October 9, 2019

Bear Creek Model Scenarios

BUILDING A WORLD OF DIFFERENCE®

GEI Consultants

BLACK & VEATCH

Project Overview

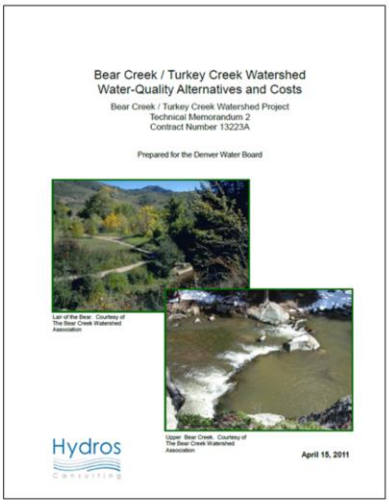
- **Develop predictive models of Bear Creek watershed and reservoir**
  - **Total phosphorus and total nitrogen**
  - **Use models to identify sources, inputs to the reservoir and reservoir dynamics**
- **Define potential management scenarios to control nutrient inputs**
- **Incorporate management scenarios into models**

Modeling Changes from Last Meeting

- **Developed management scenarios for simulation**
- **Incorporated recommendations form CDPHE and BCWA**

Scenarios

- **Use the models to quantify potential management implications**
  - **How are changes in the watershed management reflected in the reservoir?**
  - **Can changes in reservoir management improve water quality?**
  - **How would combined approaches impact water quality?**


Bear Creek / Turkey Creek Watershed
Water-Quality Alternatives and Costs

Bear Creek / Turkey Creek Watershed Project
Technical Memorandum 2
Contract Number 13223A

Prepared for the Denver Water Board

Lair of the Bear. Courtesy of The Bear Creek Watershed Association

Upper Bear Creek. Courtesy of The Bear Creek Watershed Association

Hydros Consulting

April 15, 2011

Hydros 2011 Watershed Management Scenarios

- ISDS modifications
  - Replace Existing ISDSs with a More Efficient Design
  - ISDS to Sewer Conversion / Connect to an Existing WWTP
  - ISDS to Sewer Conversion / Connect to a New WWTP
  - Providing Public Education on Proper ISDS Maintenance
- Rely on Evolving Nutrient Regulations
- Divert Bear Creek Water During Times of Suitable Water Quality
- Pretreatment via Constructed Wetlands
- Pretreatment via a Mechanical Pre-Treatment Plant

Reservoir Management Scenarios

- Change the operation schedule of the current aeration system
- Add a binding agent to reduce the PO4 mobility from the sediment
- Reduce inflow concentrations
- Reduce sediment oxygen demand

Watershed Scenarios

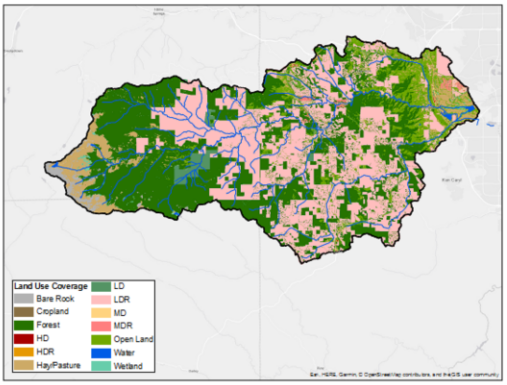
- **Understand watershed dynamics**
- **Quantify source contributions**
- **Quantify changes to treatment plant concentrations**

Source Quantification

- **Watershed model includes**
  - **Land use water and nutrient runoff**
  - **Point source inputs**
  - **On-site Wastewater Treatment Systems (OWTS)**
- **Can "turn off" sources to quantify the total delivered load**
  - **Ran model for 1998-2016 simulation period**

Model Land Use

- **Combined different data sets to develop unified land use**
  - **USDA crop land use data**
  - **Use parcel data from Clear Creek and Jefferson Counties**

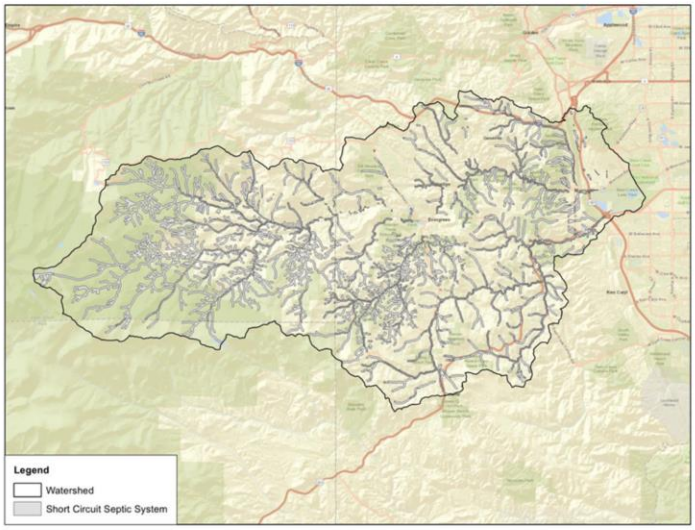


Wastewater Treatment Facility Input

- 11 WWTF discharge and water quality data
  - Provided discharge data
  - Reg 85 data
  - DMR data
- Total phosphorus
  - More complete data set for period of record
- Total nitrogen
  - Not complete time series for any input
  - Typically ammonia with some nitrate as well

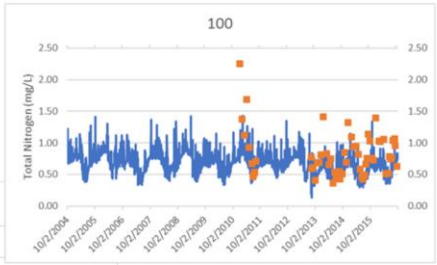
OWTSs

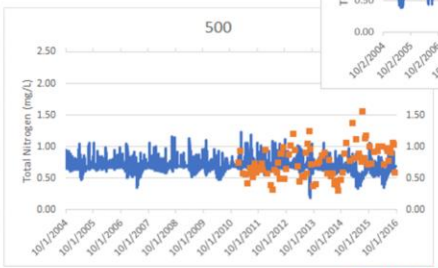
- NHD streams with 200 foot buffer as recommended by BCWA
- Erased buffered NHD streams from intersected Census Block data
- Intersected buffered NHD streams with intersected Census Block data



Total Nitrogen Model Calibration

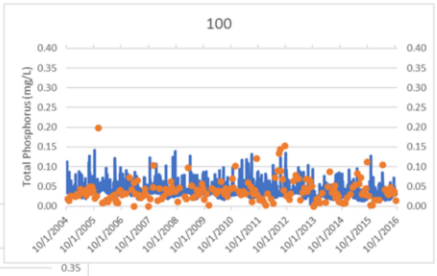
- **Model predicted seasonal changes well**
- **Model median errors TN within 10% of observed values**

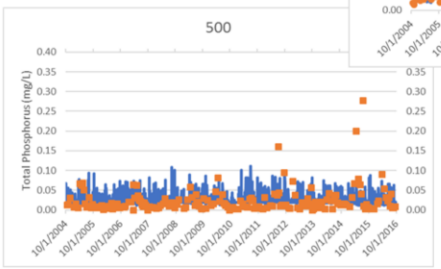




Total Phosphorus Model Calibration

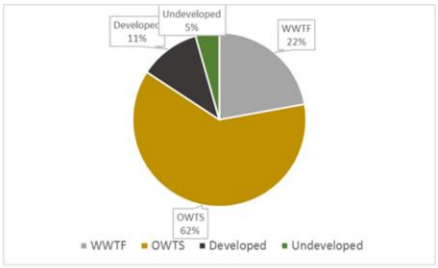
- More robust data set for both streams
- Model median errors TP within 2% of observed values



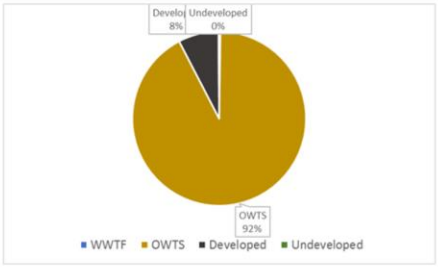


Total Nitrogen Source Identification

Bear Creek

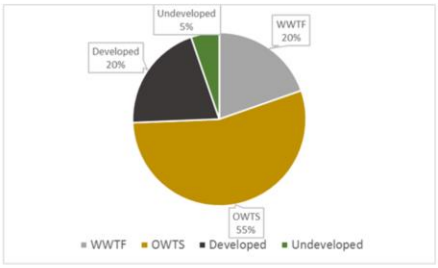


Turkey Creek

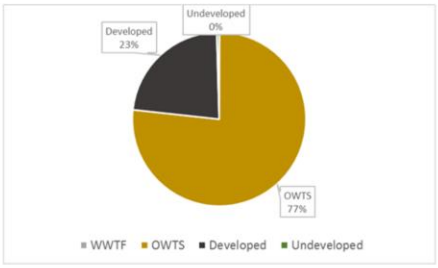


Total Phosphorus Source Identification

Bear Creek

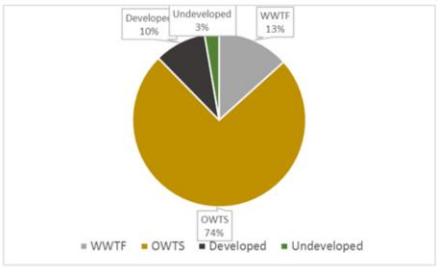


Turkey Creek

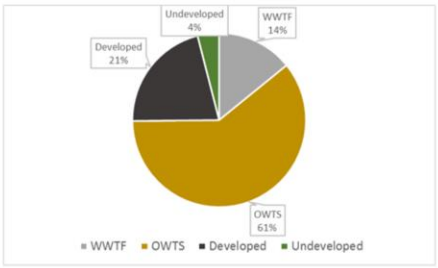


Total Source Identification

Total Nitrogen



Total Phosphorus



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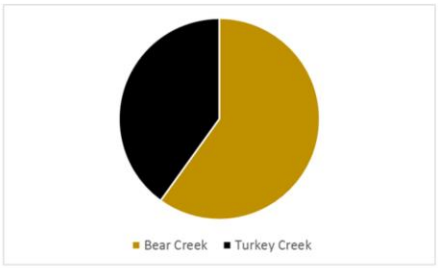
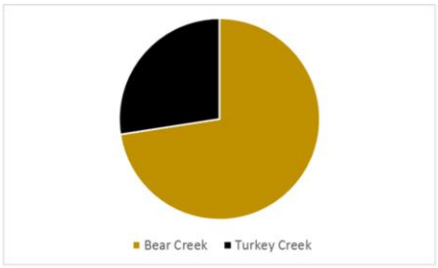
Total Nitrogen



Total Phosphorus



Transformation sensitivity

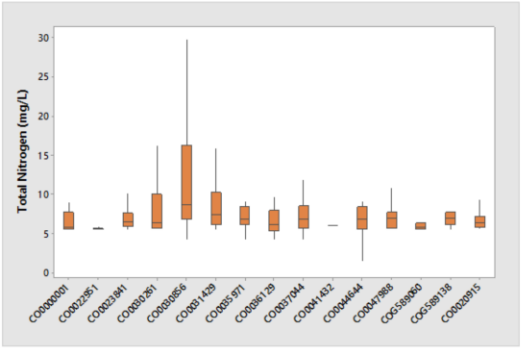
- HSPF simulates nutrient fate and transport
- Assumed first order nutrient loss
  - Aggregates potential uptake mechanisms
  - Changed parameter by +/- 25%
- Total nitrogen loads changed by <0.5%
- Total phosphorus loads changed by <0.25%
  - Summer slightly more sensitive than winter by remained <0.5%

WWTF Model Scenarios

- Reg 85 TP only (TP = 1.0 mg/L)
- Reg 85 TP & TN – 10 years (TP = 0.7, TIN = 7 mg/L)
- Reg 85 TP & TN – 10 years (TP = 0.7, TIN = 15 mg/L)
- BCWA recommendation TP = 0.2 mg/L
- BCWA recommendation TP = 0.05 mg/L
- BCWA recommendation TN = 2 mg/L

WWTF Total Nitrogen Concentrations

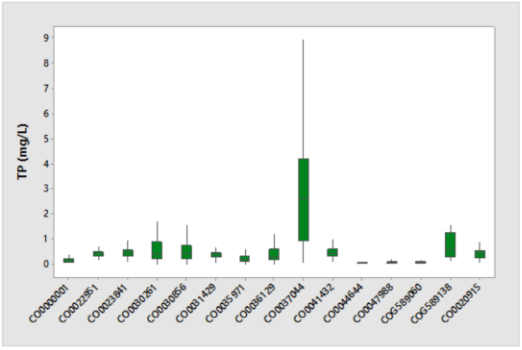
- TN data record incomplete for all
  - WWTFs
- Made assumptions to get to TN



Didn't have complete TN for any facility

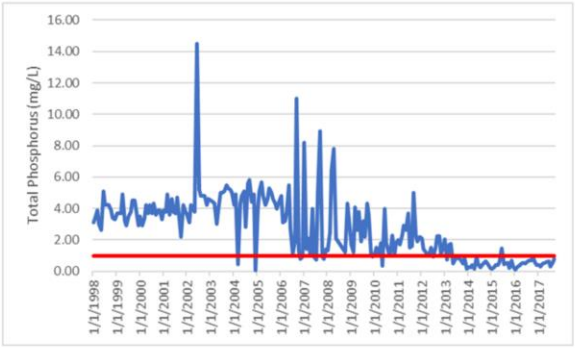
WWTF Total Phosphorus Concentrations

- TP data set more complete for all
  - WWTFs



Scenario Modeling Approach

- **Example effluent concentration**
- **Scenario 1: TP = 1 mg/L**
- **Steady concentration to test limit impacts**



WWTF Scenario Results

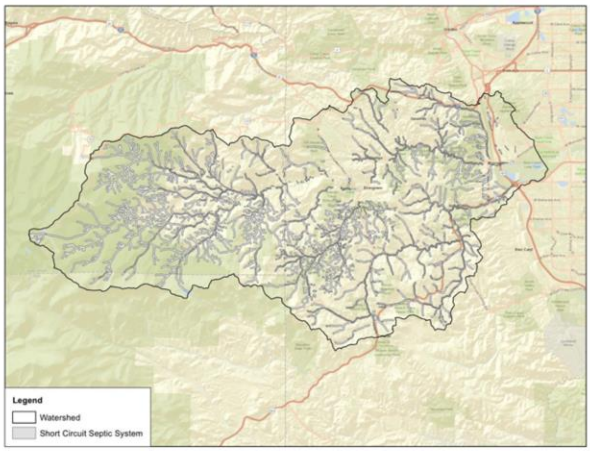
Scenario	Median Annual Delivered TN Load (lb)	Percent Change	Median Annual Delivered TP Load (lb)	Percent Change
WWTP @ TP 1.0 mg/L			863	+8%
WWTP @ TP 0.2 mg/L			767	-4%
WWTP @ TP 0.05 mg/L			748	-7%
WWTP @ TIN 15 mg/L TP 0.7 mg/L	18,850	+11%	823	+3%
WWTP @ TIN 7 mg/L TP 0.7 mg/L	17,210	+1%	823	+3%
WWTP @ TN 2.0 mg/L	16,440	-4%		

OWTS Sensitivity

- **OWTS load modeling options**
  - **Steady flow and load into stream**
  - **Monthly variable loads**
  - **Dynamically simulating**
- **Dynamic simulation incorporates environmental conditions on loadings**
  - **When it's dry, less OWTS loads**

OWTS Sensitivity

- Assumed OWTS inputs within the 200' buffer were reduced
- Assumed flows from OWTS were ½ of the baseline model
- Delivered TN loads reduce by 37%
- Delivered TP loads reduce by 29%

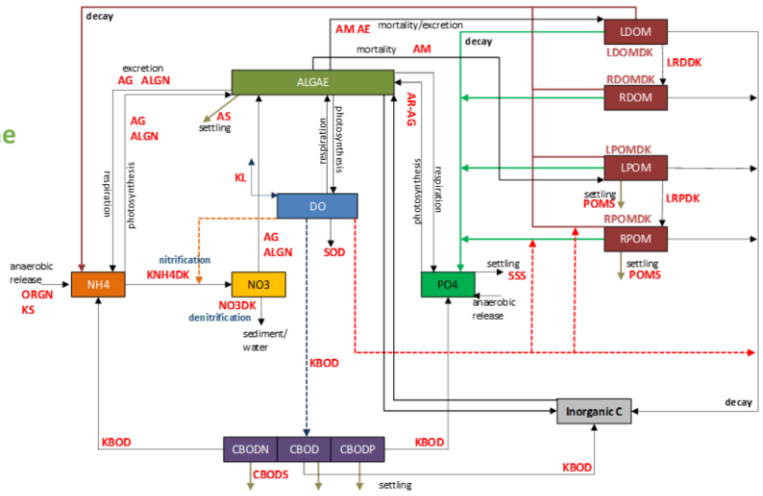


Reservoir Model Sensitivity

- Model flows from measured USACOE
  - Split flows between Bear Creek and Turkey Creek based on HSPF results
- Inflow TN and TP concentrations from HSPF results
  - Fractioned into nutrient species based on monitoring data
- Temperature and dissolved oxygen inputs from monitoring data

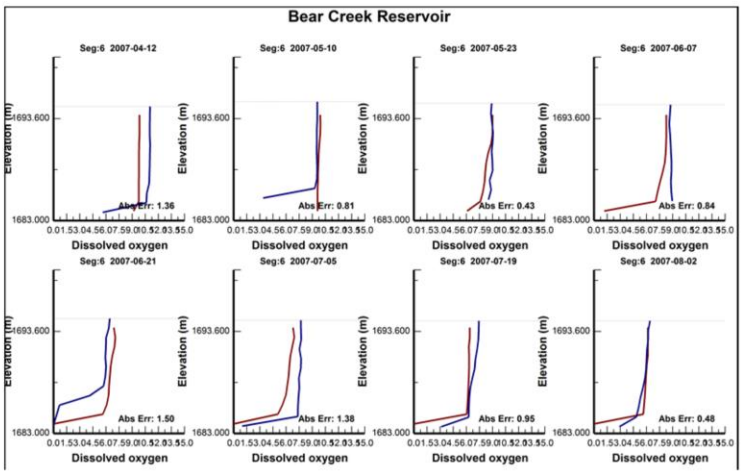
Water Quality

- CE-QUAL-W2 model
  - Two-dimensional, time variable model
- Complex processes
- Can include multiple algae groups



Temperature Profiles

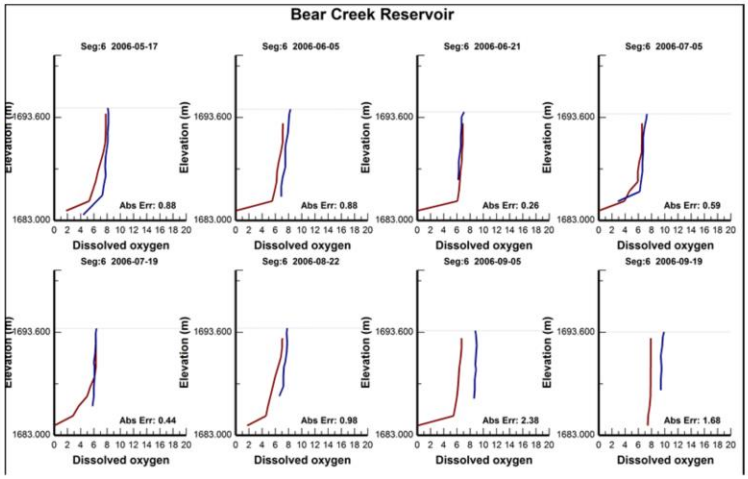
- Overall error
  - Median 0.13 °C
  - Absolute median 0.8 °C



Blue line measured
Red line modeled

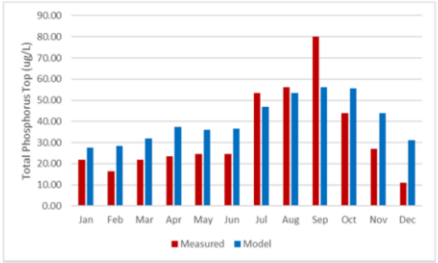
Dissolved Oxygen Profiles

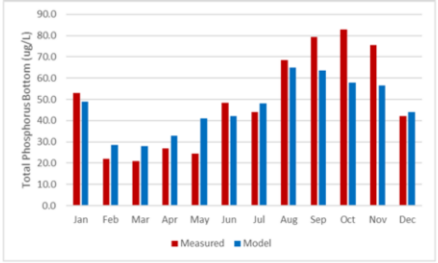
- Overall error
  - Median 0.01 mg/L
  - Absolute median 1.07 mg/L

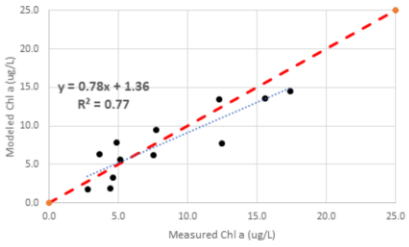


Blue line measured
Red line modeled

Reservoir Calibration

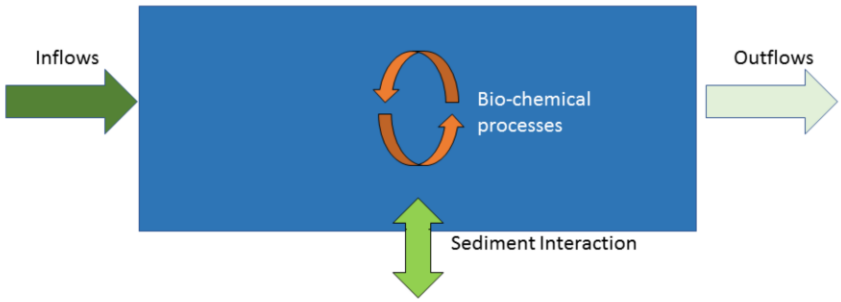






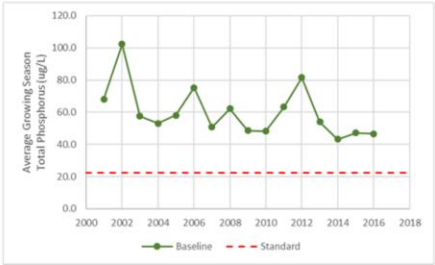
Reservoir Model Insights

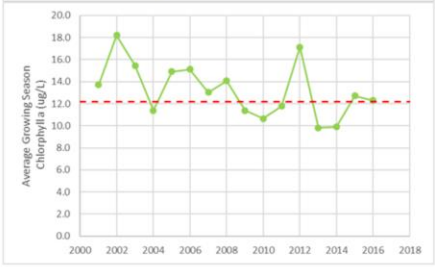
- **Models help understand processes**



Reservoir Scenarios

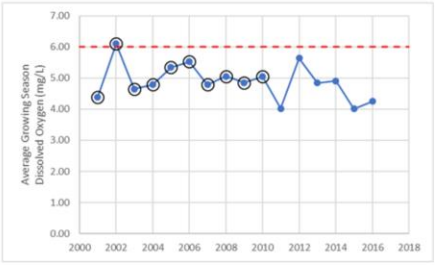
- Used the model to evaluate current conditions
- Total phosphorus and chlorophyll a
  - Top 2 m of the water
  - Model output every 5 days for 16 years
  - Average results for growing season by year
  - Compared against WQ standards
    - TP = 22.2 ug/L
    - Chl a = 12.2 ug/L





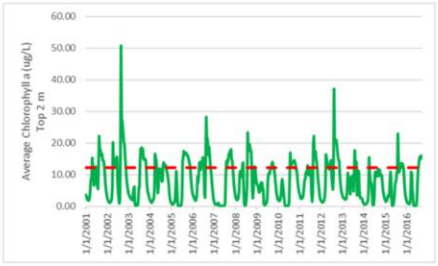
Dissolved Oxygen Results

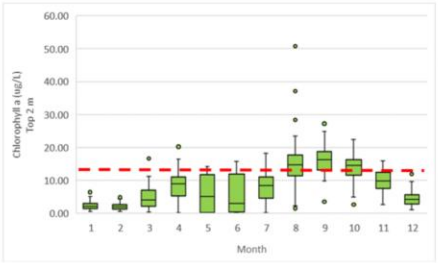
- Bottom 2 m of the water
- Average results for growing season by year
- Compared against WQ standards (6 mg/L)
- Don't have records of aeration before 2011, made assumptions based on post-2011 data



Chlorophyll a Results

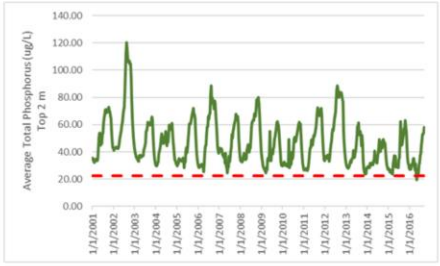
- **Time series plot of top 2 m**
- **Monthly variation across all years**

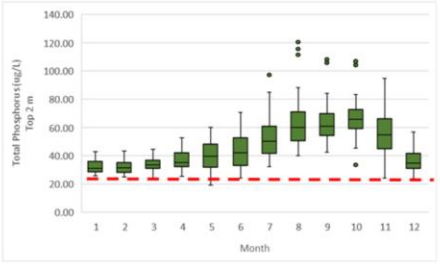


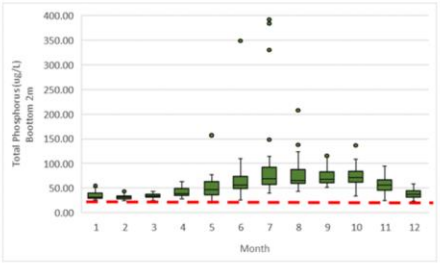


Total Phosphorus Results

- **Time series plot of top 2 m**
- **Monthly variation across all years for top and bottom 2 m**

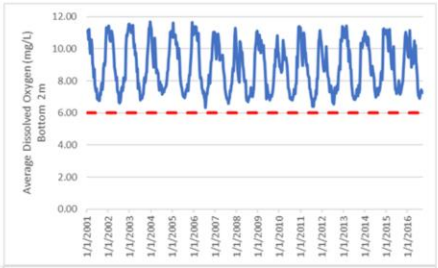


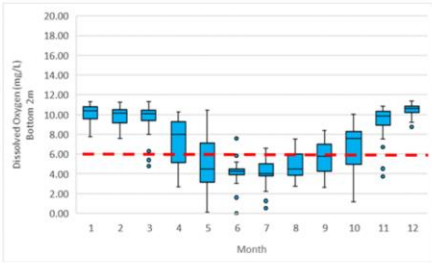


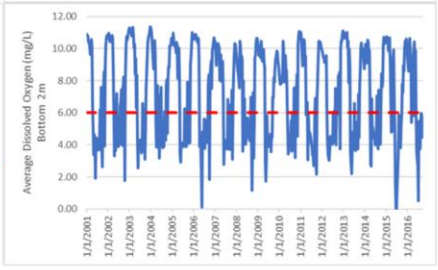


Dissolved Oxygen Results

- **Surface waters always above 6 mg/L**
- **Bottom and top 2 m**







Reservoir Scenarios

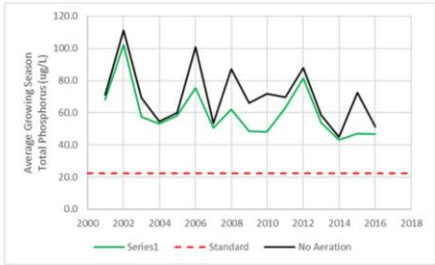
- Aeration
  - Turn off aeration
  - Set aeration at different starting points
- Change external loads
- Change sediment loading

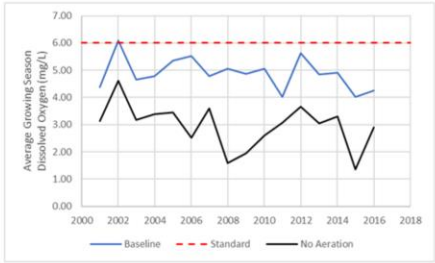
Aeration Simulations

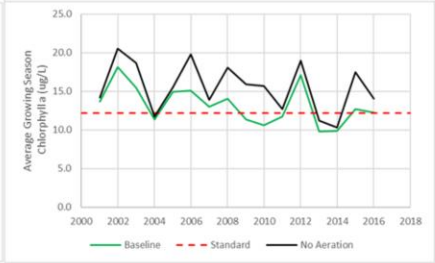
- Turn off aeration
- Change start date
  - Historically not a consistent schedule
- Look at impacts of turning on March, April…July

No Aerators

- **Aerators are helping improve water quality**



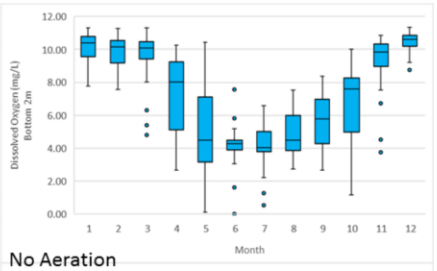




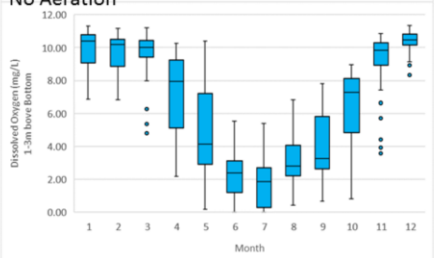
No Aerators-Dissolved Oxygen

- **Bottom dissolved oxygen improves considerably**

Baseline



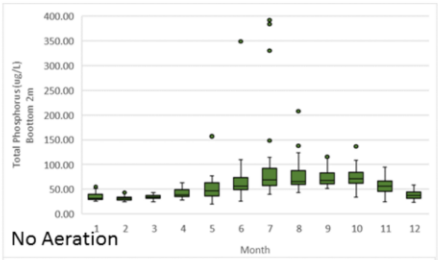
No Aeration



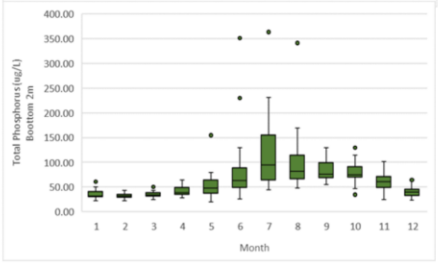
No Aerators-Total Phosphorus

- **Aerators are helping to reduce benthic phosphorus release**

Baseline



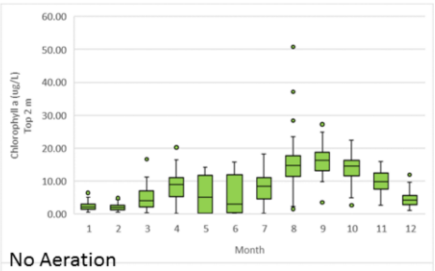
No Aeration



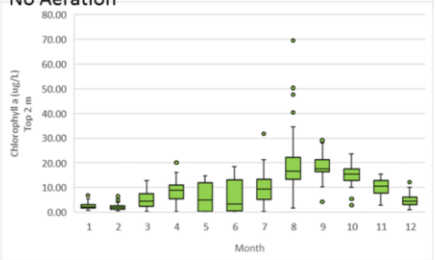
No Aerators-Chlorophyll

- **Aerators are helping to reduce algal growth**

Baseline

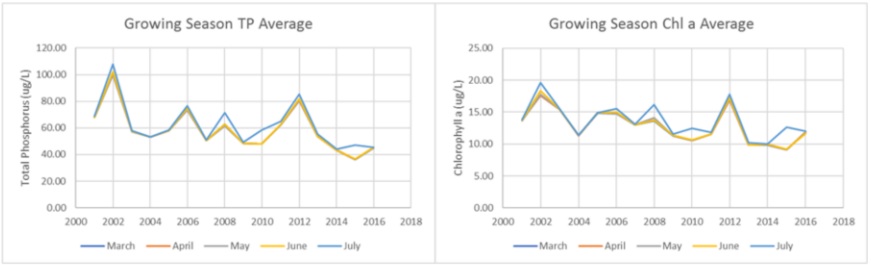


No Aeration



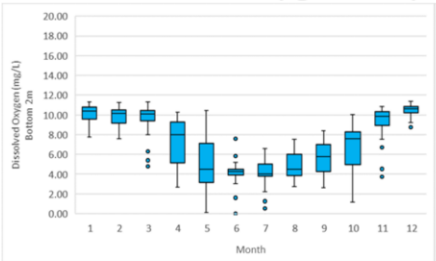
Aeration Compliance impact

- **Not much impact on the growing season TP and Chl a average**

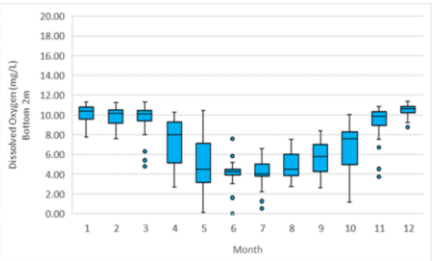


Aeration Dissolved Oxygen Impact

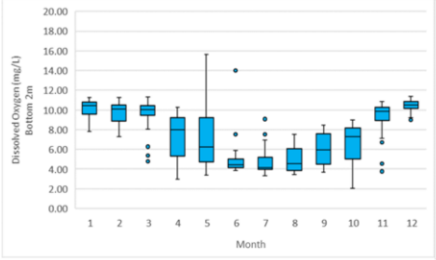
Baseline



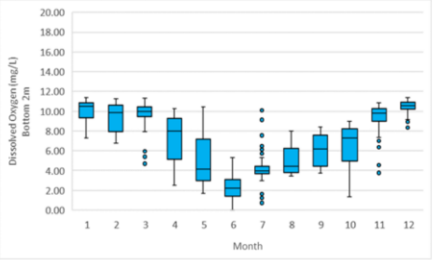
March



May



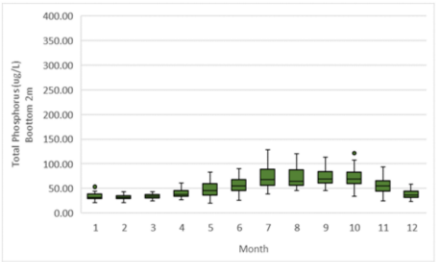
July



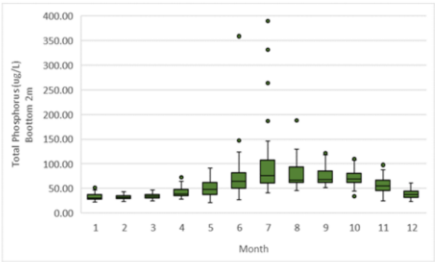
Aeration Total Phosphorus Impacts

- **Different perspective (bottom 2 m)**

March aeration start



July aeration start

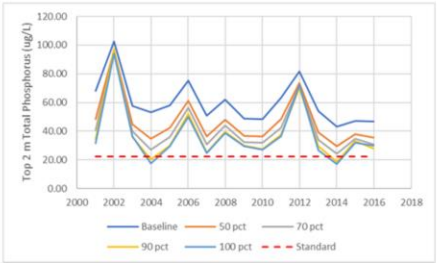


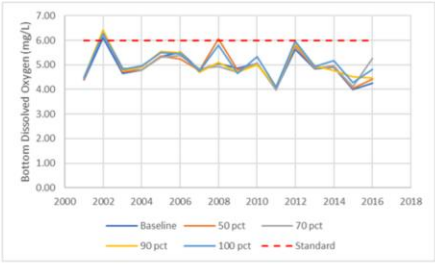
Aeration Results Summary

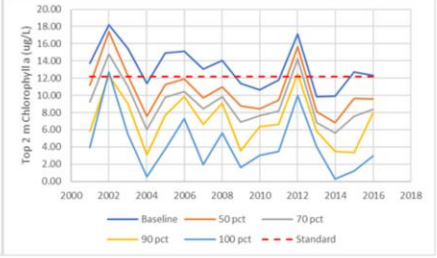
- Aeration has a slight impact on chlorophyll and TP
- Primary impact on dissolved oxygen
  - If start before May 1, bottom DO typically over 4 mg/L

External Source Evaluation

- **Reduce watershed nutrient inputs**
  - **50, 70, 90 and 100 percent**

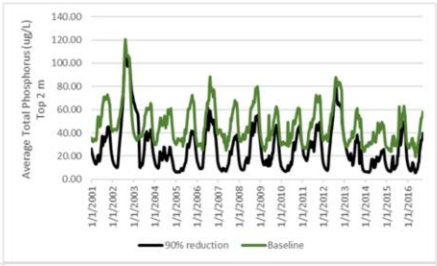


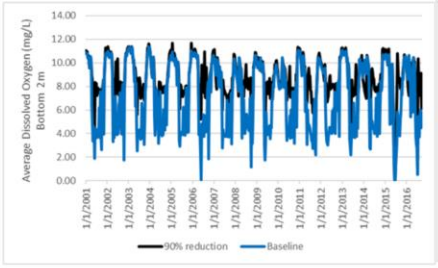


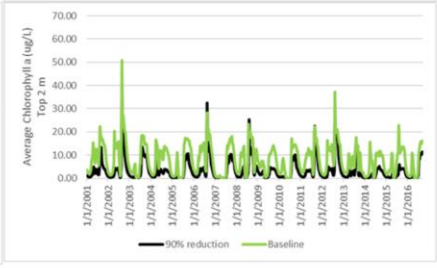


90 percent Load Reduction – Time Series

- **Recall that removing 50% of OWTS**
  - **Delivered TN loads reduce by 37%**
  - **Delivered TP loads reduce by 29%**







External Load Summary

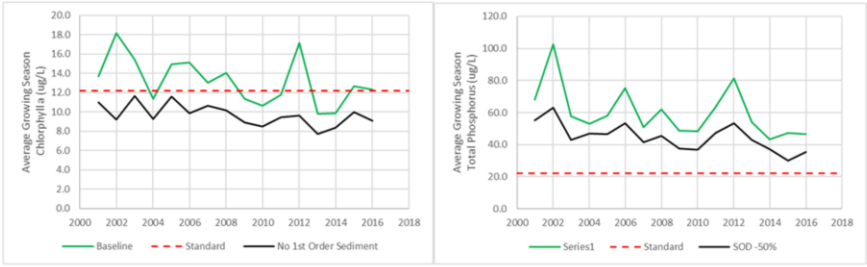
- **Reducing external loads can help reduce TP and chlorophyll**
- **Reducing loads alone, can't solve those issues**

Sediment as a Source

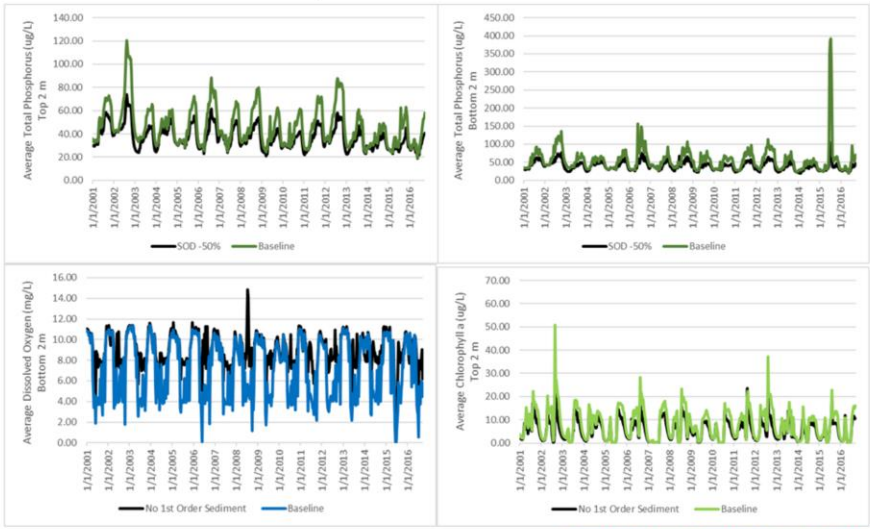
- Sediment can be a significant source of phosphorus, especially with low oxygen
- Tested the model by turning off those sources
  - First order sediment
  - PO4 source
  - NH4 source
  - Combination

First Order Sediment Impacts

- **Modeled sediment to account for organic accumulation**
  - **Will increase SOD with more organics**

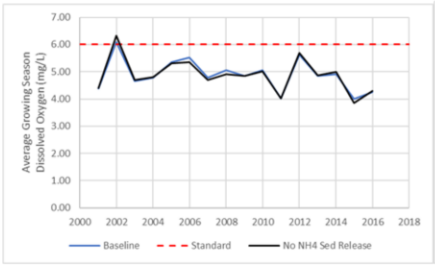


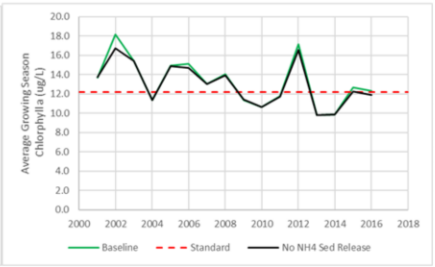
First Order Sediment Impacts - Time Series



Sediment Ammonia Release Impacts

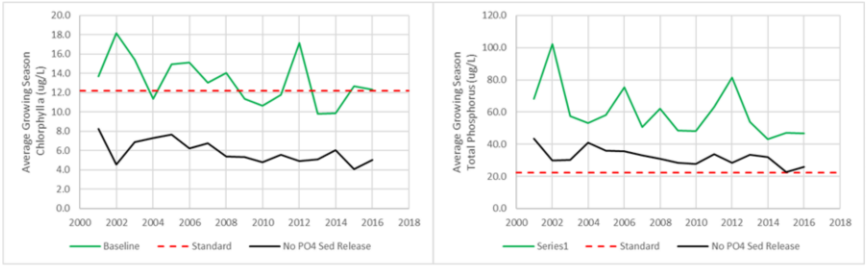
- **No significant impact on nutrients, chlorophyll or oxygen through the growing season**





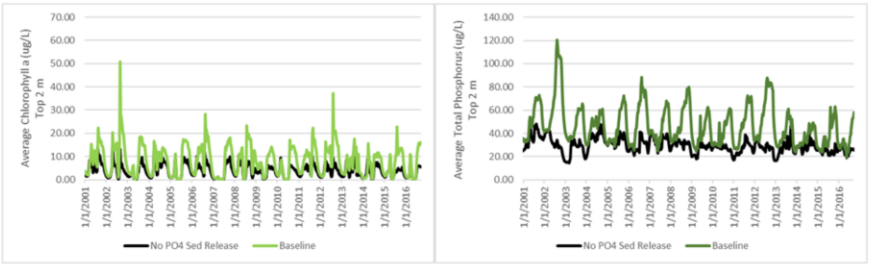
Sediment Phosphorus Release Impacts

- **Sediment is a significant source of phosphorus**
- **Impacts growing season chlorophyll and TP concentrations**



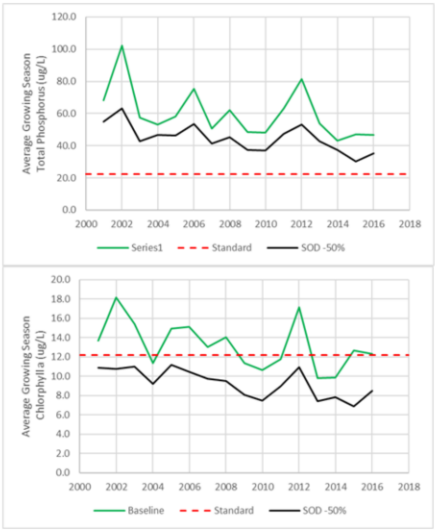
Sediment Phosphorus Release Impacts – Time Series

- **See a dampening of chlorophyll and TP**
- **Removed a significant source**



Sediment Oxygen Demand

- **Reduce zero-order sediment oxygen demand by 50%**
- **Improves TP and chlorophyll levels**
- **SOD will decrease with lower nutrient loads**
  - **50% reduction in loads would result in ~30% decrease in SOD**



Sediment Load Summary

- **Reducing sediment loads can help reduce TP and chlorophyll**
- **Reducing loads alone, can't solve those issues**

Where to now…

- B&V will complete model report
- Model has evaluated individual scenarios
  - Attainment will require combination of approaches
  - Will develop scenarios with multiple management approaches
- CDPHE will move into TMDL development

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1 October 2019

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