



# Old McDonald had a fire...but did it affect water quality?

Brooke G. Bain-White, PhD candidate

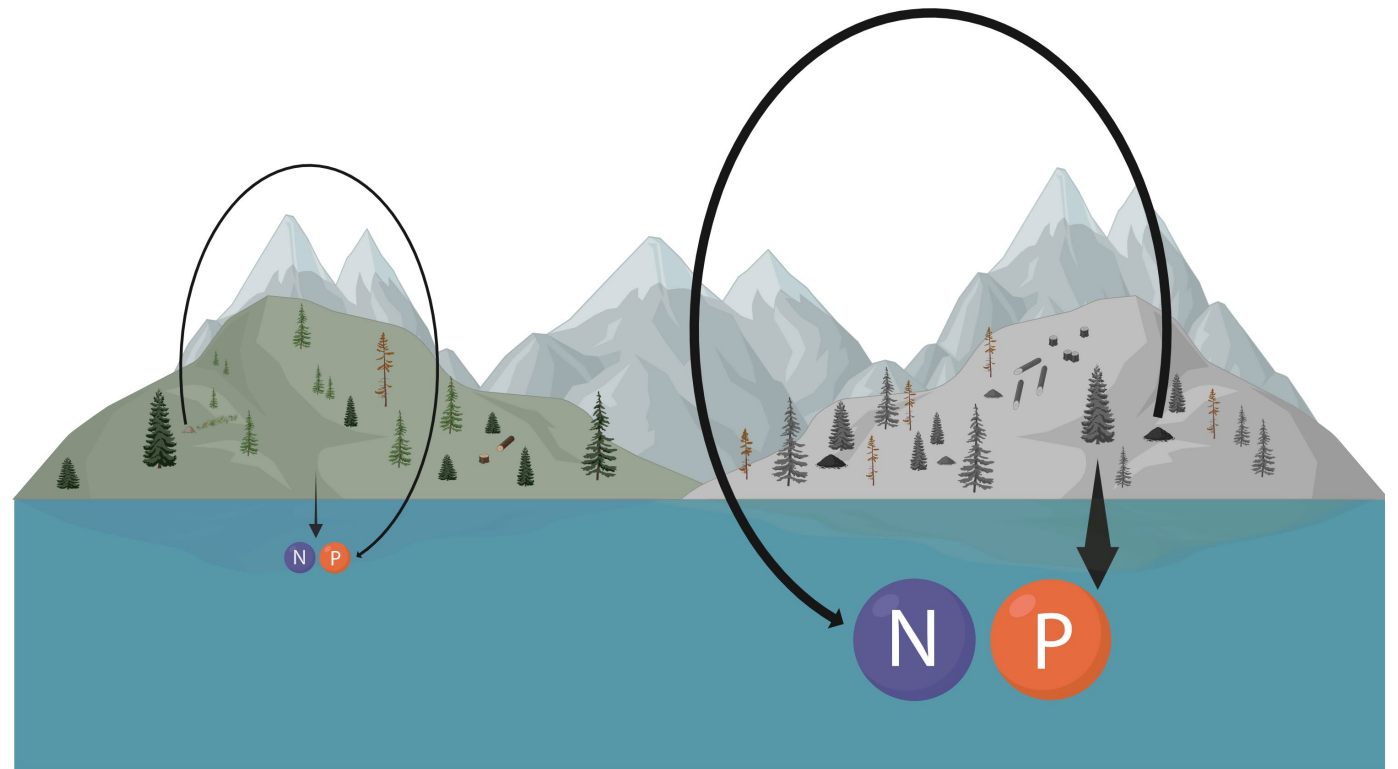
Advisor: Dr. Ashley Ballantyne

Co-investigators: Dr. James J. Elser and Chris Downs



# Climate change, fire, and lakes

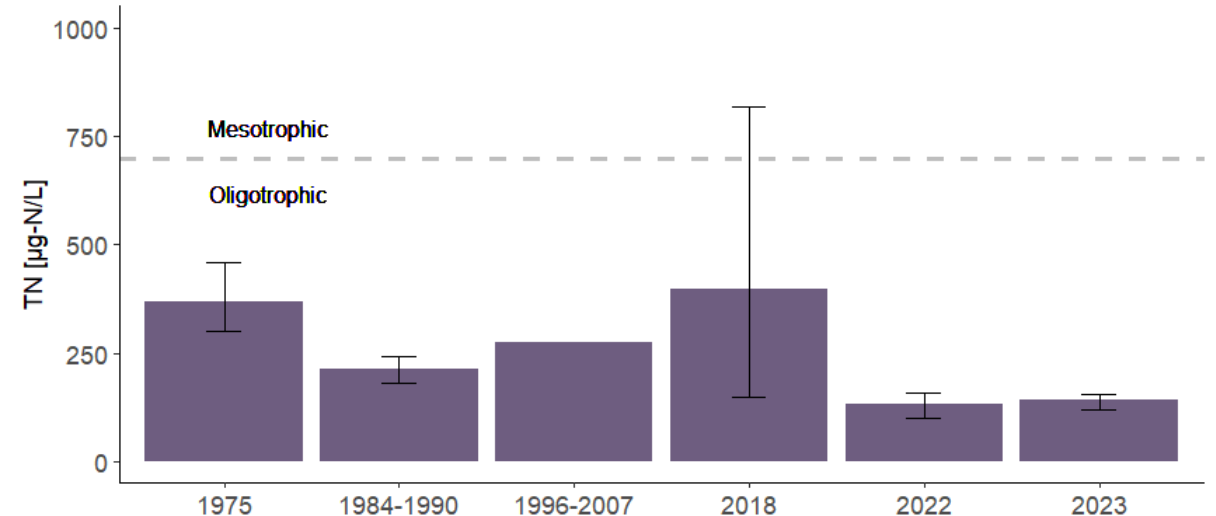
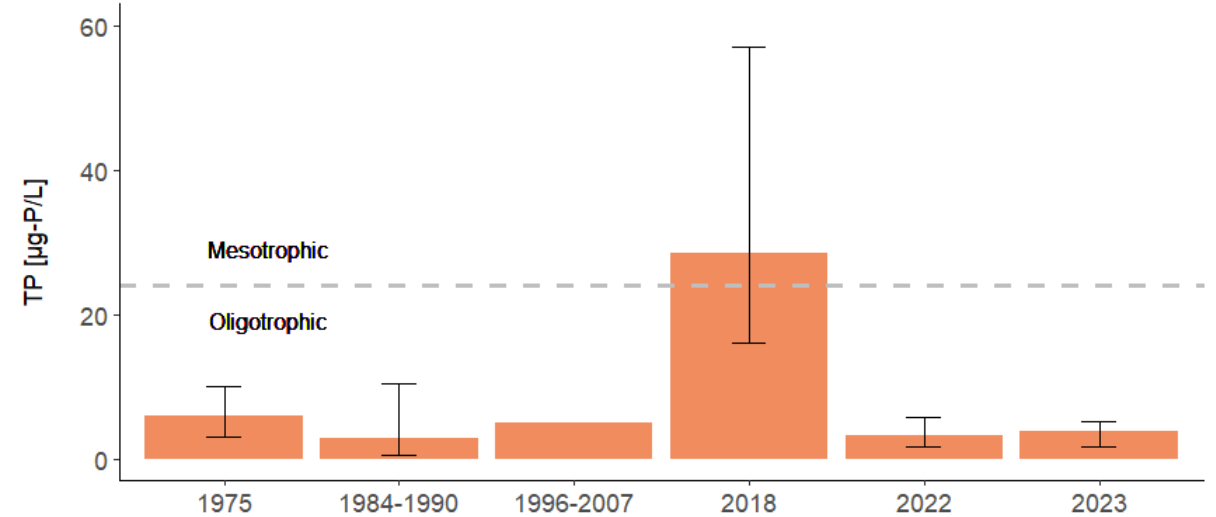
- More wildfire activity is anticipated in flammable regions of the world
- Thus far, studies indicate that wildfires enrich lakes with N and P, but how that enrichment results has yet to be explored



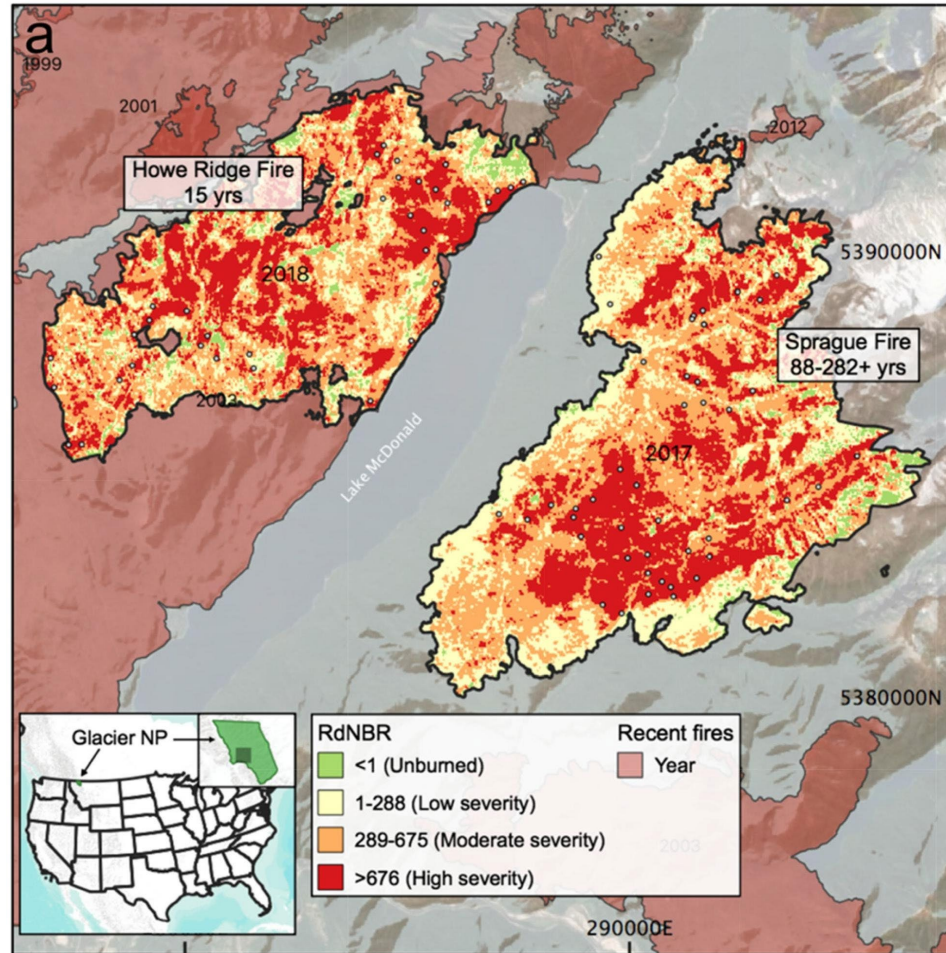
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# Lake McDonald, Glacier National Park

- Past water quality surveys indicate low nutrient concentrations (i.e., oligotrophy) until 2018
- What might have caused the 2018 enrichment?
- Nutrient concentrations have returned to pre-2018 levels



# 2017 Sprague and 2018 Howe Ridge wildfires



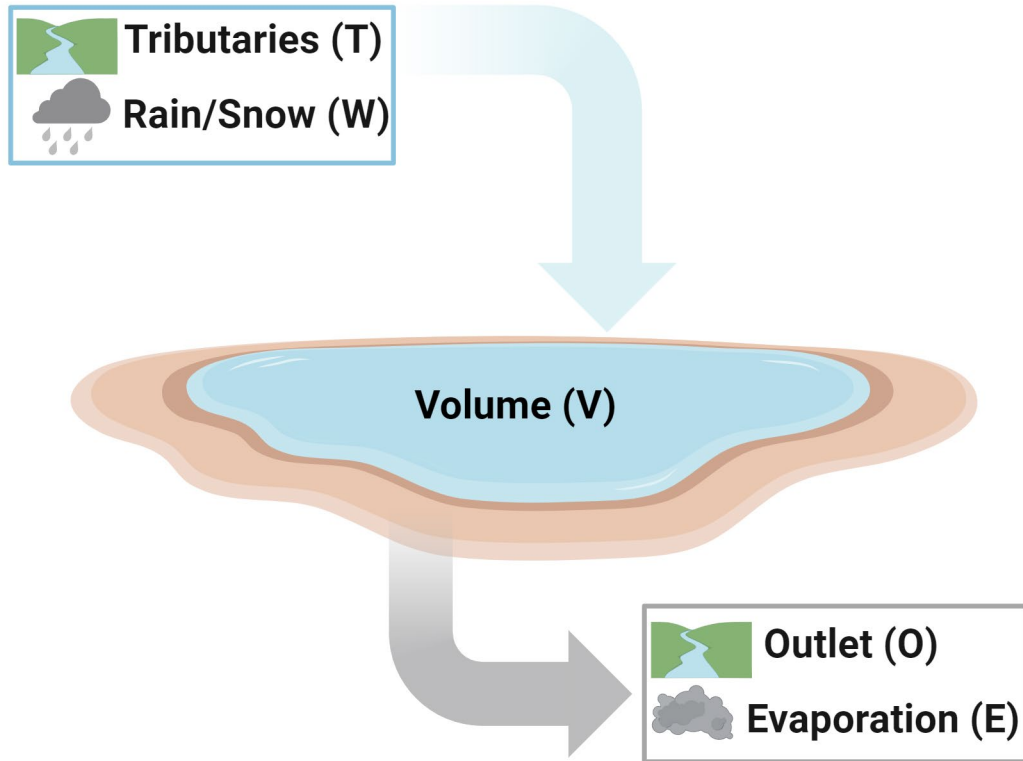
**Image sources:**  
<https://hungryhorsenews.com/news/2018/aug/12/howe-ridge-fire-in-glacier-grows-to-inferno-10/>  
<https://www.nps.gov/glac/learn/nature/fire-information.htm>

**Source:** Hoecker, T. J., and M. G. Turner. 2022. A short-interval reburn catalyzes departures from historical structure and composition in a mesic mixed-conifer forest. *Forest Ecology and Management* 504:119814.

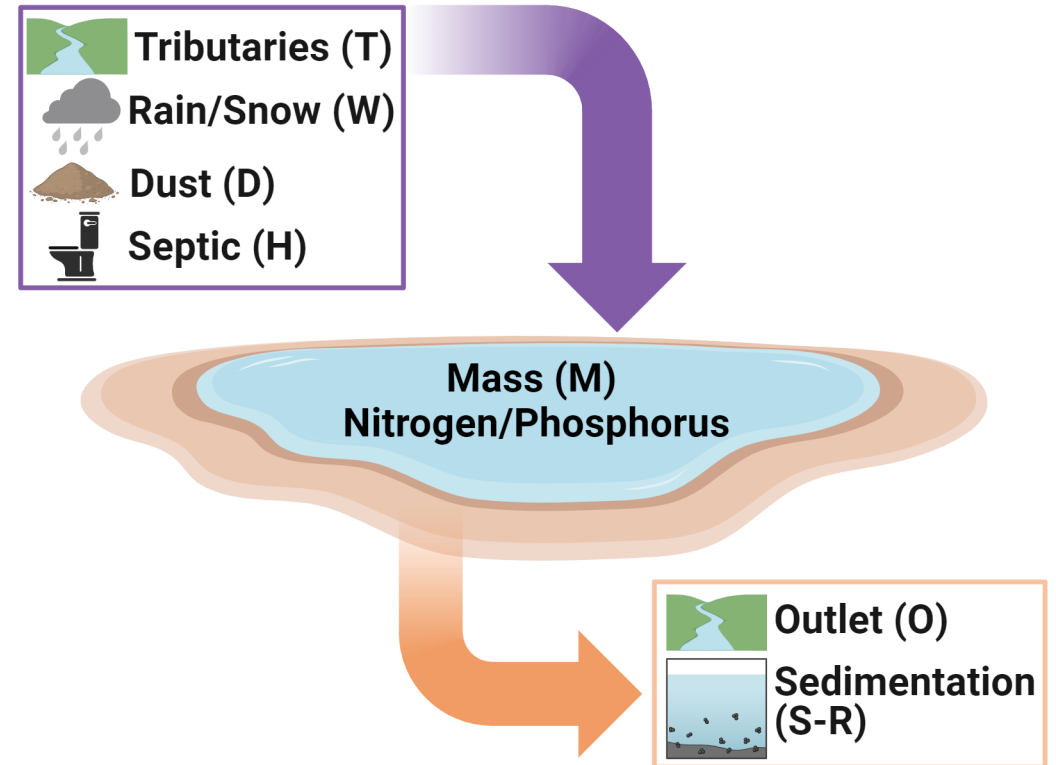
**Images sources:**  
<https://flatheadbeacon.com/2018/08/20/wind-advisory-issued-glacier-park-howe-ridge-fire-continues-smolder/>  
<https://flatheadbeacon.com/2017/08/31/red-flag-warning-effect-fire-season-drags-september/>

# Study approach

$$\frac{\Delta V}{\Delta t} = T + W - O - E$$



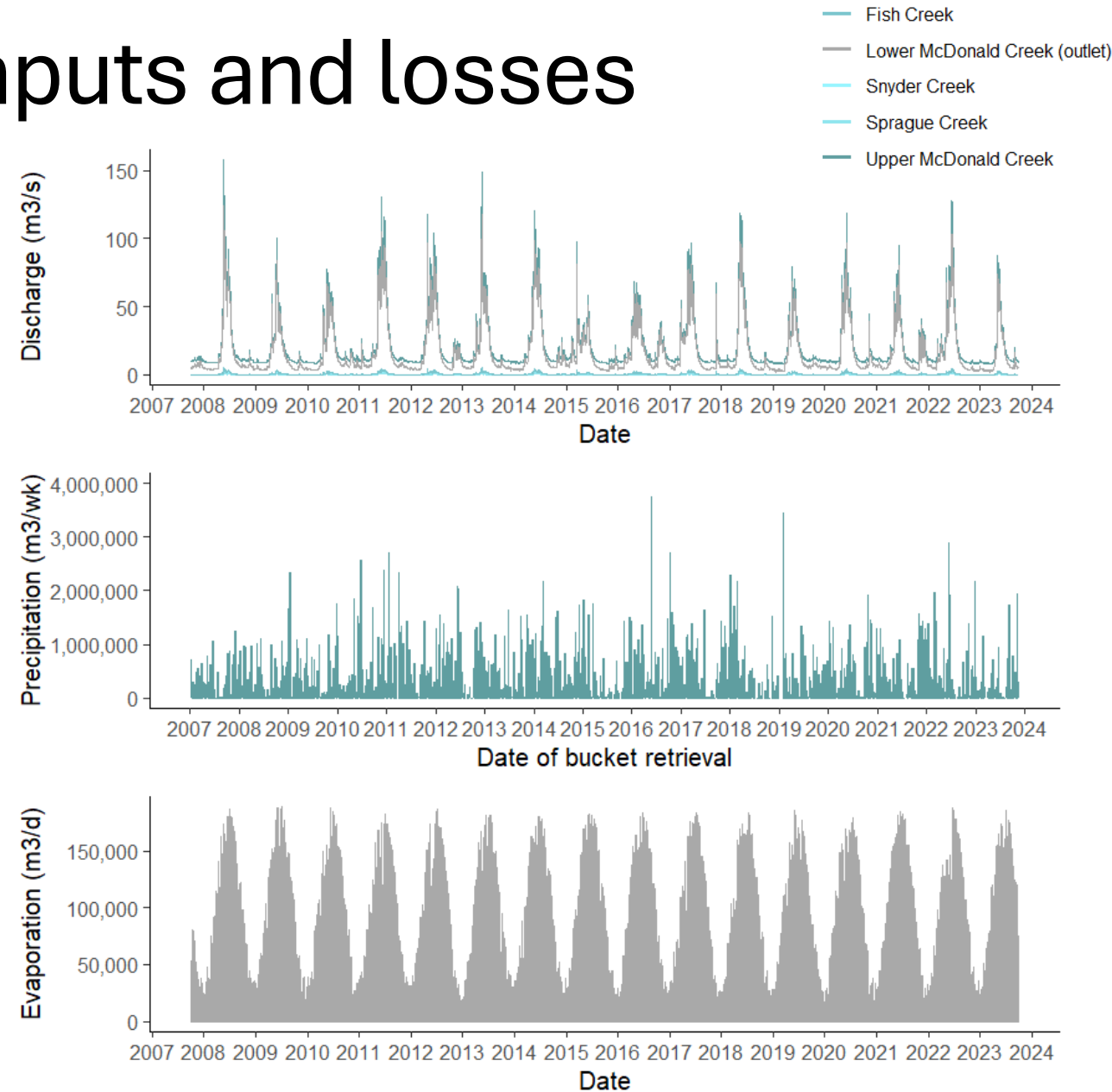
$$\frac{\Delta M}{\Delta t} = T + W + D + H - O - (S - R)$$



# Quantified hydrologic inputs and losses

$$\frac{\Delta V}{\Delta t} = \mathbf{T} + \mathbf{W} - \mathbf{O} - \mathbf{E}$$

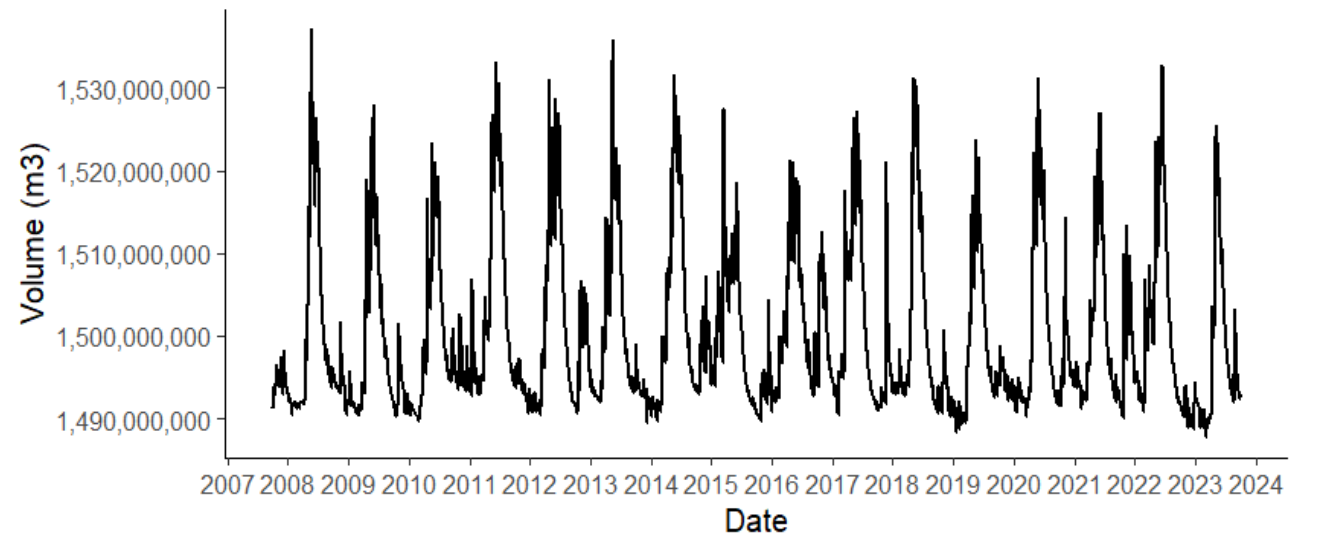
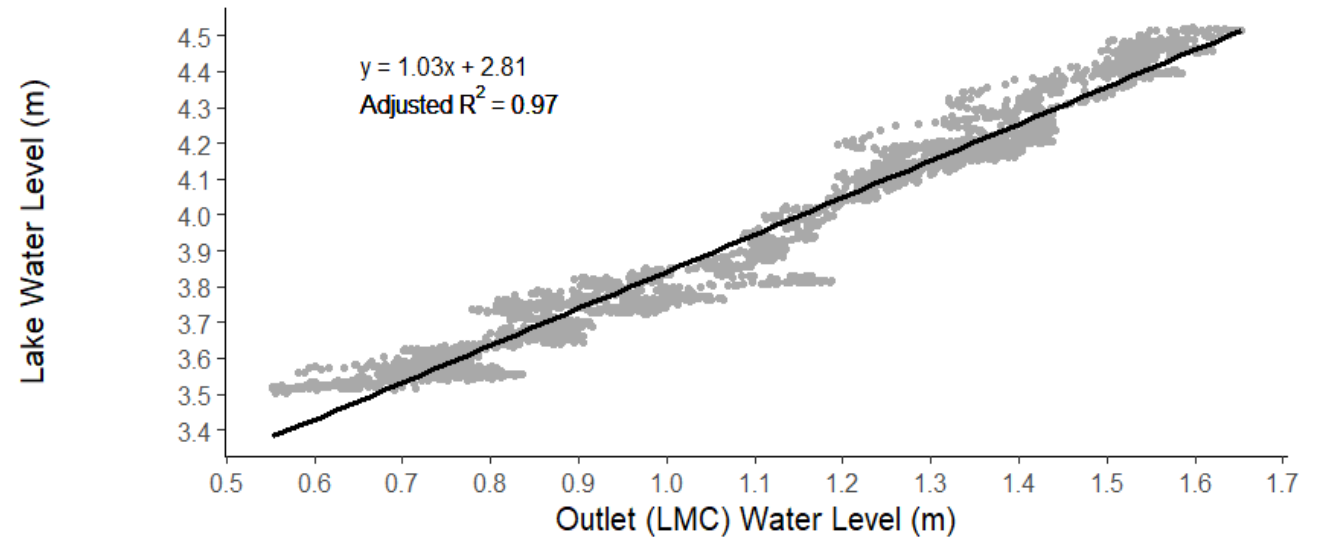
- Donor gage to model discharge for 4/13 tributaries and the outlet
- National Atmospheric Deposition Program
- NASA POWER



# Estimated volume of Lake McDonald

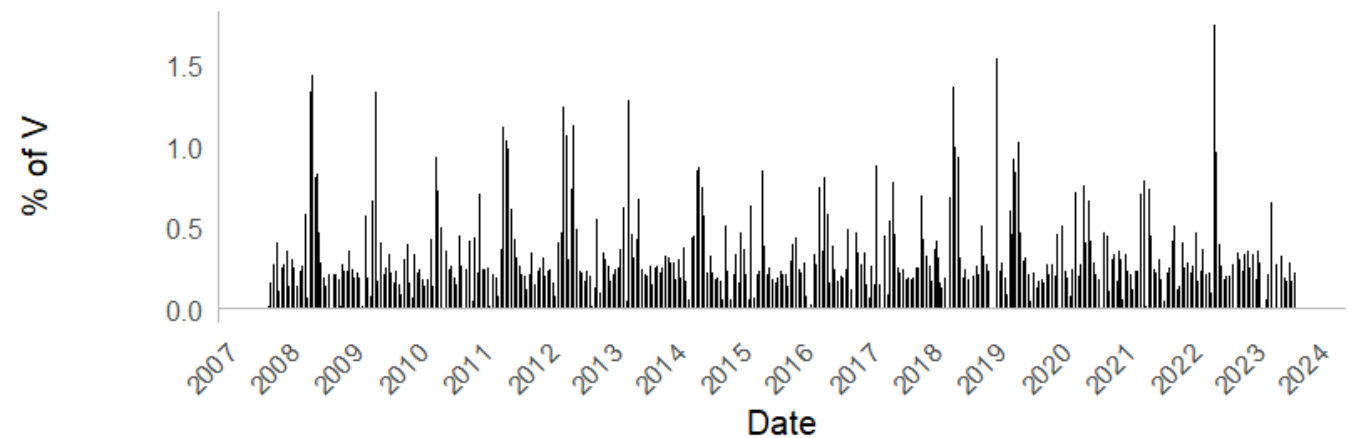
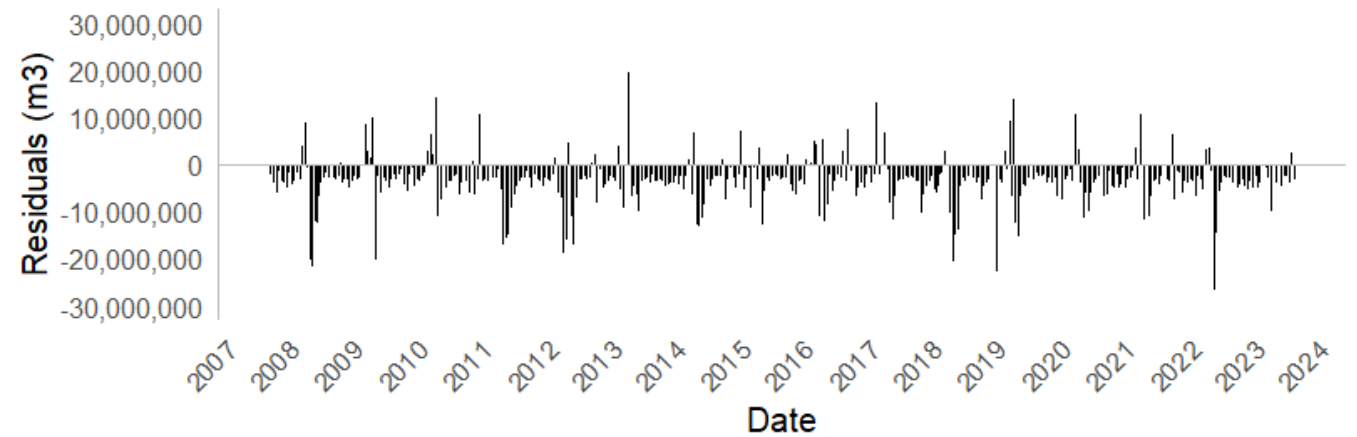
$$\frac{\Delta V}{\Delta t} = T + W - O - E$$

- Based on modeled discharge in the outlet
- Initial volume = 1,491.191 x 10<sup>6</sup> m<sup>3</sup>



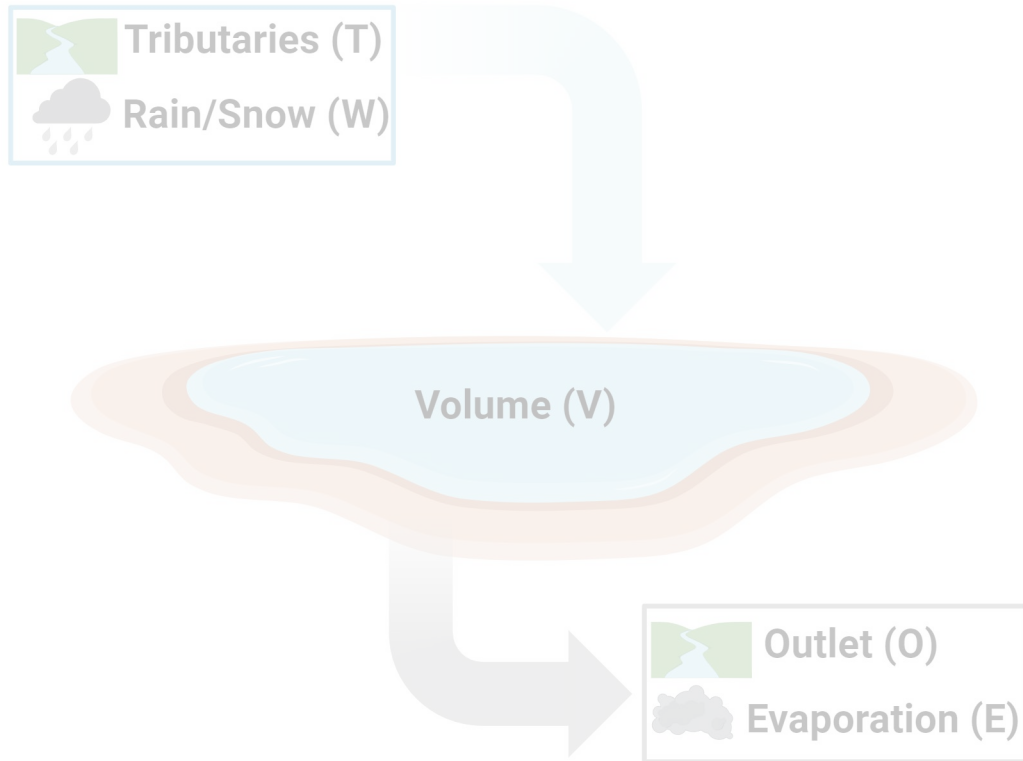
$$\frac{\Delta V}{\Delta t} - \mathbf{T} - \mathbf{W} + \mathbf{O} + \mathbf{E} = \text{Residuals}$$

- Gains or losses may be coming from groundwater, runoff, or error
- Residuals < 2% of the lake volume

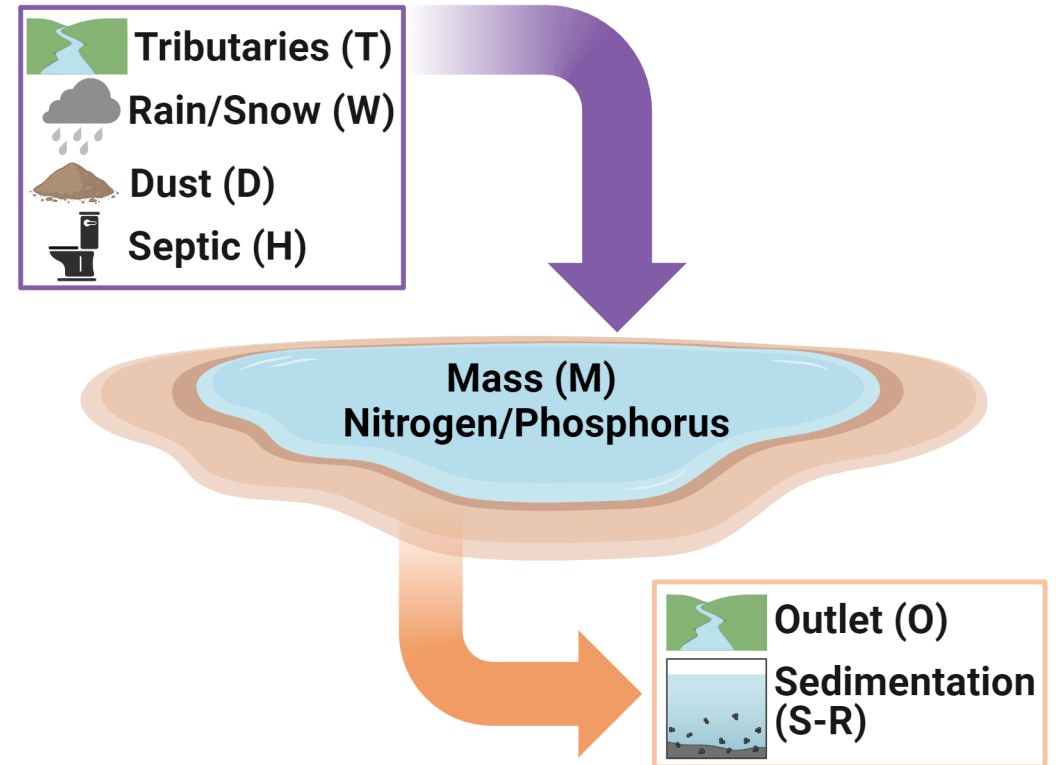


# Study approach

$$\frac{\Delta V}{\Delta t} = T + W - O - E$$

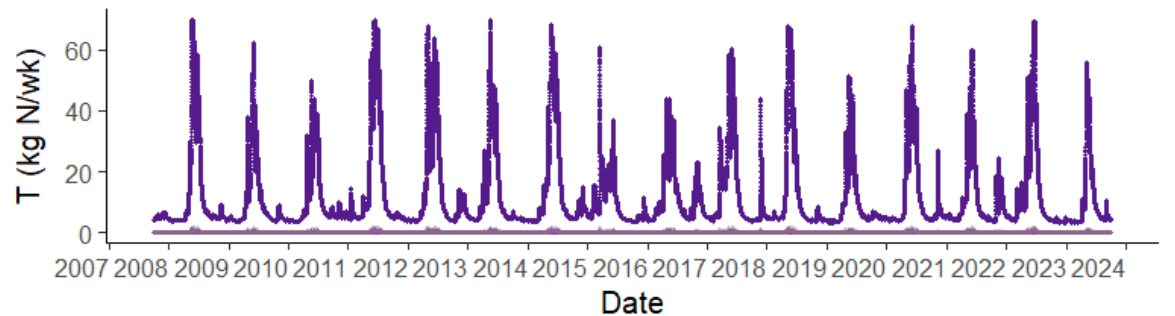
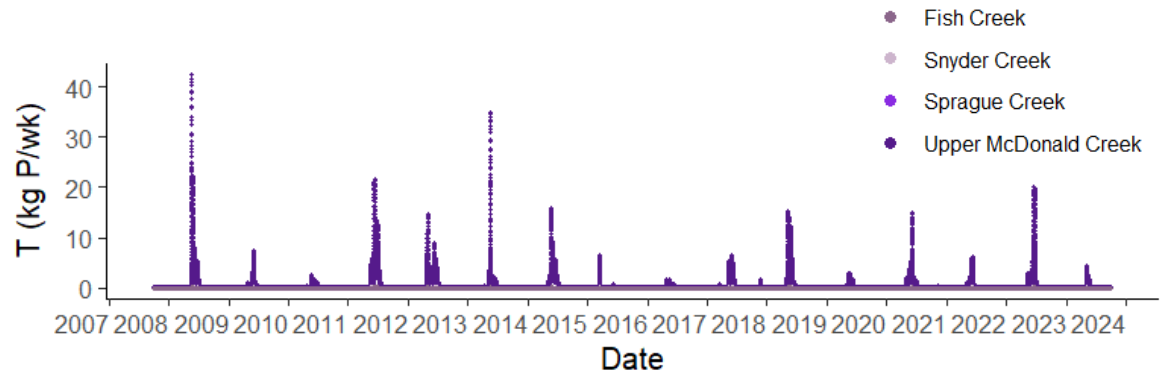
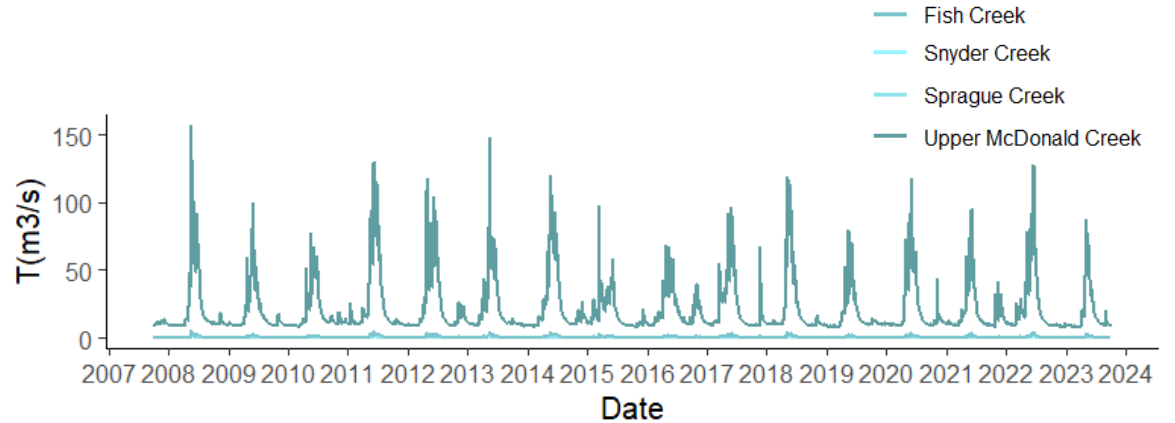


$$\frac{\Delta M}{\Delta t} = T + W + D + H - O - (S - R)$$



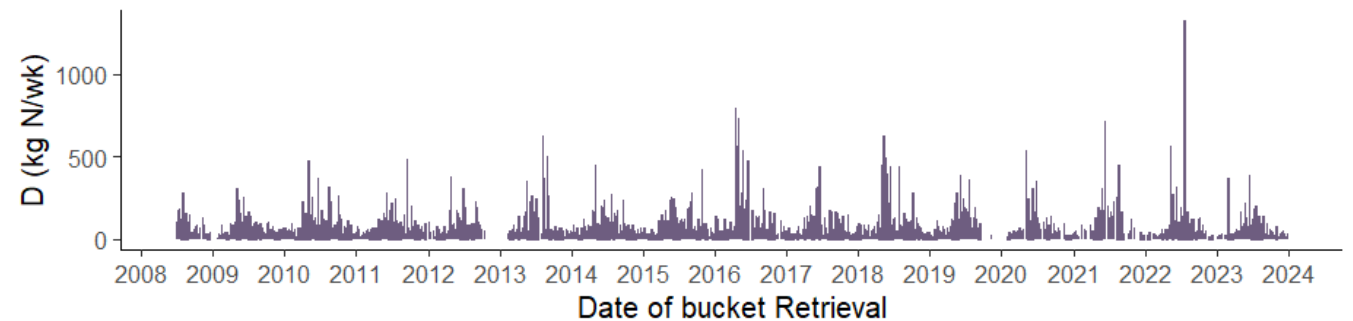
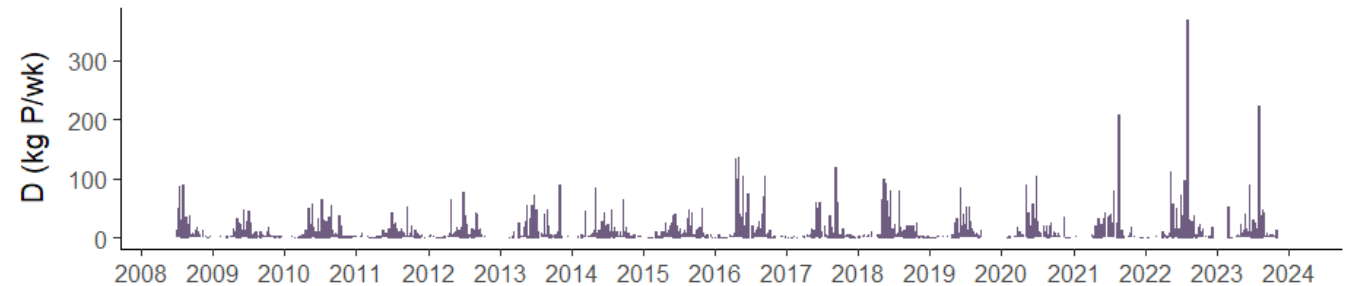
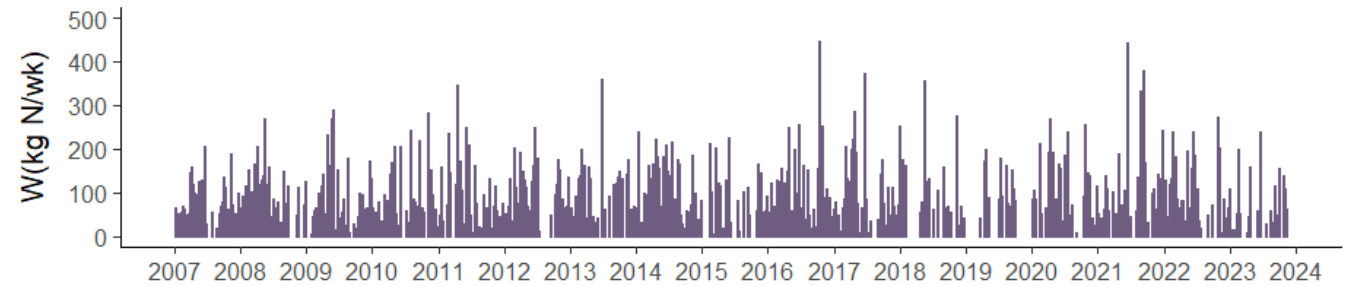
# Nutrient sources

- $\frac{\Delta M}{\Delta t} = T + W + D + H - O - (S - R)$
- LOADEST model 2  $\rightarrow$   
 $\log(\text{Load}) = \beta_0 + \beta_1 \log(Q)$
- National Atmospheric Deposition Program & Flathead Lake Monitoring Program
- Septic contributions



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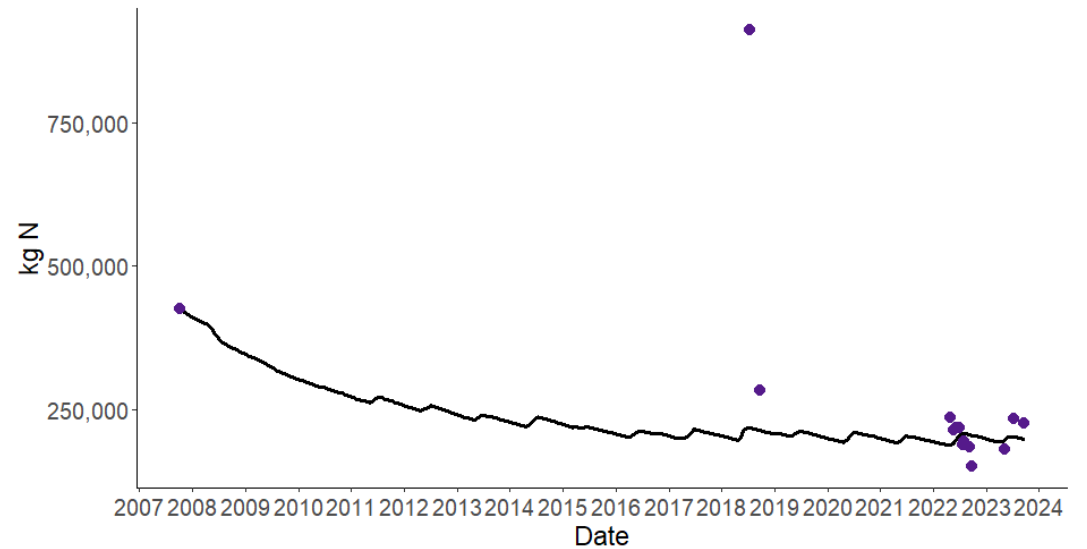
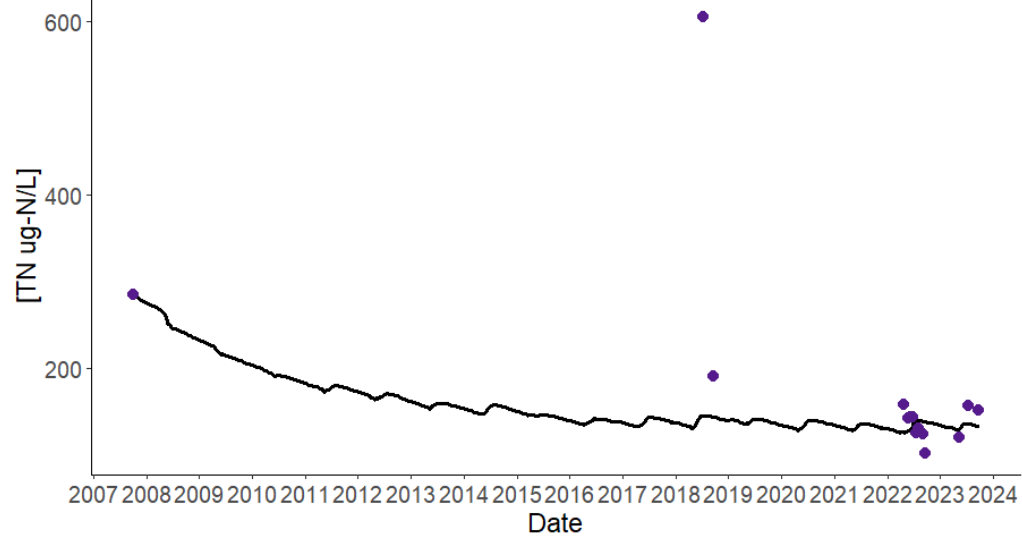
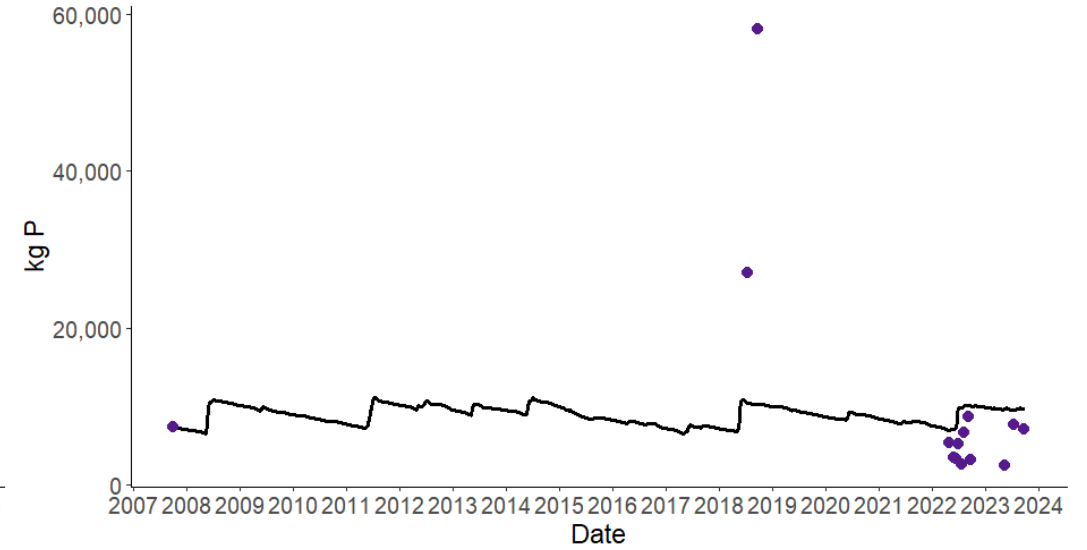
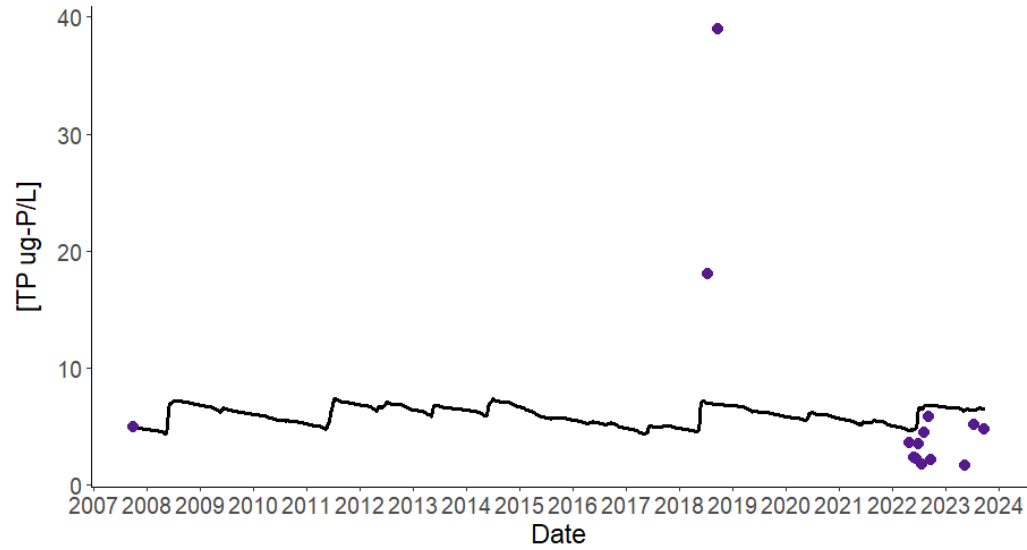


# Nutrient losses

- $\frac{\Delta M}{\Delta t} = T + W + D + H - O - (S - R)$
- Outlet ( $O_t$ ) =  $\frac{M_{t-1}}{V_{t-1}} * O_t$
- Sedimentation – resuspension ( $S-R$ ) based on paleolimnological study



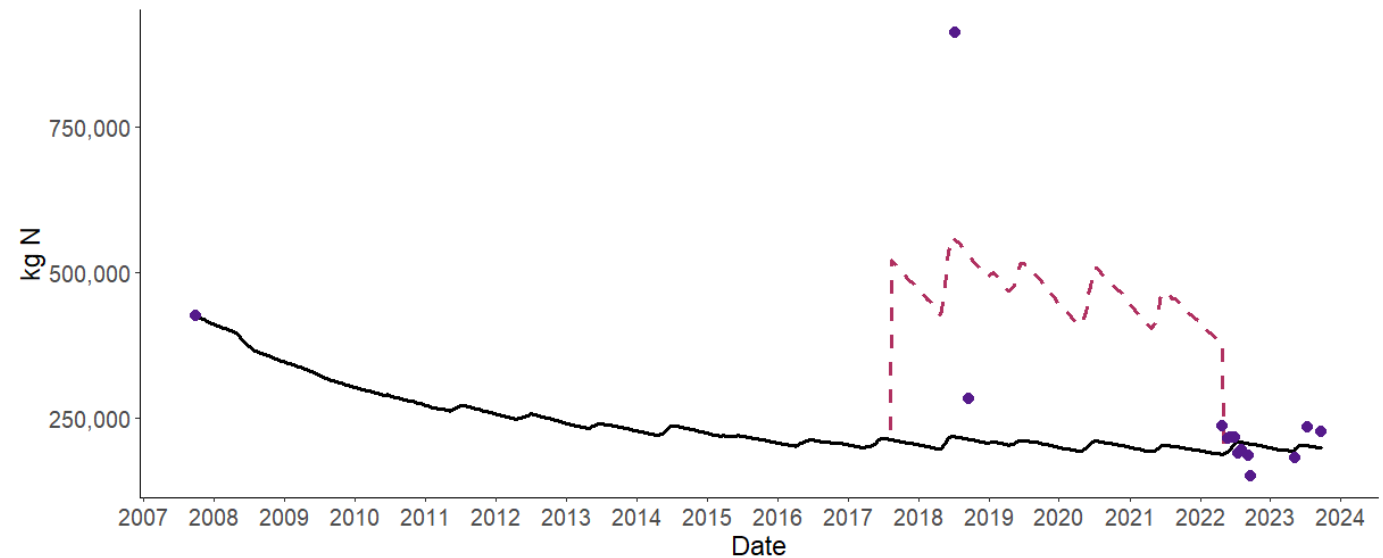
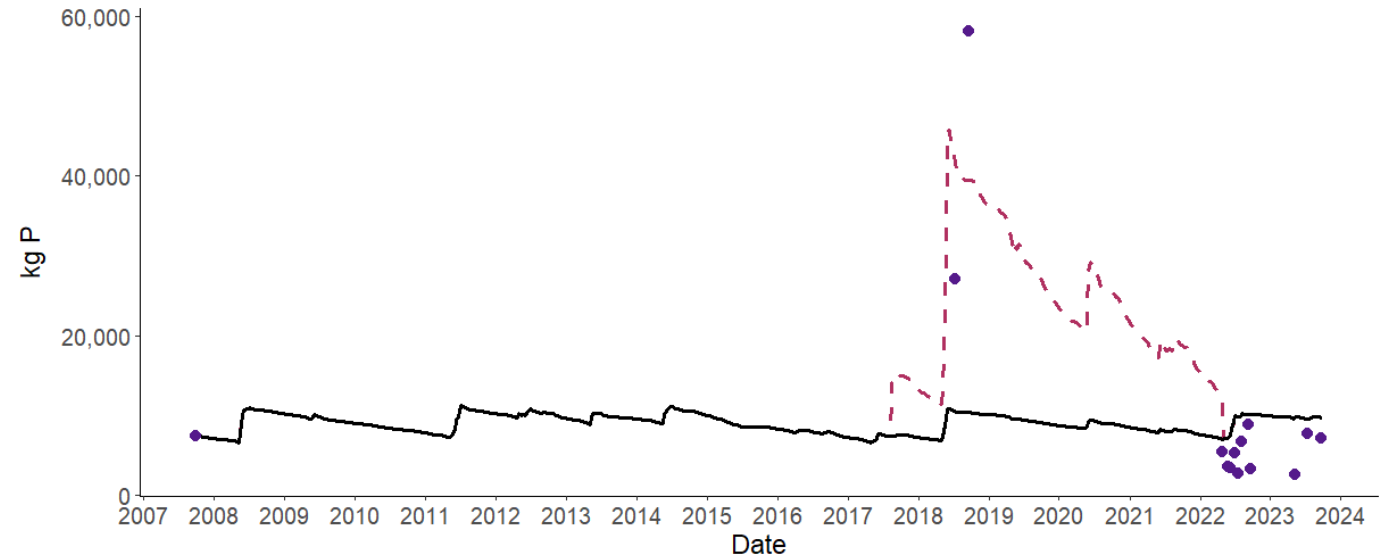
# Time series of P and N in Lake McDonald



# How must our model change to fit the data?

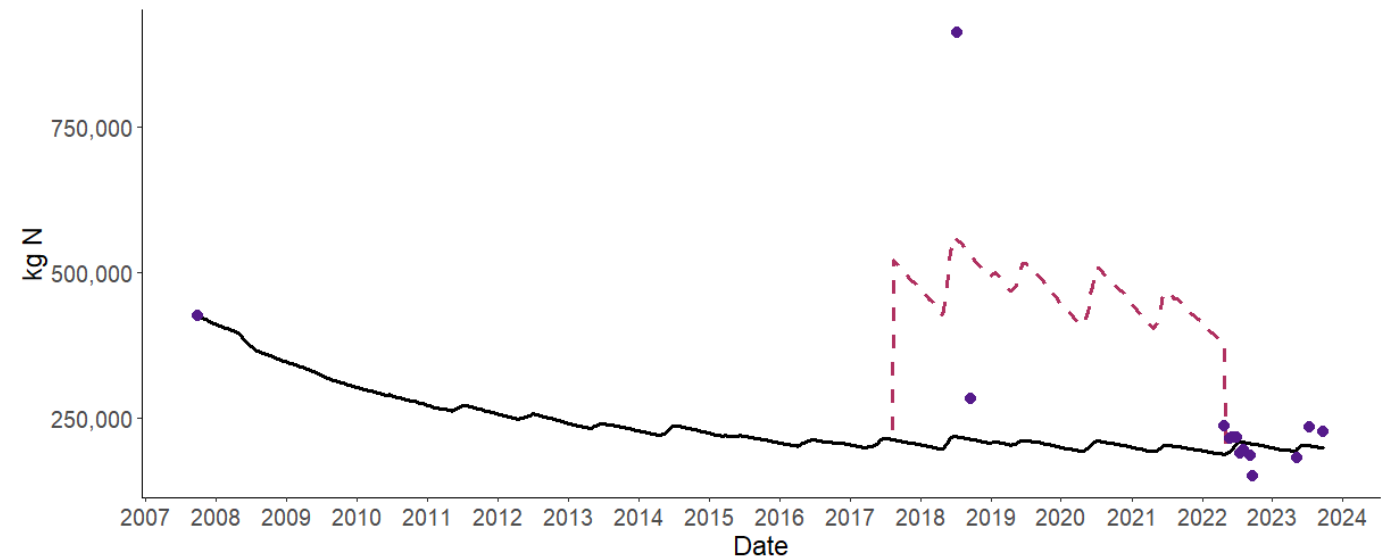
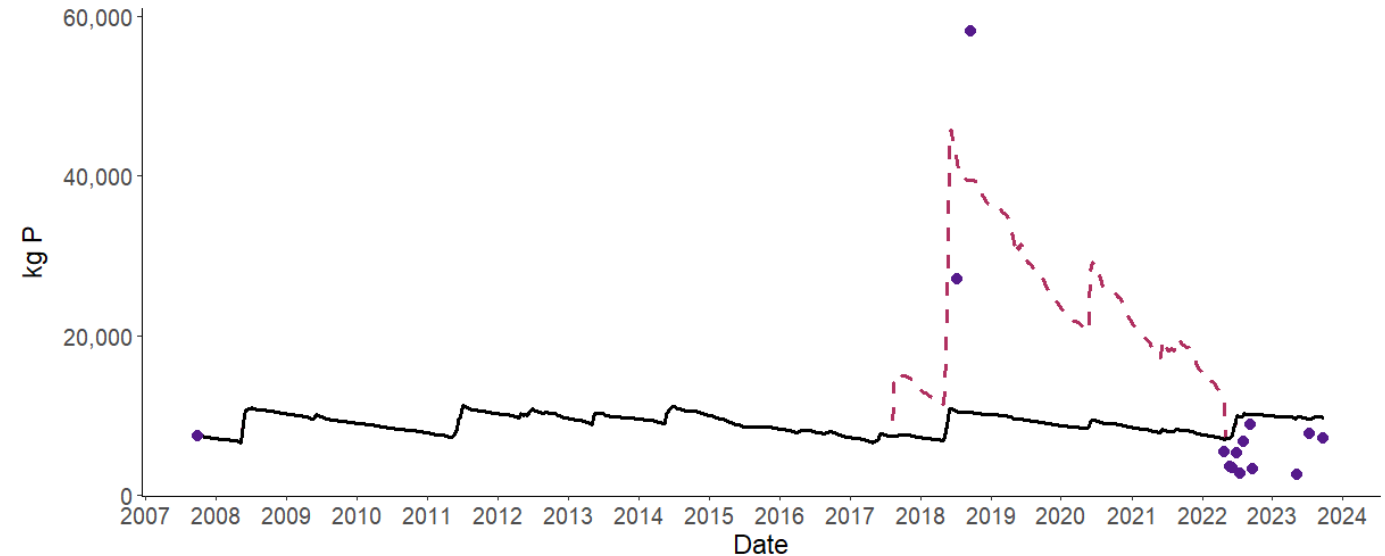
- Fit a nonlinear least squares model (power law)

- $M_{\text{measured}} = a * M_{\text{modeled}}^b$



# Where did the nutrients come from?

- $\frac{\Delta M}{\Delta t} = T + W + D + H - O - (S - R)$
- If **D** increased 2-30x when the fires first ignited
- Loading from burned tributaries – Upper McDonald, Snyder, and Sprague – would have had to increase **~2.5x**





# THANK YOU to all organizations and people that have made this possible!!!!

## Glacier National Park

Chris Downs

Jon McCubbins

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