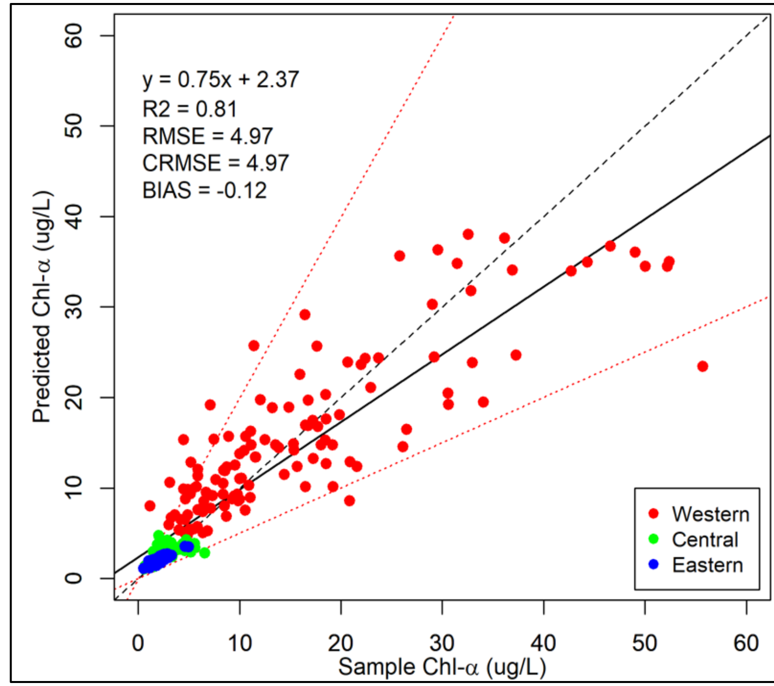
Chl-α Model (Published Work)



Prediction of seasonal Chl-α



- Over 80% of variance in chl-α measurements is explained by the RF model
- Eutrophic conditions (chl-α < 5 ug/L) are identified 94.7% of the time

C. Feng Chang et al., 2021 (in press). Linking multi-media modeling with machine learning to assess and predict lake chlorophyll α concentrations. Journal of Great Lakes Research.

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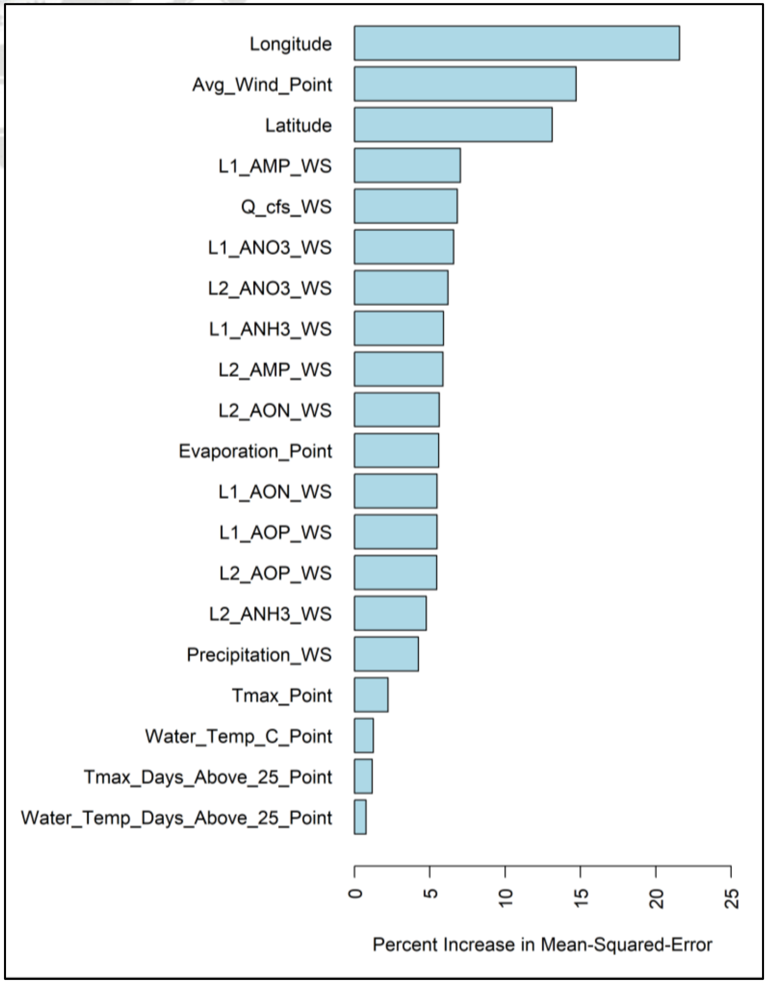
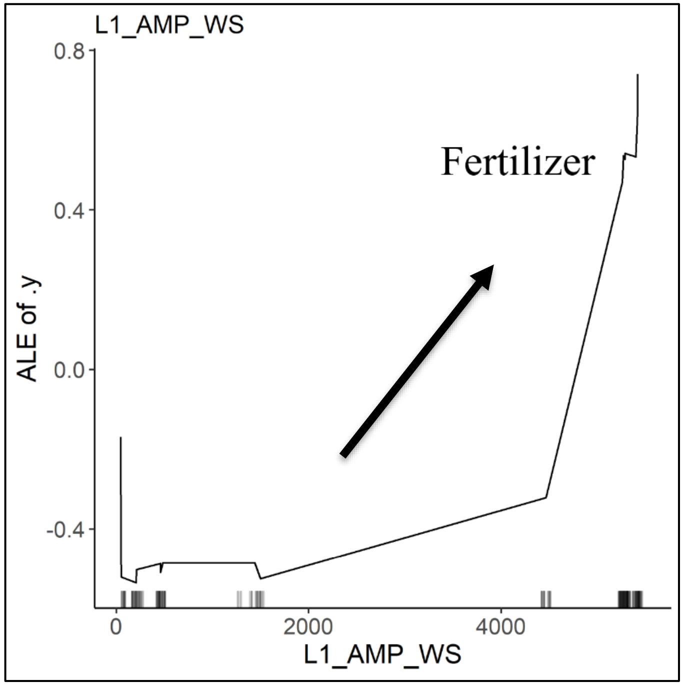
Chl-α Model (Published Work)

Variable Importance Plot



Accumulated Local Effect Plot



C. Feng Chang et al., 2021 (in press). Linking multi-media modeling with machine learning to assess and predict lake chlorophyll α concentrations. Journal of Great Lakes Research.

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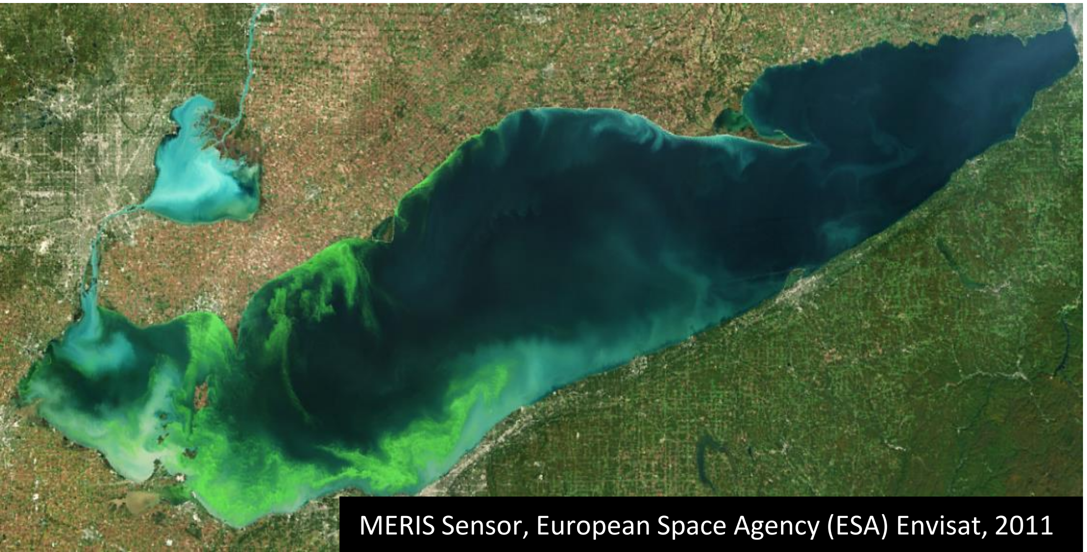
Scope and Objectives

SCOPE: Investigate how managing agricultural fertilizers affects the prediction of chlorophyll-α (chl-α), a proxy for algal growth

Use **multi-media modeling** and **machine learning (ML)** to:

- Evaluate how fertilizer application reduction scenarios can impact predicted chl-α concentrations
- Identify whether reducing fertilizer applications can revert predicted chl-α concentrations back to healthy levels



MERIS Sensor, European Space Agency (ESA) Envisat, 2011

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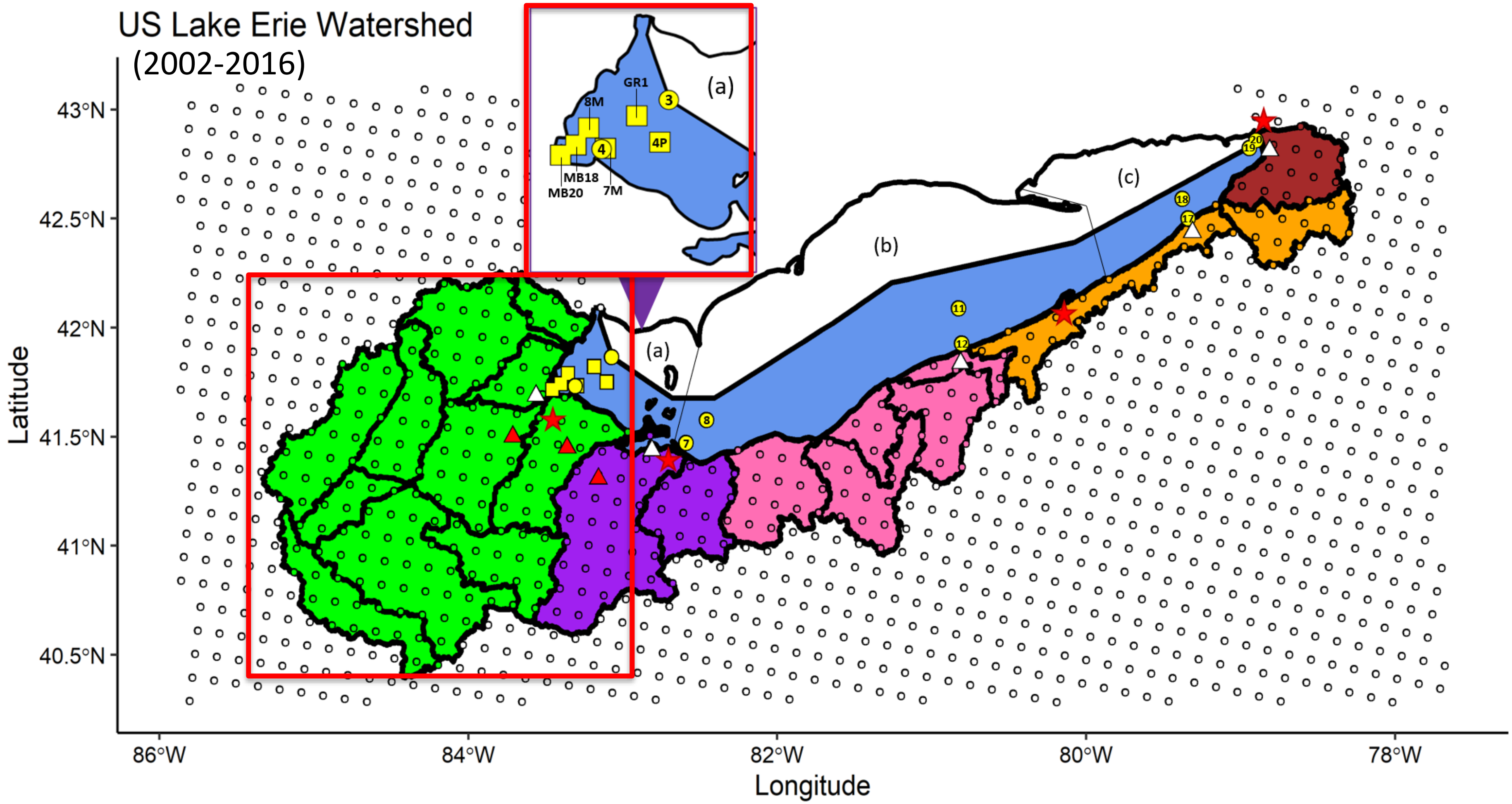
MODEL DATA: Observed Variable



- In-situ chl-α measurements provided by:
  - Lake Erie Committee Forage Task Group (LECFTG)
  - University of Toledo Lake Erie Center (UT-LEC)
- Chl-α measurements are seasonally averaged (May to September)

MODEL DATA: Modeled Variables

Explanatory Variables	Units	Model
Latitude (static variable)	degrees (°)	
Longitude (static variable)	degrees (°)	
Tmax (Point)	°C	WRF
Tmax_Days_Above_25 (Point)	days	WRF
Precipitation (WS)	mm	WRF
Avg_Wind (Point)	m/s	WRF
Evaporation (Point)	kg/m^2	VIC
Water Flow (WS)	cfs	VIC
Water_Temp_C (Point)	°C	VIC
Water_Temp_Days_Above_25 (Point)	days	VIC
Layer1 N-NO3 (Nitrate) Application Rate (WS)	tons	EPIC
Layer1 N-NH3 (Ammonia) Application Rate (WS)	tons	EPIC
Layer1 ON (Organic N) Application Rate (WS)	tons	EPIC
Layer1 MP (Mineralized P) Application Rate (WS)	tons	EPIC
Layer1 OP (Organic P) Application Rate (WS)	tons	EPIC
Layer2 N-NO3 (Nitrate) Application Rate (WS)	tons	EPIC
Layer2 N-NH3 (Ammonia) Application Rate (WS)	tons	EPIC
Layer2 ON (Organic N) Application Rate (WS)	tons	EPIC
Layer2 MP (Mineralized P) Application Rate (WS)	tons	EPIC
Layer2 OP (Organic P) Application Rate (WS)	tons	EPIC

Reduction of fertilizer applications

Methodology:

- Training chl-α model: 2002-2015 data
- Application of reduction scenarios: 2016 data
  - Only changing fertilizer application rates

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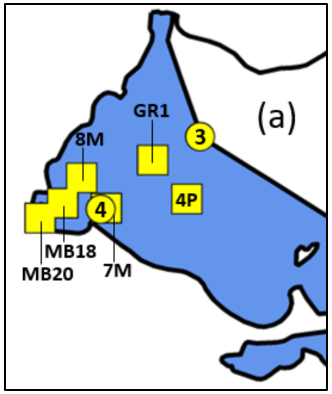
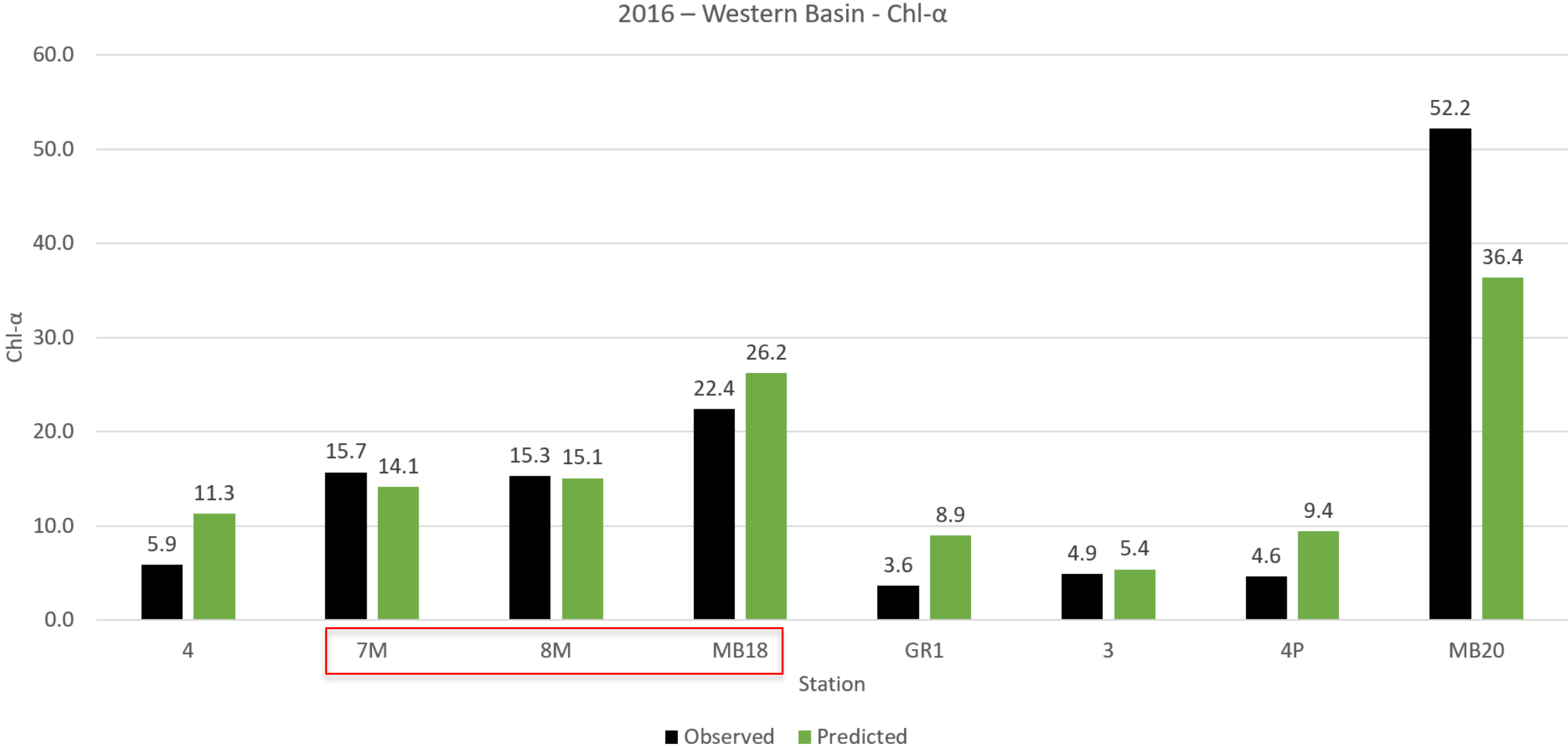
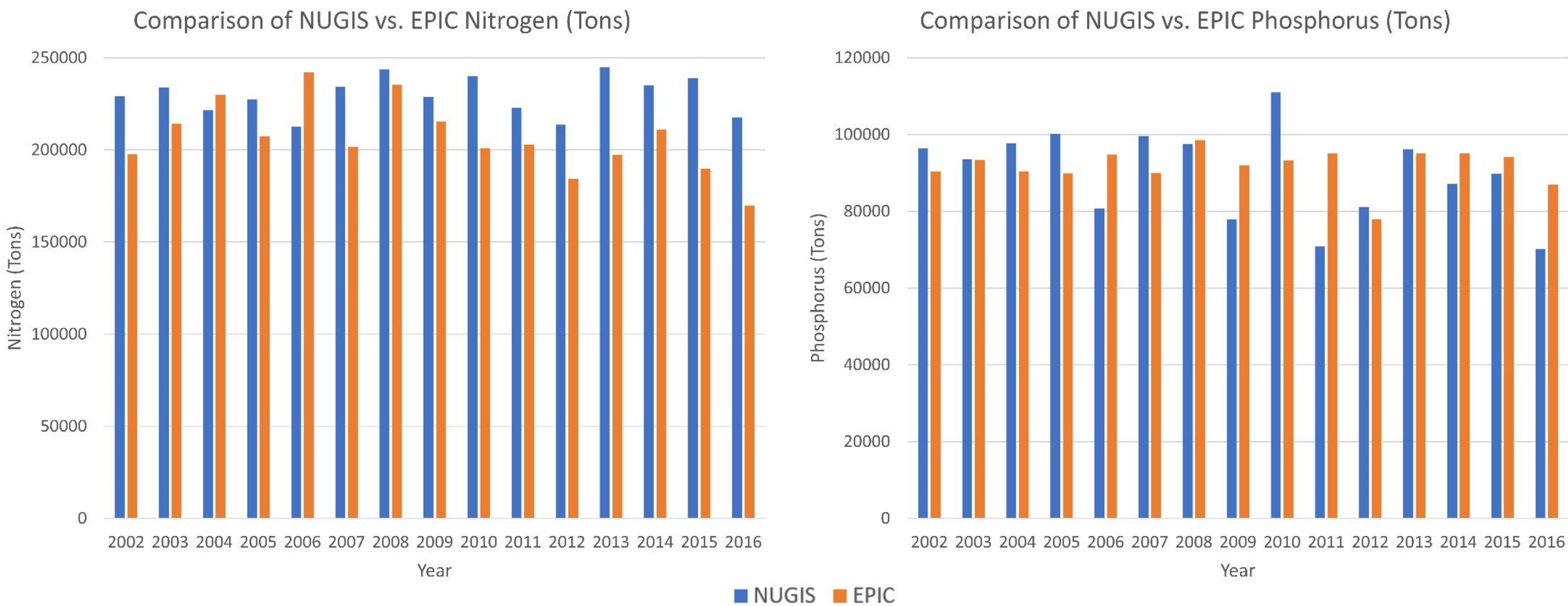
MODEL DATA: Stations of Interest



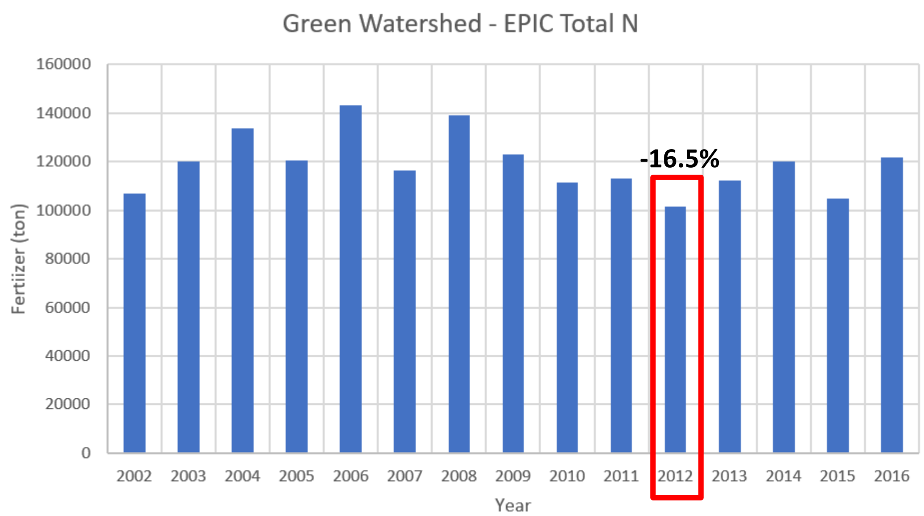


Evaluation of EPIC for Lake Erie

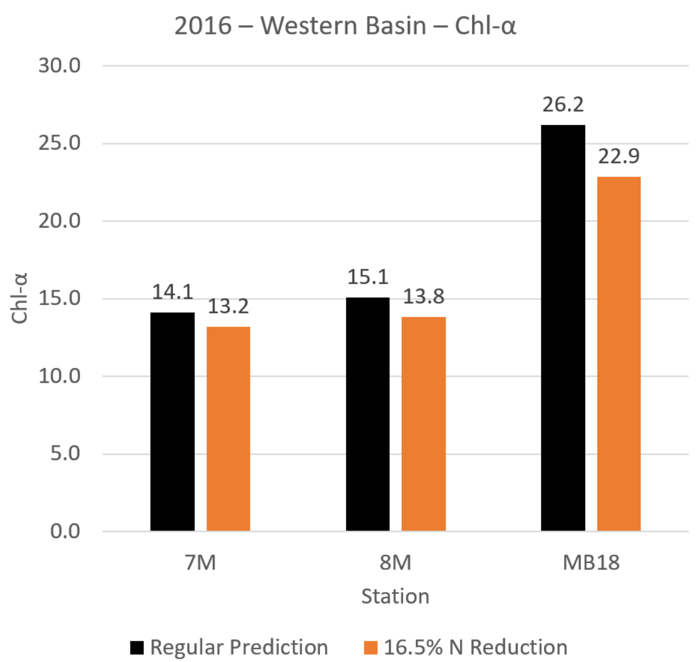


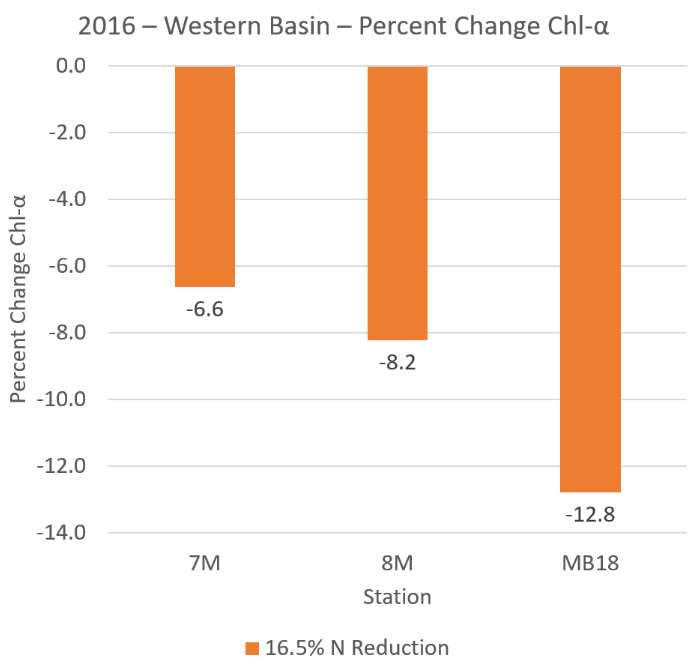
- EPIC under-predicts applied N by 9.86% error and overpredicts applied P by 3.59% **(C. Feng Chang et al., (in press))**

Results: N Baseline Reduction



- What if the amount of 2016 N fertilizer applications were reverted to its lowest point in 2012?
  - N reduction of 16.5%





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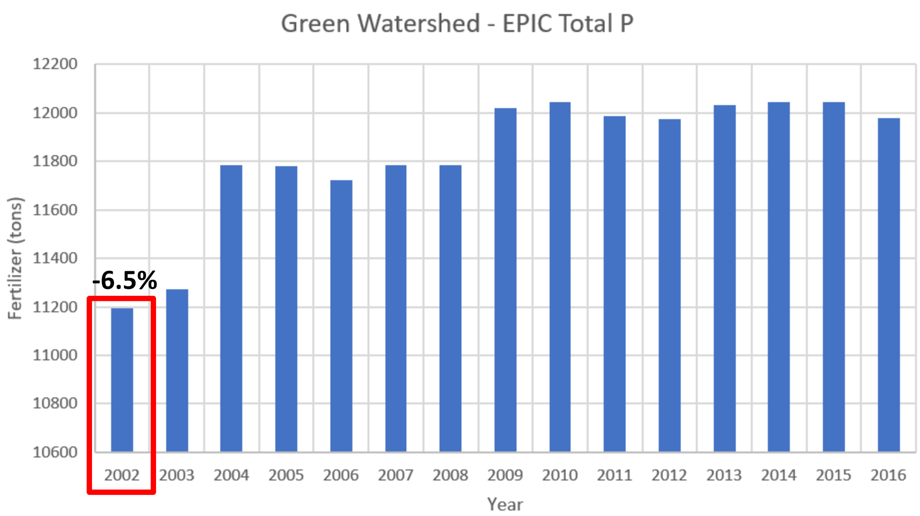
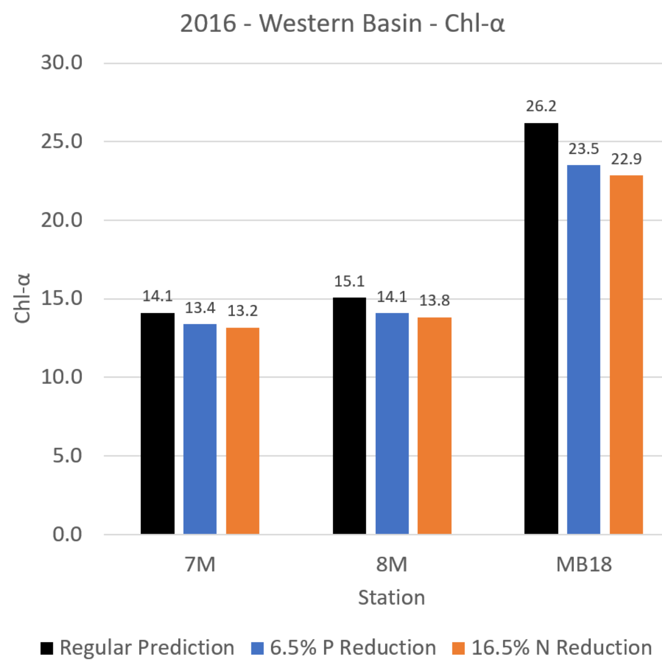
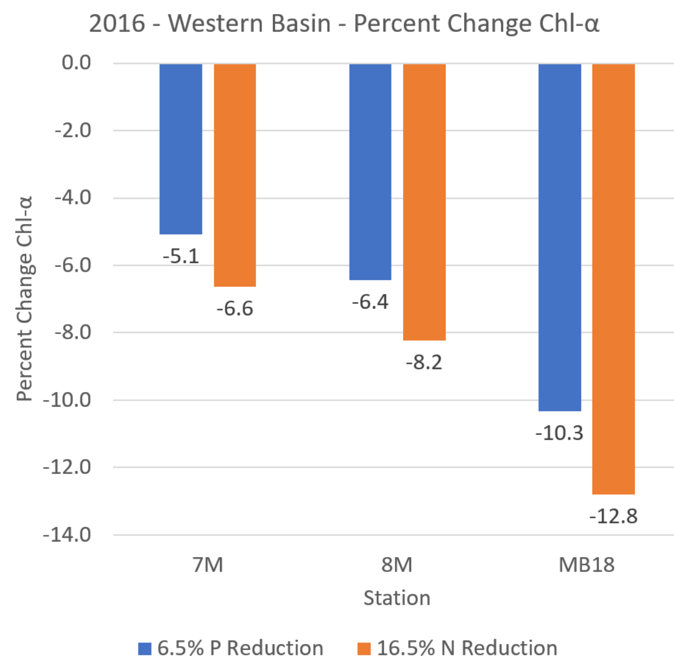
Results: P Baseline Reduction



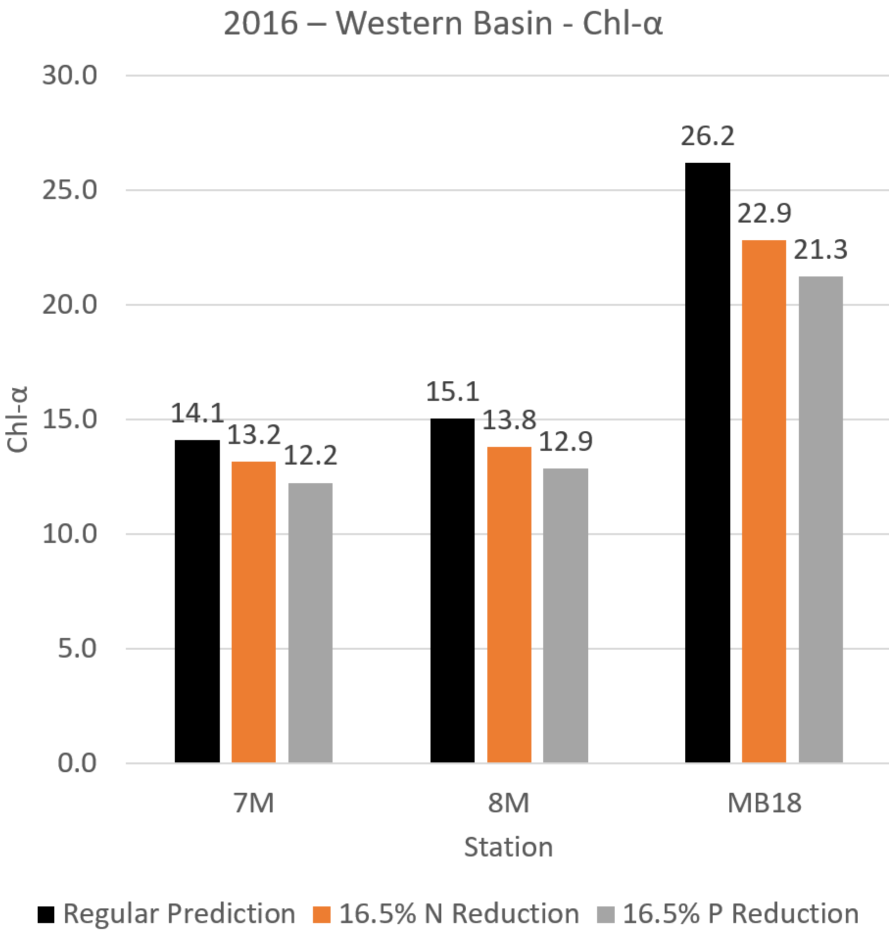
- What if the amount of 2016 P fertilizer applications were reverted to its lowest point in 2002?
  - P reduction of 6.5%

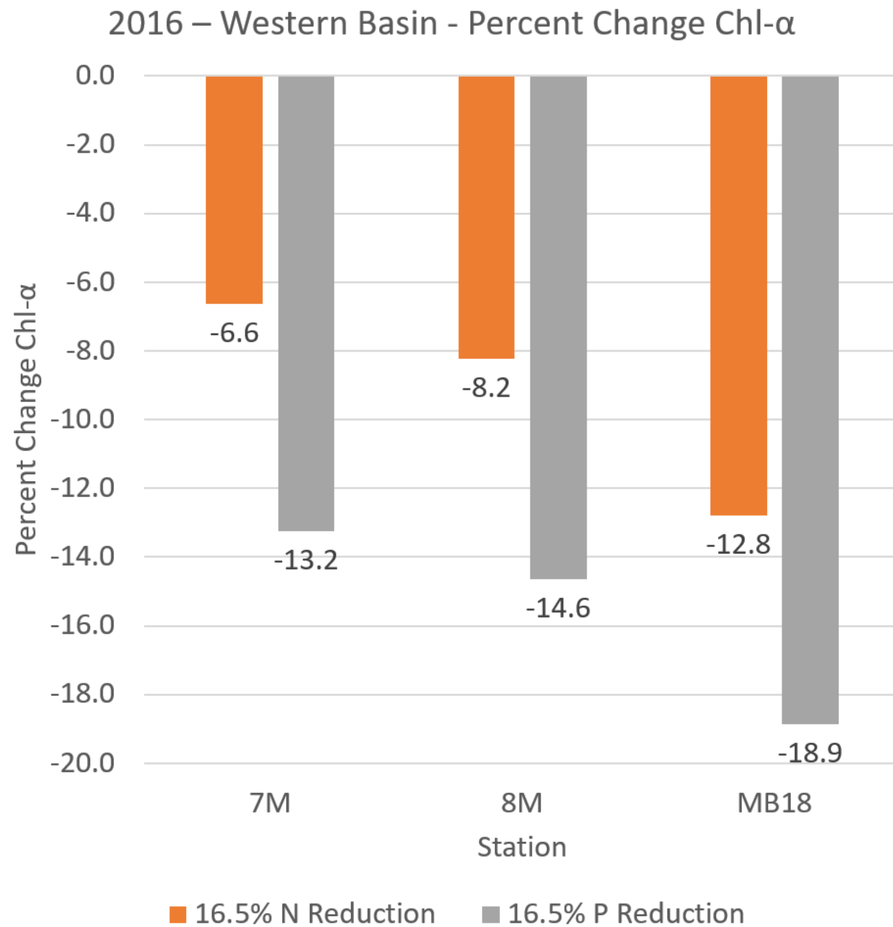




Results

- What if the amount of 2016 P fertilizer applications were reduced by 16.5%?





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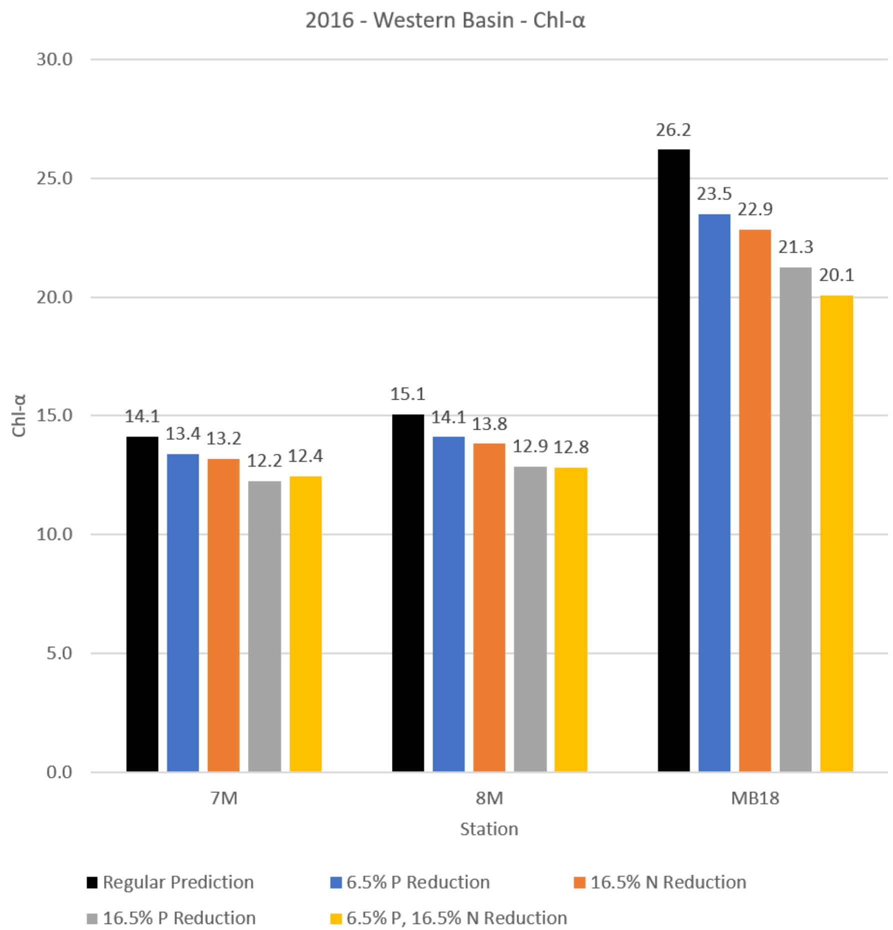
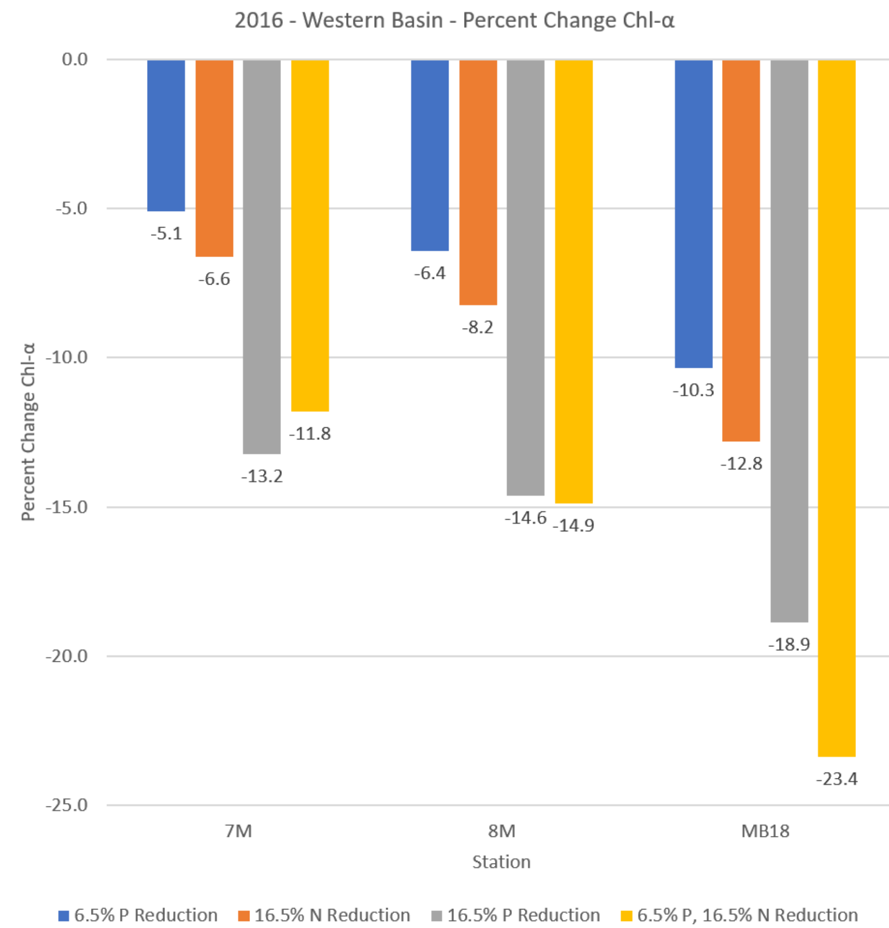
Results and Discussion: Combined Baseline Reduction

- What if both 2016 P and N fertilizer applications were reduced?





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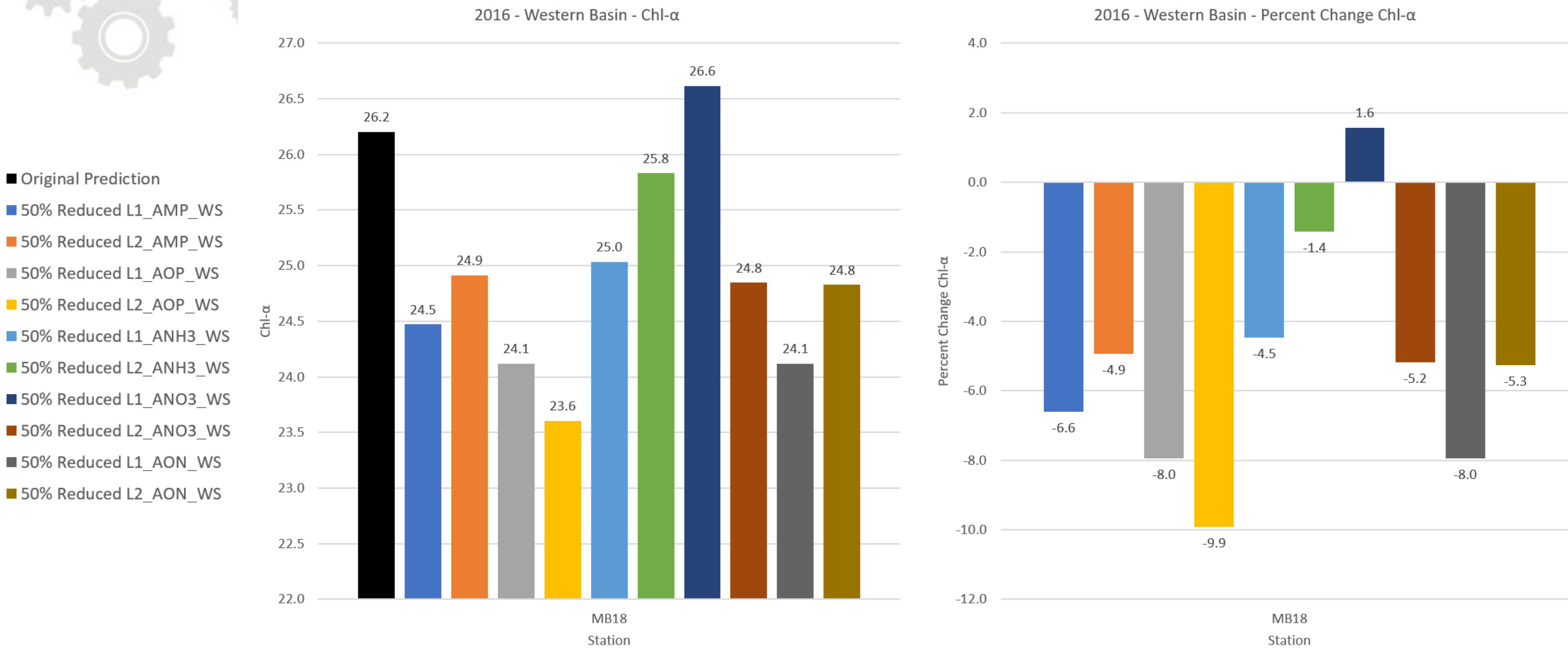
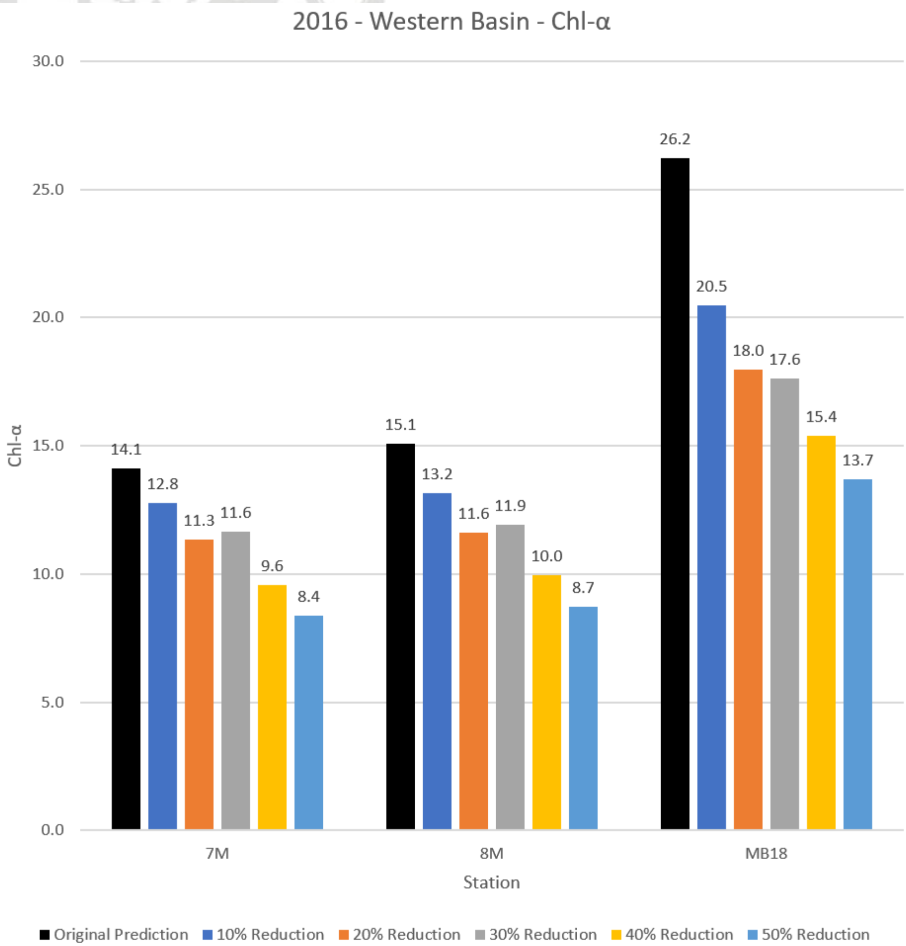
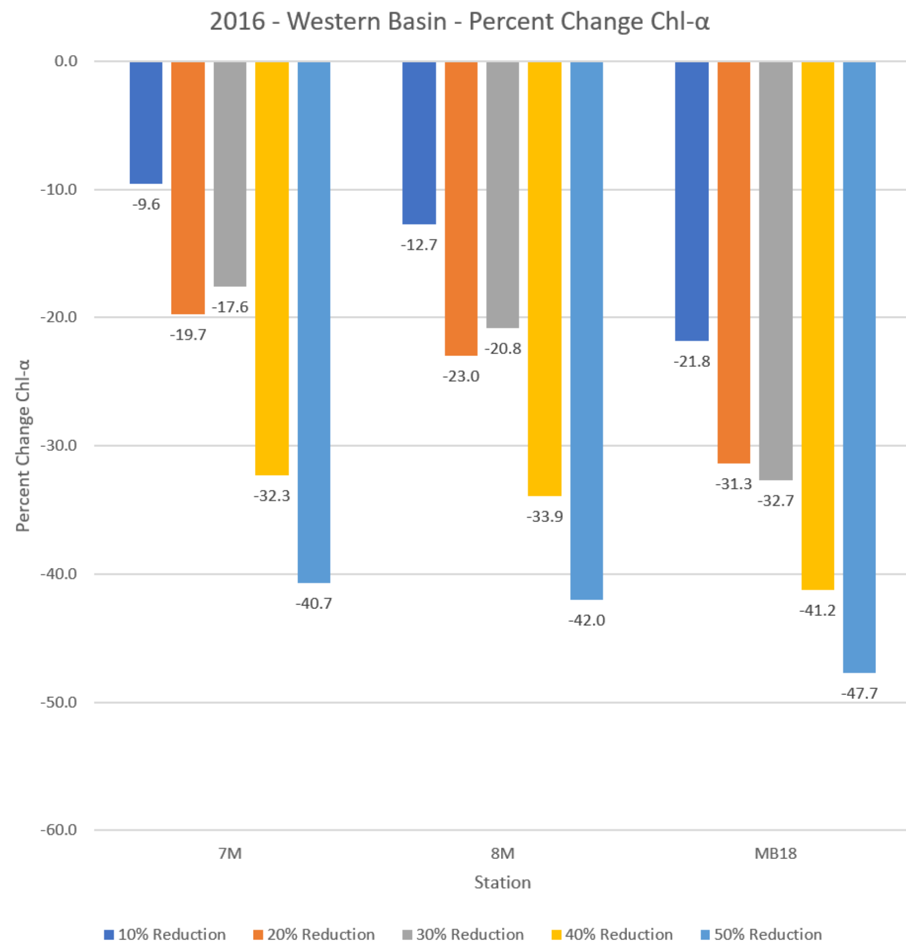
Results and Discussion: Individual 50% Reduction



Results and Discussion: Combined % Reduction

Total N and Total P Reduction





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Limitations

- Differences between the actual number of fertilizers vs. predicted EPIC fertilizer applications
- Synergistic roles of meteorology and hydrology that affect the fate and transport of fertilizer applications and the prediction of chl-α are not included
- Fertilizer application management scenarios presented are difficult to attain and unrealistic
- Current scenarios conducted are low in granularity:
  - Considers the effects of fertilizer reductions in one watershed for the western stations only
  - Does not consider changes in cropland usage (e.g., increase/decrease in corn production)
  - Focuses solely on fertilizer reduction (e.g., explore other agricultural management practices such as till vs. no-till farming)

SUMMARY and FUTURE WORK

Summary of ongoing work

- More problematic chl-α stations will benefit the most from fertilizer reductions
- Reducing only P fertilizers leads to a higher reduction in chl-α than reducing only N fertilizers, however, a combined reduction of both leads to the best results
- Even with a dramatic reduction in fertilizers, it is not possible to achieve chl-α concentrations less than < 5 ug/L, however, it is beneficial in lessening the intensity of algal blooms

Future Steps

- Establish a connection between the change in fertilizer applications and nutrient loading in the tributary
- Investigate how a change in crop production would affect chl-α concentrations
- Investigate the balance between fertilizer reductions to improve water quality vs. the effects on agricultural management
- Incorporate climate change scenarios

Acknowledgements

- Special thanks to Jesse Bash for providing the new EPIC and WRF simulations; Chunling Tang for running new VIC simulations; and Valerie Garcia and Marina Astitha for the constant guidance and support.

- We would also like to thank James Markham and Patrick Kocovsky from the Lake Erie Forage Task Group for providing valuable information and guidance on utilizing the LECFTG data; and Professor Thomas Bridgeman and the University of Toledo Lake Erie Center for sharing the UT-LEC data.

Questions:

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