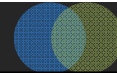


# Lake of the Woods TMDL: Internal Loading Update

November 23, 2016

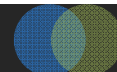
**RESPEC**



## Outline

- HSPF update
- Bathtub update
- Internal loading update
- Next steps

**RESPEC**

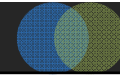


## HSPF Update

- Completed in September
- 70,000 km<sup>2</sup>
- ~ 615 HUC12s
- >30,000 Waterbodies
- 9 Linked HSPF models



**RESPEC**

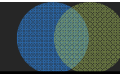


## HSPF Update

- Update incorporated University of Minnesota 2010 land use update
- Very small changes in Q and TP loading
  - 2.7% increase in Q
  - 4% decrease in TP load to Lake of the Woods
  - Changes due largely to vast ungauged areas coupled with changes in land use

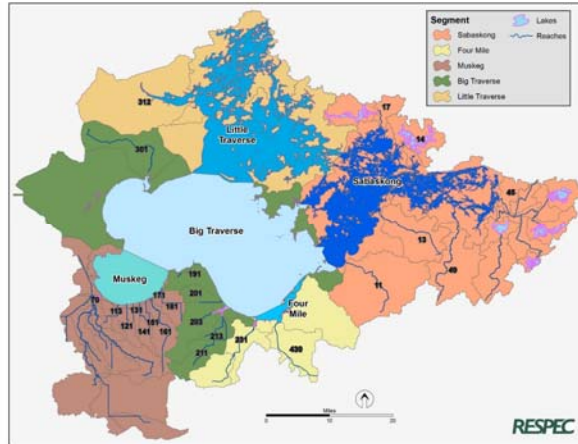
Aggregated Land Use	Land Use Area by Model (km <sup>2</sup> )		
	NLCD/LCC 2001	UMN 2010	Change
Open Water	12,943	12,286	-658
Developed	683	926	242
Barren	132	73	-59
Forest	40,531	38,028	-2503
Hay/Pasture	3,781	1,272	-2510
Cropland	618	305	-313
Wetland	10,840	16,602	5762

**RESPEC**

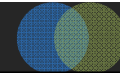


## Bathtub Update

- Bathtub has been updated with updated HSPF Q and FWMCs for each tributary and lakeshed

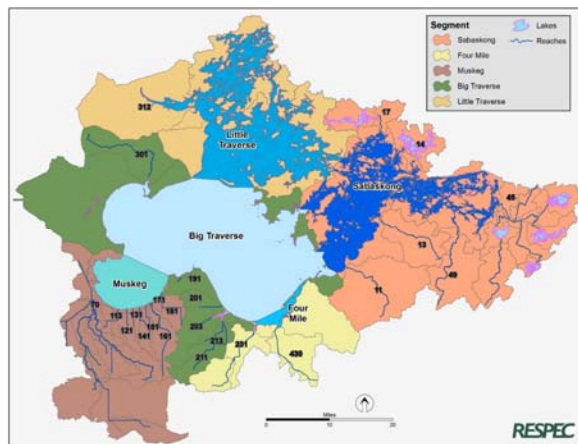


**RESPEC**

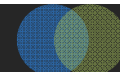


## Bathtub Update: Next Steps

- Need final estimate for internal loading
- TP model selection update based on new analysis
  - Complex system that is not well represented by any one Bathtub model option
- Calibration



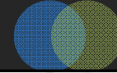
**RESPEC**



## Internal Loading: Past Work

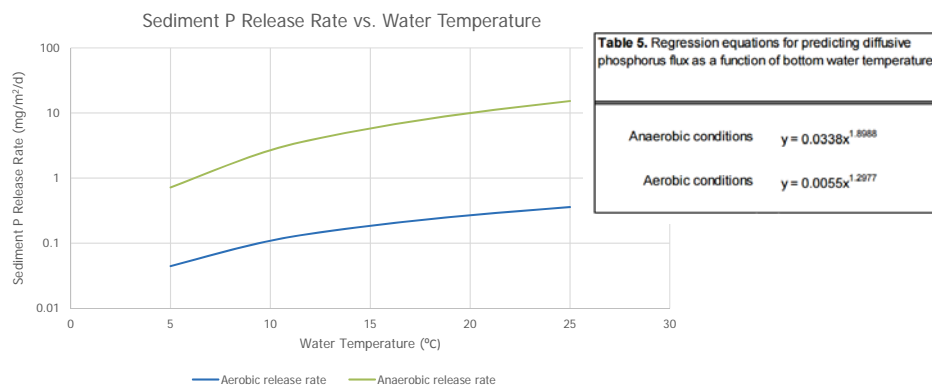
- Bill James – 2012
  - Dissolved oxygen-mediated sediment P release
  - Aerobic release: 0.2 to 0.6 mg P m<sup>-2</sup> d<sup>-1</sup>
    - 91 to 272 tons/yr from Big Traverse (1,243 km<sup>2</sup>)
  - Anaerobic release: 8.3 to 12.5 mg P m<sup>-2</sup> d<sup>-1</sup>

RESPEC

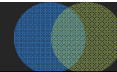


## Internal Loading: Past Work

- Bill James – 2015
  - Temperature- and dissolved oxygen-mediated sediment P release



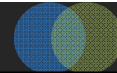
RESPEC



## Internal Loading: Past Work

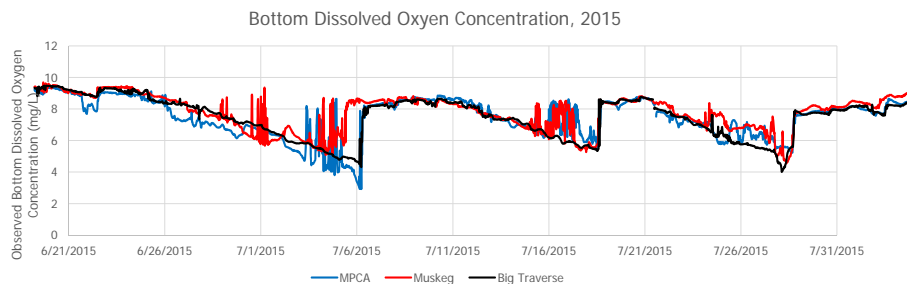
- Bill James – 2015
  - Aerobic release:  $0.12 \text{ mg P m}^{-2} \text{ d}^{-1}$ 
    - 53 tons/yr from Big Traverse
    - Based on bottom water temperature by month
  - Anaerobic release:  $7.3 \text{ mg P m}^{-2} \text{ d}^{-1}$  (assumed  $T = 17 \text{ }^{\circ}\text{C}$ )
    - 9 tons/d from Big Traverse
  - Total annual sediment P release is **very** sensitive to anoxia

RESPEC

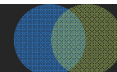


## Internal Loading: Past Work

- Science Museum of Minnesota
  - Dissolved oxygen measurements – 50cm above lake bottom
  - Show depletion ( $0.4$  to  $0.5 \text{ mg L}^{-1} \text{ d}^{-1}$ ) during calm periods
  - No anoxia observed
  - It is unknown if/how often anoxic conditions occur



RESPEC

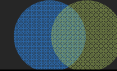


## TP Mass Balance Approach

$$\Delta TP = \Sigma \text{inflow} - \Sigma \text{outflow} + \text{Unexplained Residual}$$

- Unexplained residual “internal loading,” or more accurately
  - Net TP release, resuspension, and settling
- We know that both TP release and sedimentation/settling are happening all the time, but
  - TP release dominates during the growing season due to warmer temperatures, biological activity, and wind mixing
  - Monthly net estimates are therefore minimums for TP release into the water column

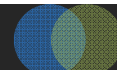
**RESPEC**



## TP Mass Balance Approach

- Approach to determine approximate **long-term mean annual** water and TP budgets
  - Corresponds to Bathtub: mean annual Q and loading
- Water balance
  - Volumes and surface areas by bay (Zhang et al (2013), MPCA)
  - HSPF tributary and lakeshed runoff (HSPF)
  - Precipitation (HSPF)
  - Evaporation (HSPF/literature data)
  - Outflow at Kenora (LWCB)

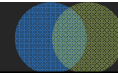
**RESPEC**



## TP Mass Balance Approach

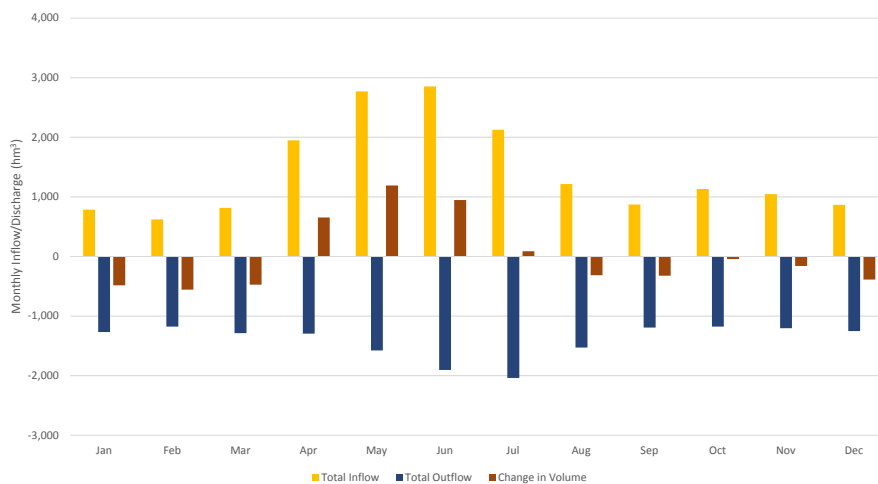
- TP mass balance
  - Loading from tributaries and lakesheds (HSPF)
  - Atmospheric deposition
  - Observed TP concentrations by month (US/Canadian monitoring data) to determine:
    - in-lake TP mass
    - TP flow through and between bays
  - Outflow at Kenora (LWCB)

**RESPEC**

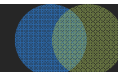


## Water Balance

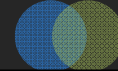
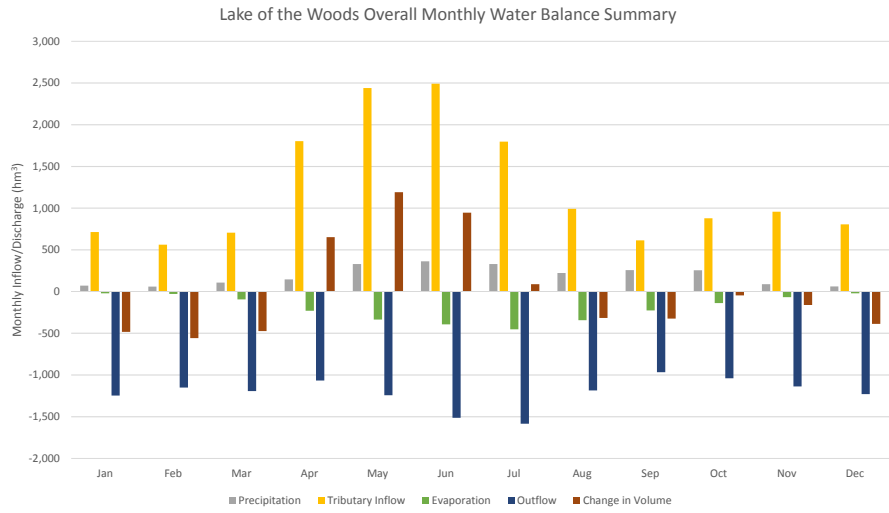
Lake of the Woods Overall Monthly Water Balance Summary



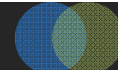
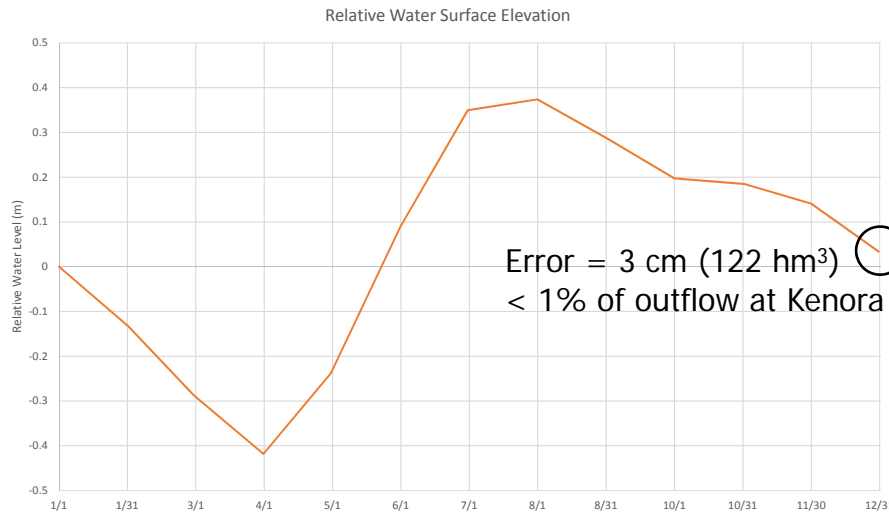
**RESPEC**



# Water Balance



# Monthly Water Surface Fluctuation

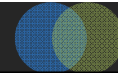




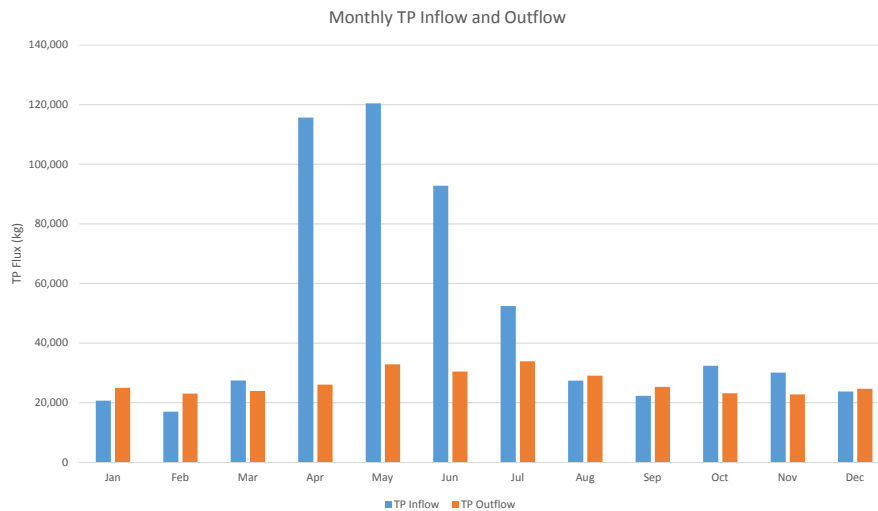
## TP Mass Balance

Pathway	Mean Annual TP Load (2005-2014), metric tons
Atmospheric Deposition	69
Tributary Inflow (includes lakeshed & PS loading)	440
SSTS Loading Direct to LOTW	0.6
Bank Erosion (Houston)	72
Internal Loading	???
<b>Total Inflow</b>	<b>&gt;582</b>
Outflow at Kenora	320

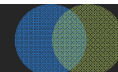
**RESPEC**



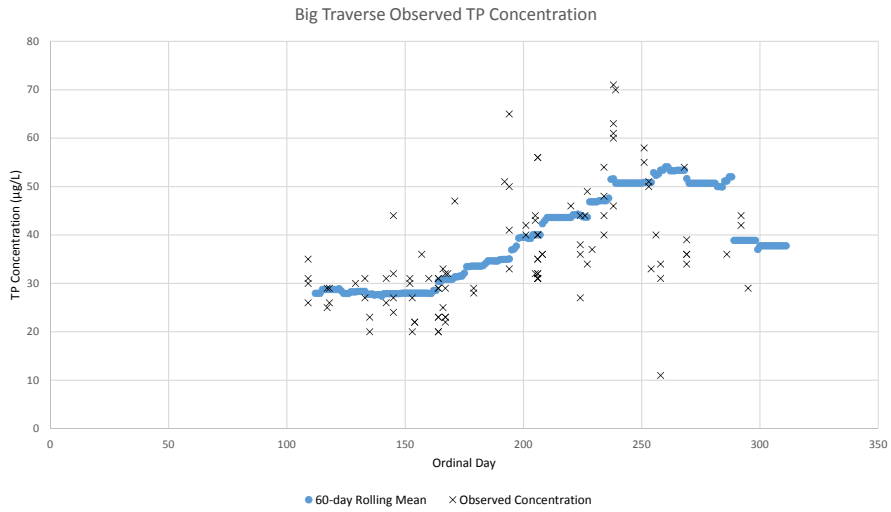
## Entire Lake TP Budget



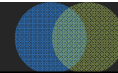
**RESPEC**



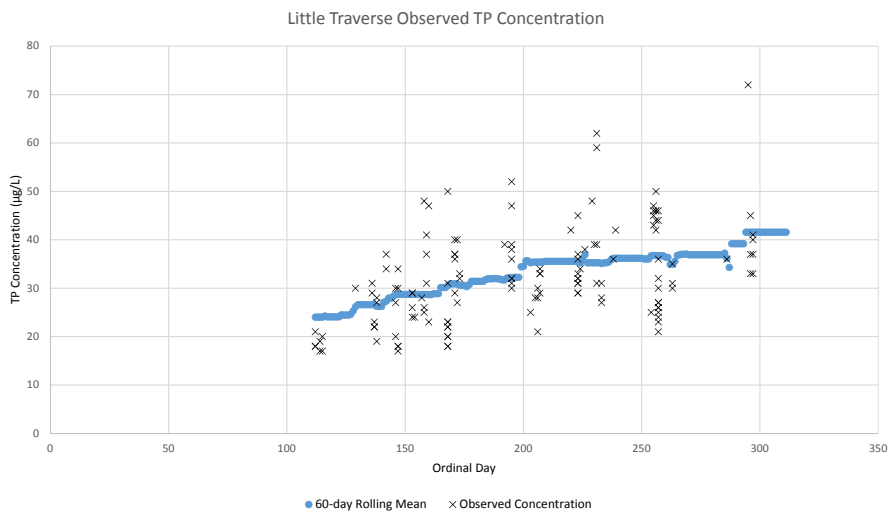
# Observed TP Concentrations



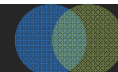
**RESPEC**



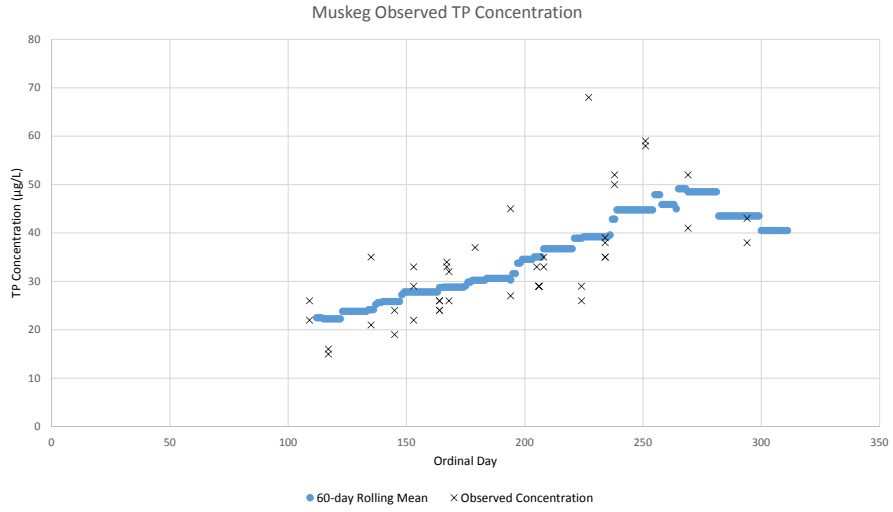
# Observed TP Concentrations



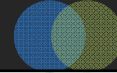
**RESPEC**



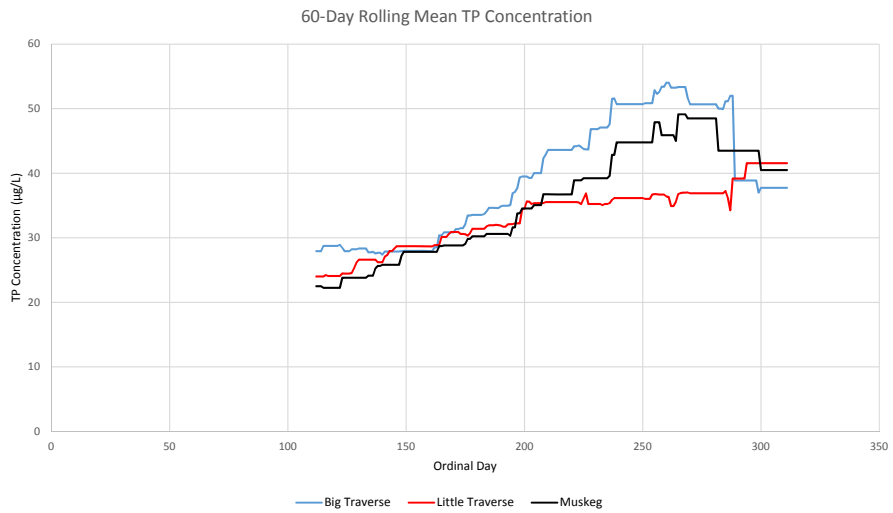
# Observed TP Concentrations



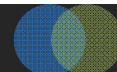
**RESPEC**



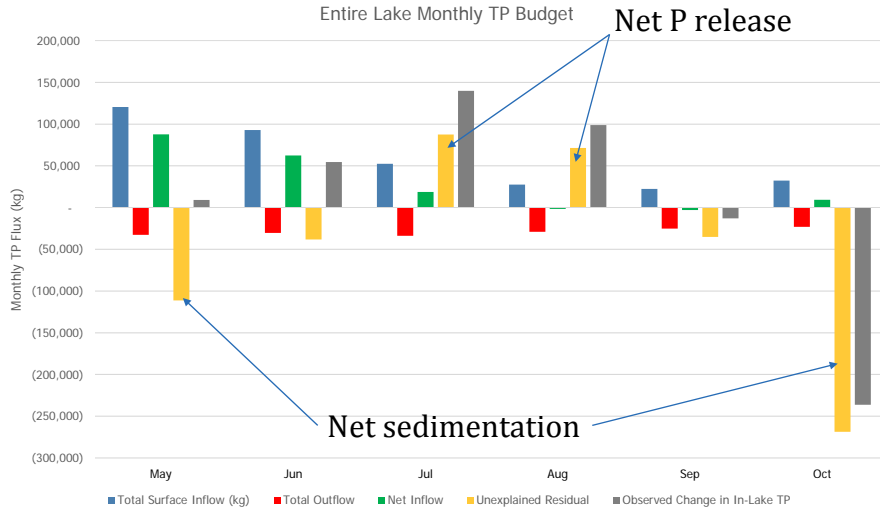
# Observed TP Concentrations



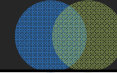
**RESPEC**



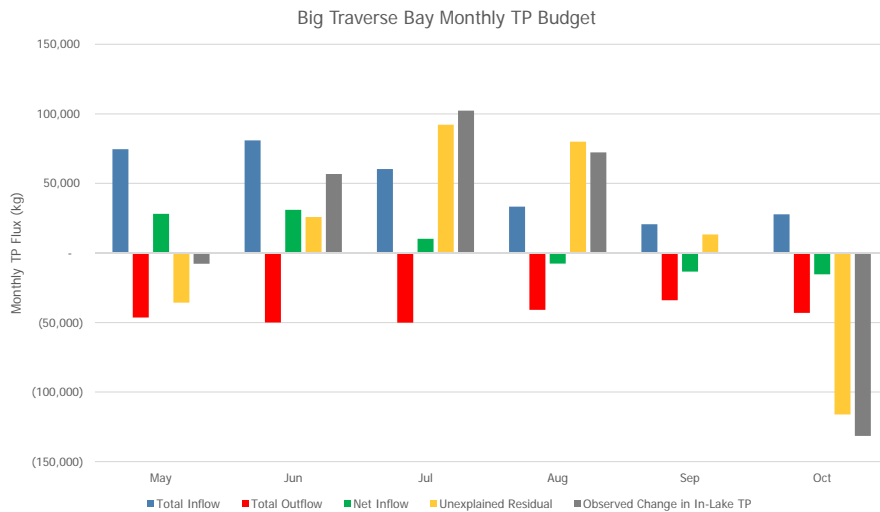
# Monthly TP Budget



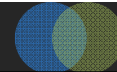
**RESPEC**



# Monthly TP Budget – Big Traverse



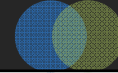
**RESPEC**



## Net Internal Loading Summary

Net Unexplained Residual TP Load (tons)					
Month	Sabaskong	Four Mile	Muskeg	Big Traverse	Little Traverse
May	7.8	(17.3)	(5.5)	(24.2)	5.1
June	3.0	10.1	(3.4)	37.2	8.3
July	(33.4)	20.9	4.7	97.8	8.6
August	(0.7)	13.3	7.3	77.7	(7.6)
September	(13.3)	4.2	3.0	7.6	(8.1)
October	(27.8)	2.3	(9.9)	(120.0)	3.4
<b>Total Mass*</b>	<b>(44.4)</b>	<b>48.6</b>	<b>11.6</b>	<b>220.3</b>	<b>1.1</b>
Loading Rate (mg/m <sup>2</sup> /d)	0 <sup>^</sup>	4.41	0.17	0.49	0.005
* calculated as net loading from June to Sept, ignoring Oct – May, when settling dominates					
<sup>^</sup> limited data available, analysis suggests settling dominates all year					

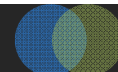
**RESPEC**



## Internal Loading Summary

- Performed detailed hydrologic and nutrient mass balance with HSPF outputs
- Monthly mass balance compared to observed in-lake TP mass
- Resulted in redefinition of internal loading as net of TP release, resuspension, and settling
- Mean annual internal loading: 282 tons

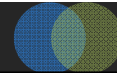
**RESPEC**



## Next Steps

- Develop draft TMDL
  - Load allocation table
  - Reasonable assurance
  - Monitoring plan
  - Implementation strategy

**RESPEC**



Thank you!

Questions/Comments?

Julie Blackburn: [Julie.Blackburn@respec.com](mailto:Julie.Blackburn@respec.com)

Geoff Kramer: [Geoff.Kramer@respec.com](mailto:Geoff.Kramer@respec.com)

**RESPEC**

