A nutrient mass balance of Fernan Lake, ID, and future directions

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CDA tributaries WAG meeting, Nov 30, 2015, CDA, ID

Funded by: NSF IDAHO EPSCoR

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Acknowledgements

- Coeur d' Alene wastewater treatment plant
- IDEQ
- FLCRA
- Bill Miller
- Marie Pengilly
- Mike Webb
- Susan Andrews

Funding provided by Idaho EPSCoR # IIA-1301792

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Outline

- Background
- Fernan Lake intro
- Mass balance
- Internal loading
- Future directions

Lake Classification

Trophic state

Oligo- **Meso-** **Eutrophic**

Eutrophication

- **Eutrophication: presence of excess nutrients that stimulate aquatic plant growth** (Schindler et al. 2008)

- **Human activities accelerate this process**
  ag, forestry, roads

What causes blooms?

Carbon**:N**itrogen**:P**hosphorus

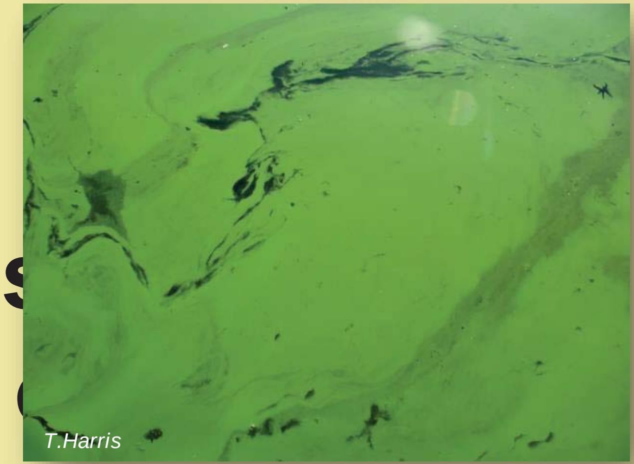
N:P 7.2:1 (by mass)

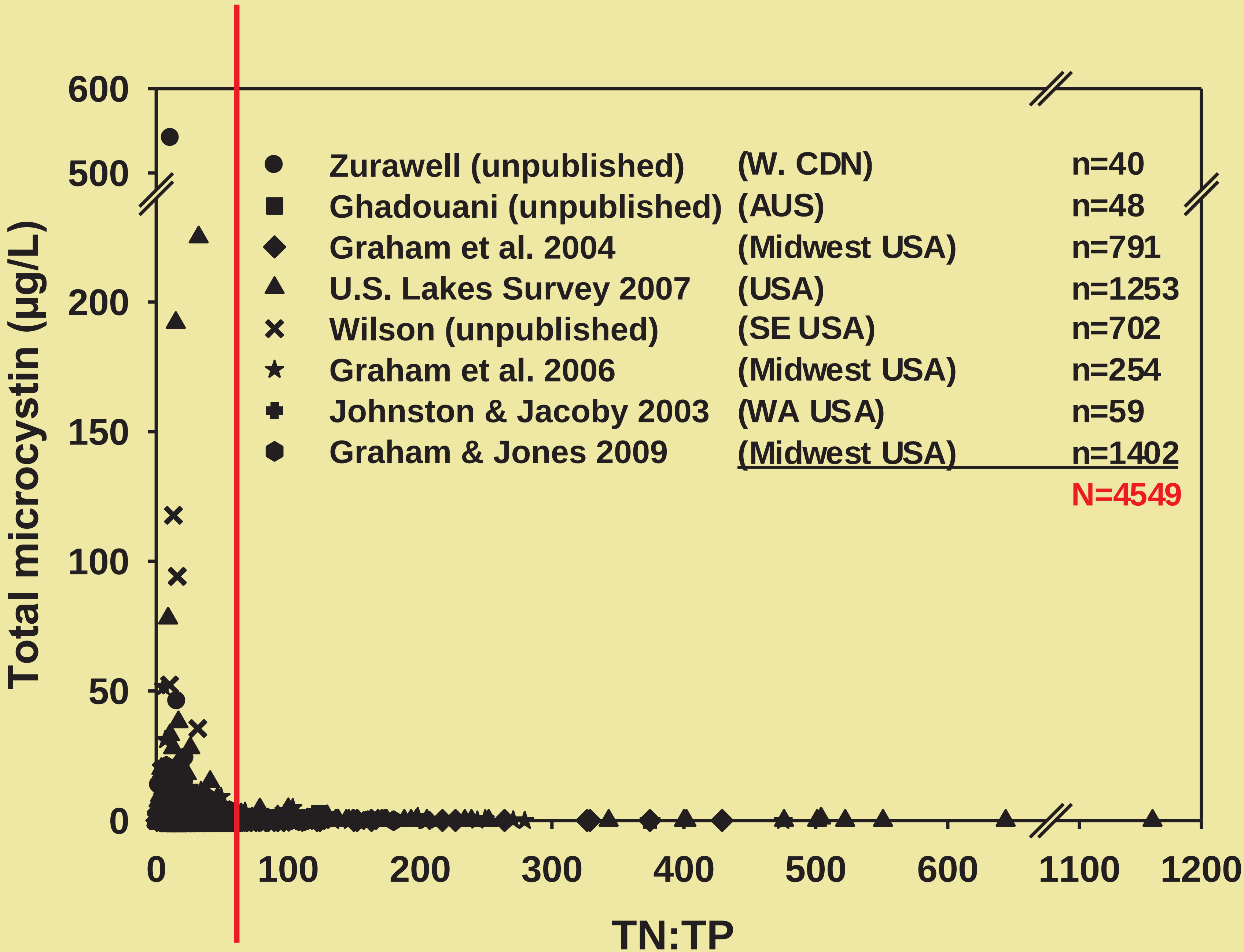
N:P = 7 = balanced

TN:TP ratio (by mass)

- **Theoretically**
  N:P > 7 = P-limited - OK
  N:P < 7 = N-limited - problems

- **In reality**
  Cyanobacteria blooms
  toxins when N:P 75:1





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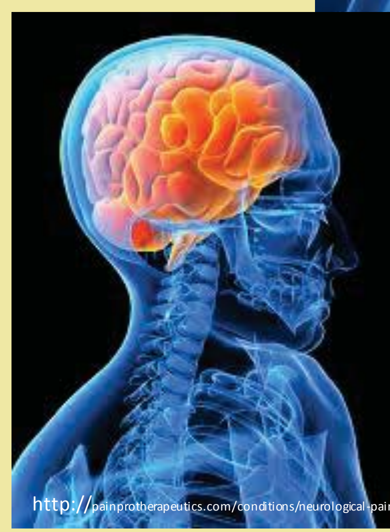
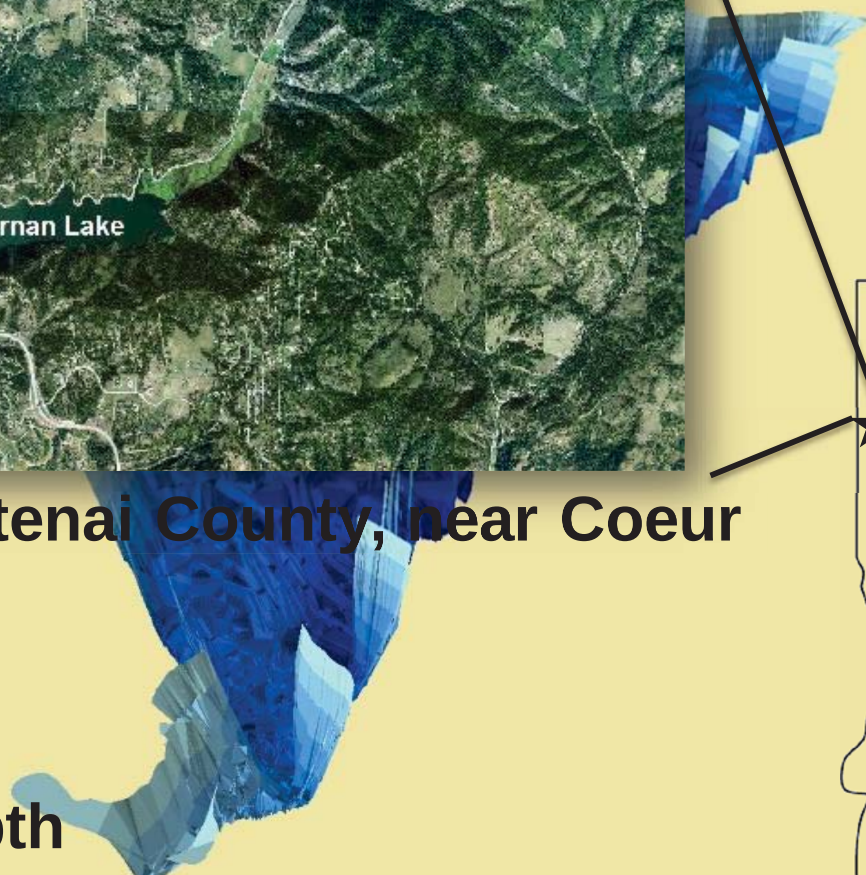
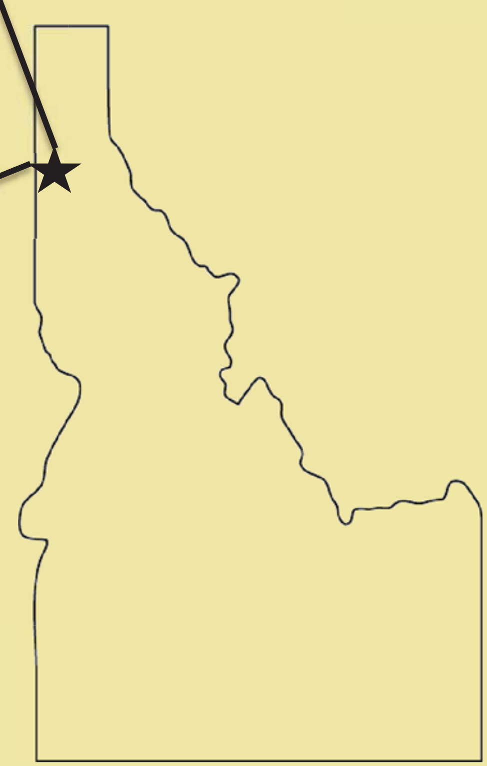
Toxins

- **Dermatoxins**
  - Skin, rashes
- **Hepatotoxins**
  - Liver toxins
- **Neurotoxins**
  - Central nervous system



Fernan Lake





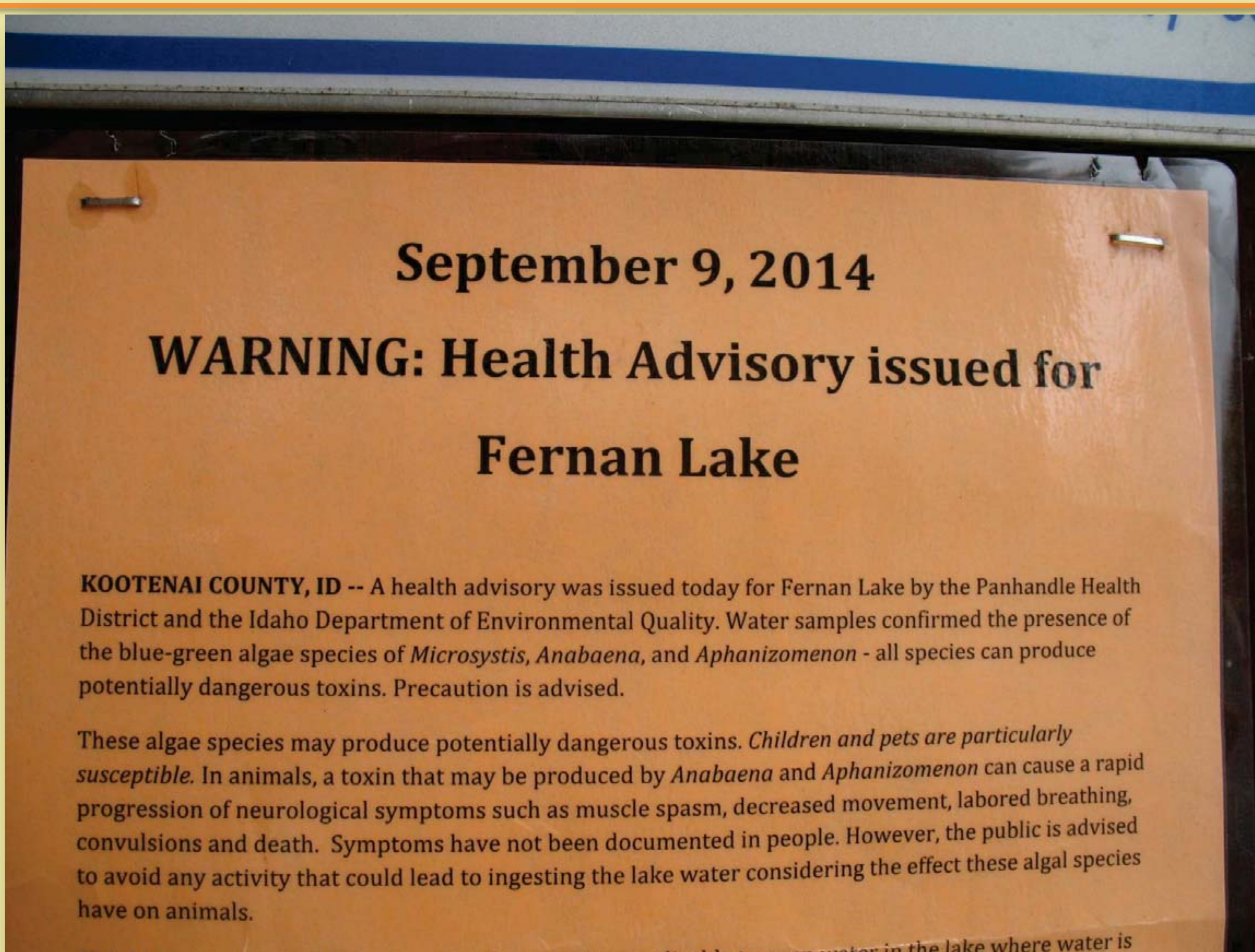
- Located in Kootenai County, near Coeur D'Alene, Idaho

- 154 ha
- 5.1 m mean depth
- 8.2 m max depth

Bloom history

Day/yr	Action
26-Jul- 2007	Bloom noted
05-Aug-2008	Bloom noted
01-Oct-2008	Bloom noted
11-Jul-2012	10 day advisory
28-Jun-2013	24 day advisory
08-Jul-2014	14 day advisory
09-Sep-2014	90+ day advisory
26-Jun-2015	ongoing

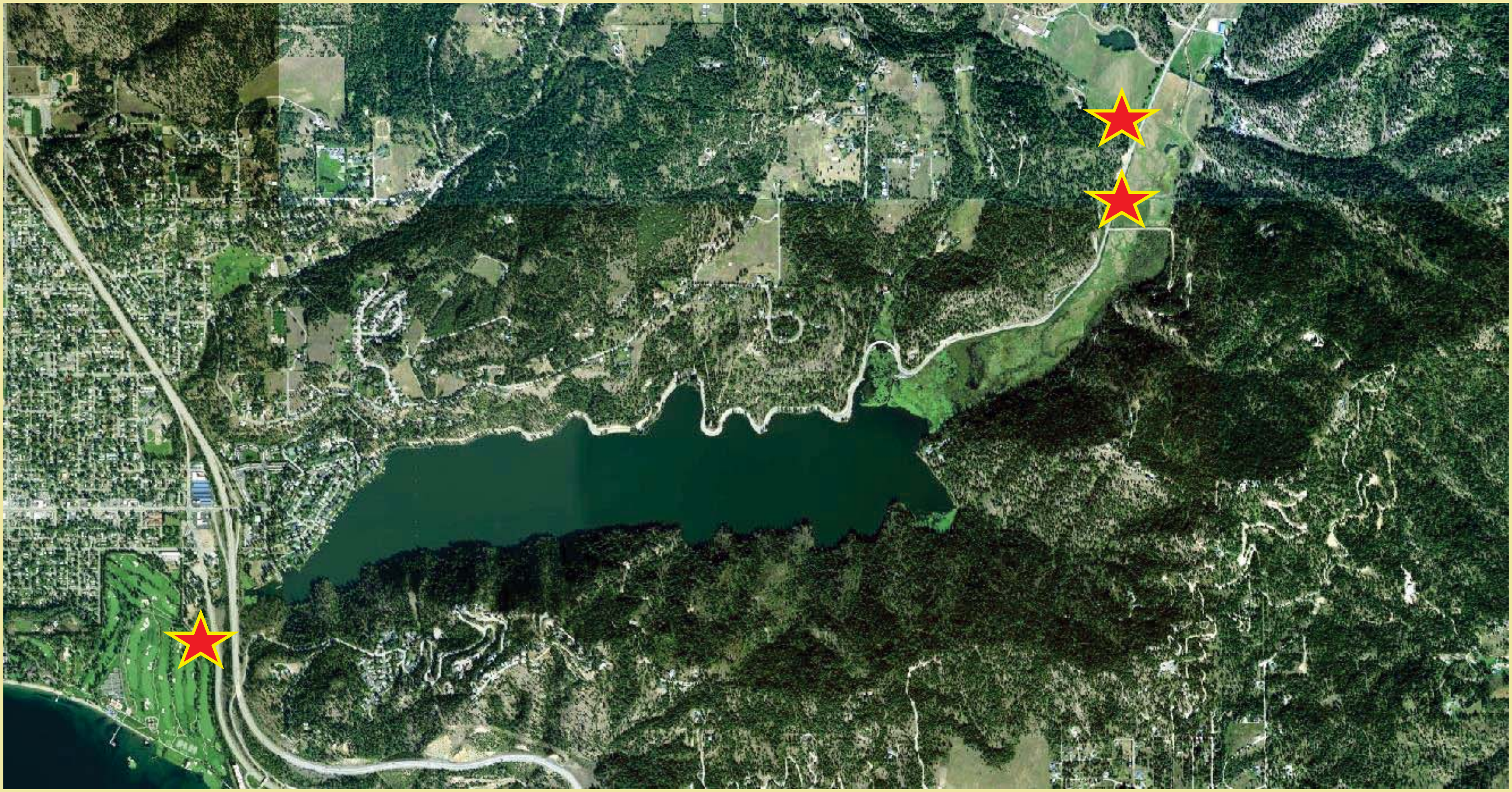
Lake closures



Objectives

- Establish detailed mass balance of phosphorus and total residue
- Sample in- and outflows for 1 year

Inflows and outflow



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Culvert locations

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Determine culvert load

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Determine wetland load

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Explore influence of the dam

13-May-14 Dam in

01-Dec-14 Dam out

03-Mar-15 Dam in

ISCO automated samplers

- One sample/day

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http://www.caeonline.com/listing/product/187711/isco-3700

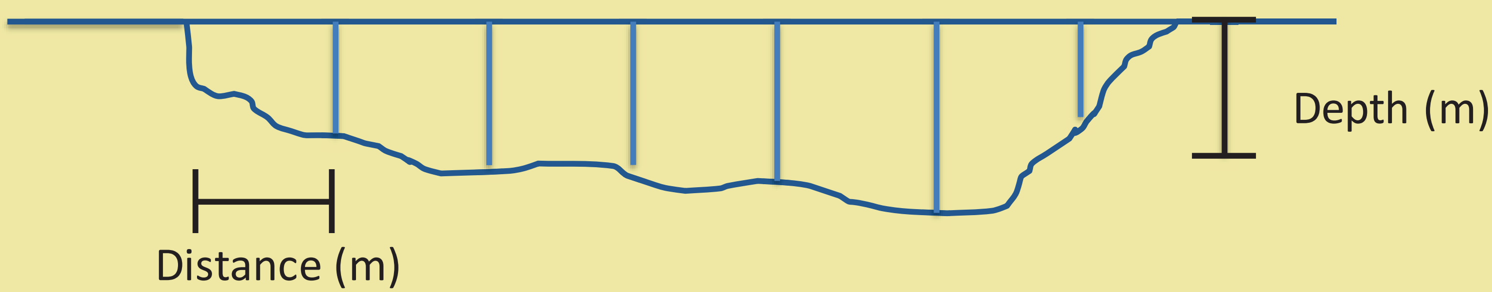
Sample analyses

- **Total residue (mg/L) was measured using standard method 2450-B** (Eaton et al. 2005)

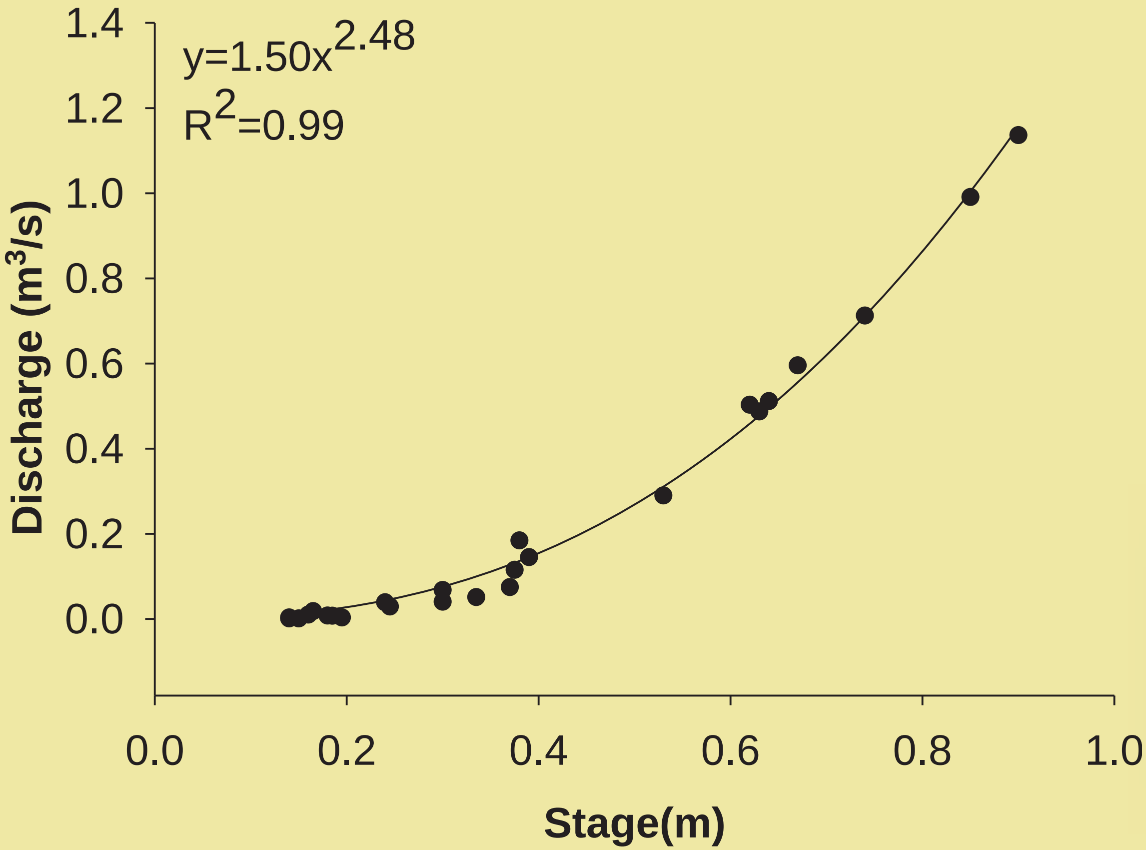
- **Total phosphorus (µg/L) was measured using method 4500-P** (Eaton et al. 2005)

Discharge

- measured by traditional cross-section and velocity
- Concentration × discharge= load



Discharge



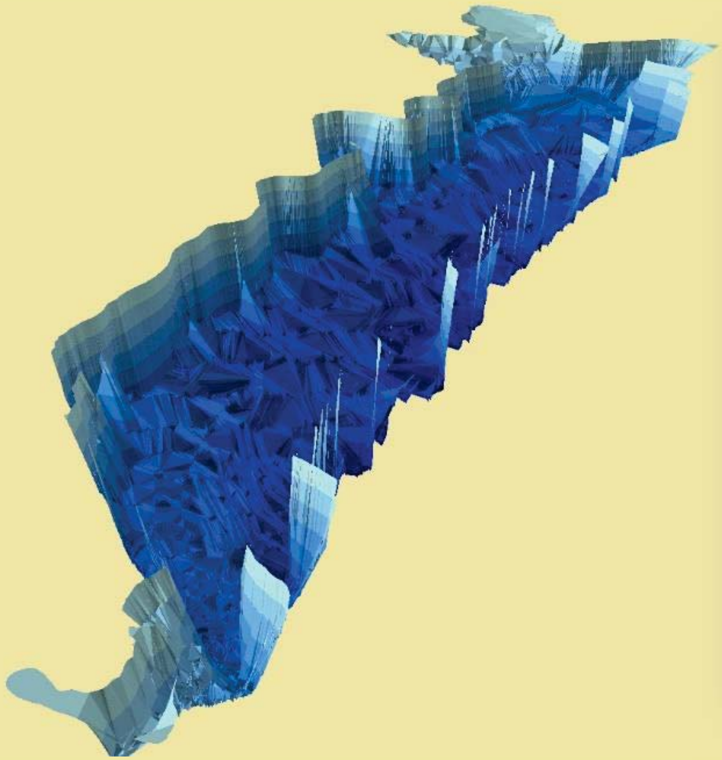
Made rating curves from bi-weekly visits

recorded stage @ 15 min intervals

http://www.onsetcomp.com/products/data-loggers/water-level

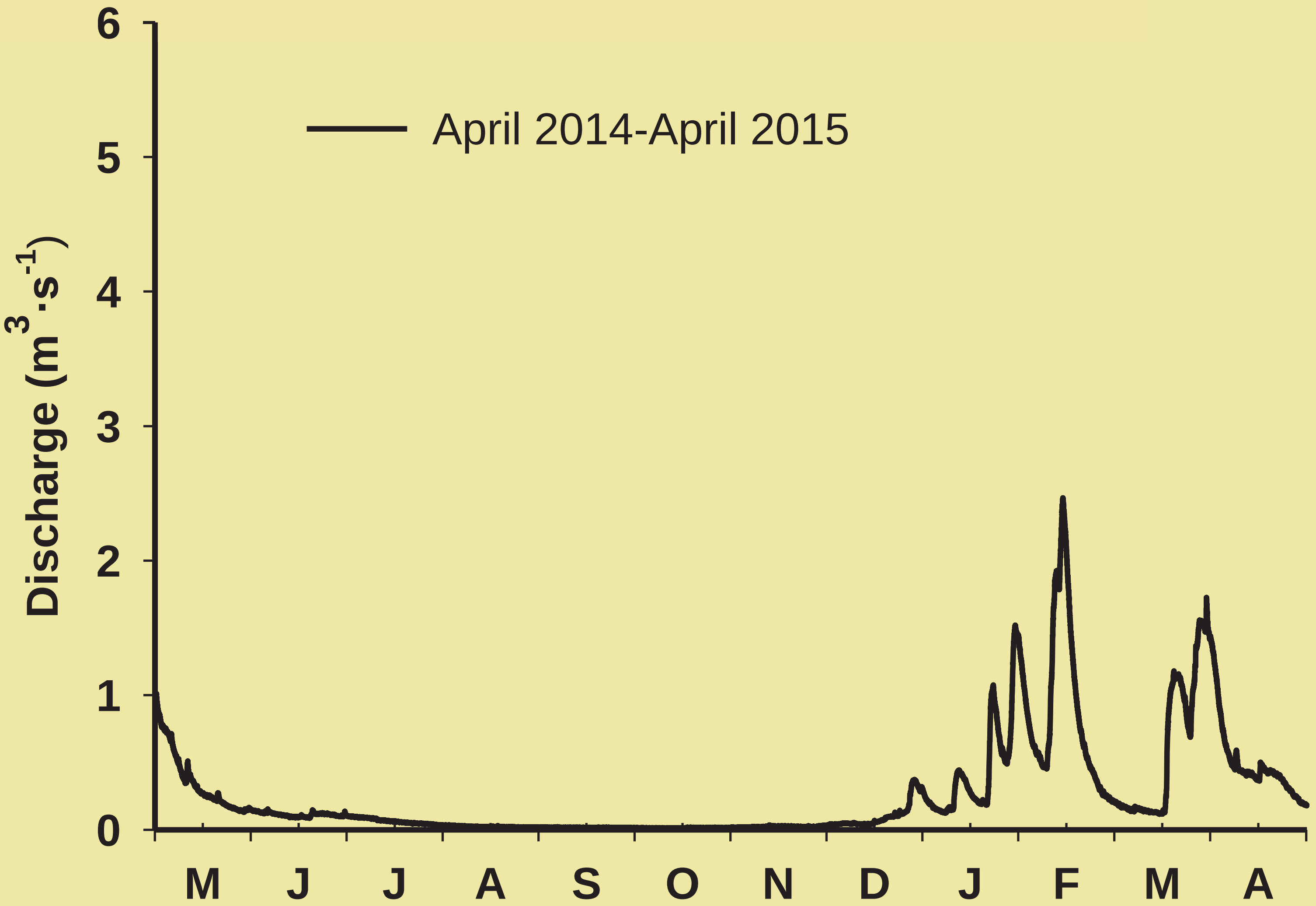
Lake surface area and volume

- Used bathymetry data
- Water level at the dam

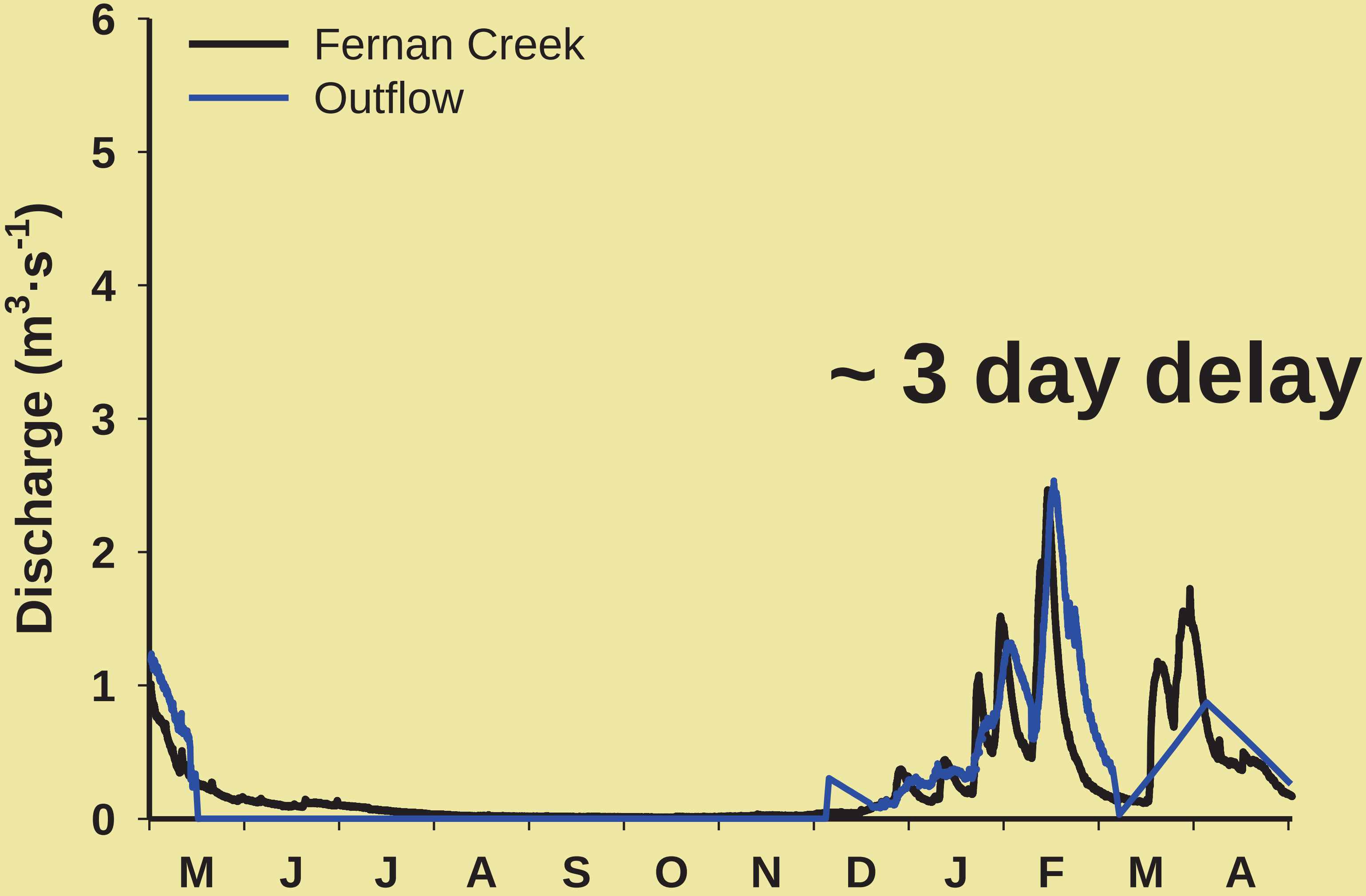


Fernan Creek Hydrograph

Fernan Creek Hydrograph



Fernan Creek Hydrograph



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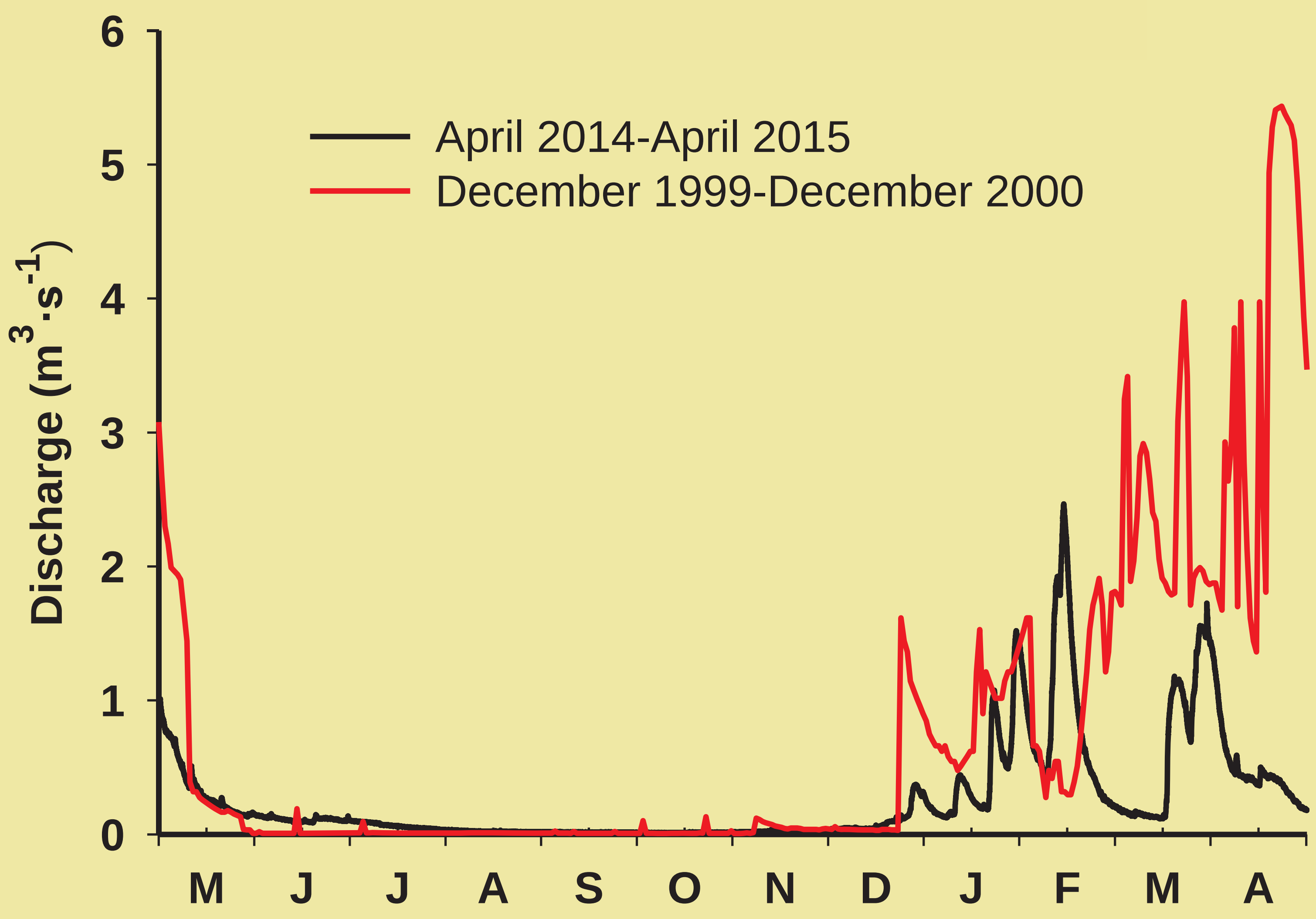
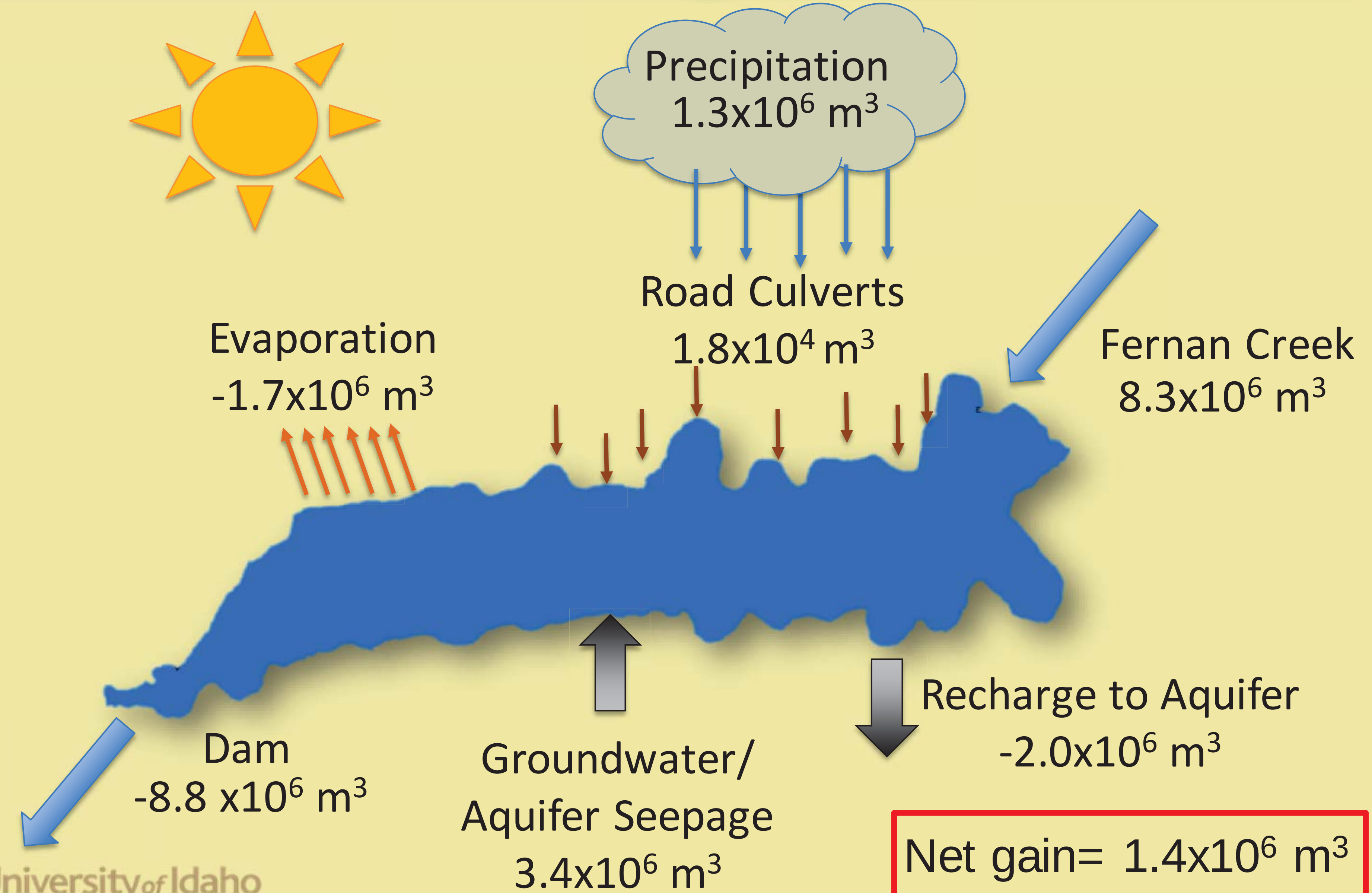
Fernan Creek Hydrograph



Annual water budget



Net gain= $1.4x10^6$ m^3

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11-Mar-14
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14-Oct-14
T. LaCroix

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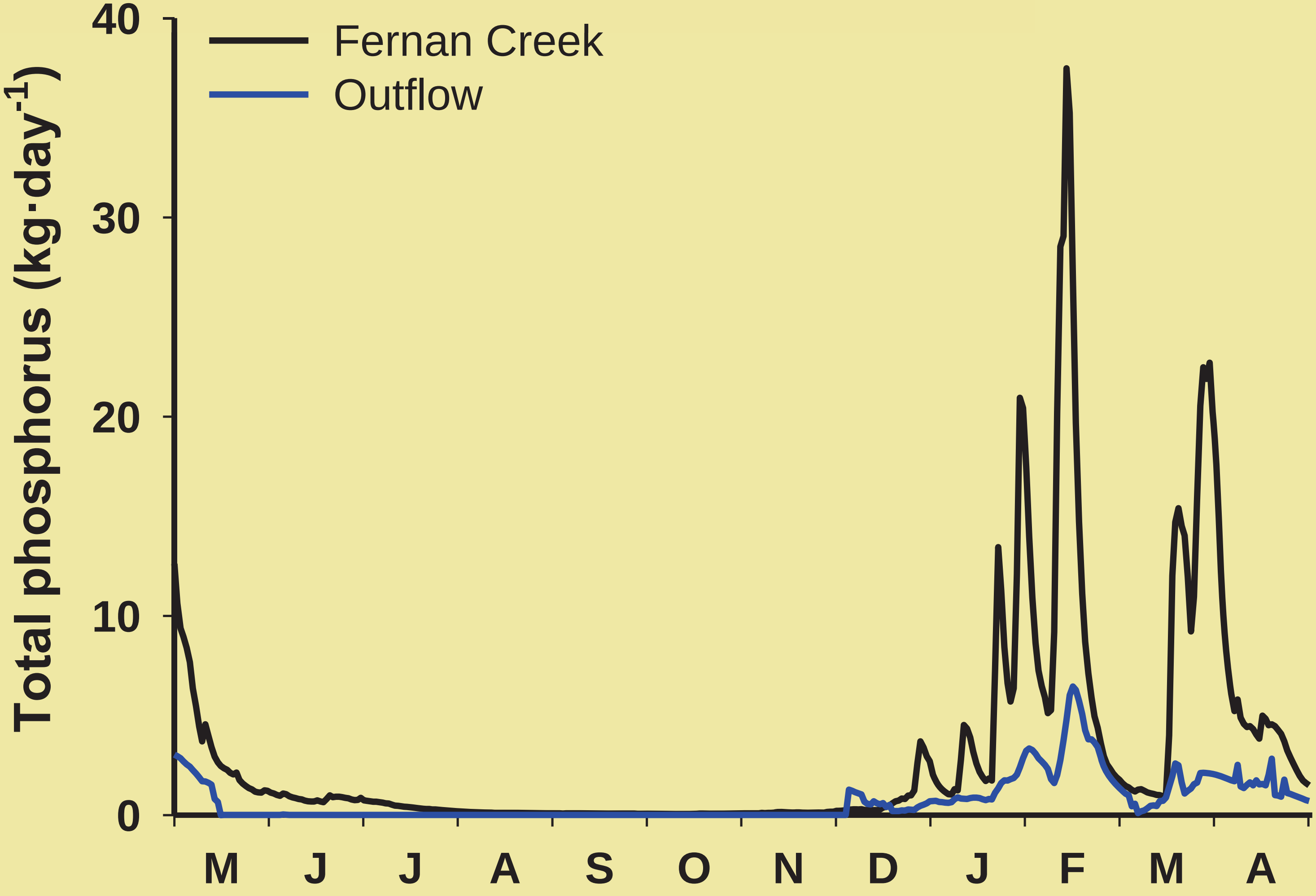
Total Phosphorus Flux



Total Phosphorus Storage

Input - Output = ΔStorage

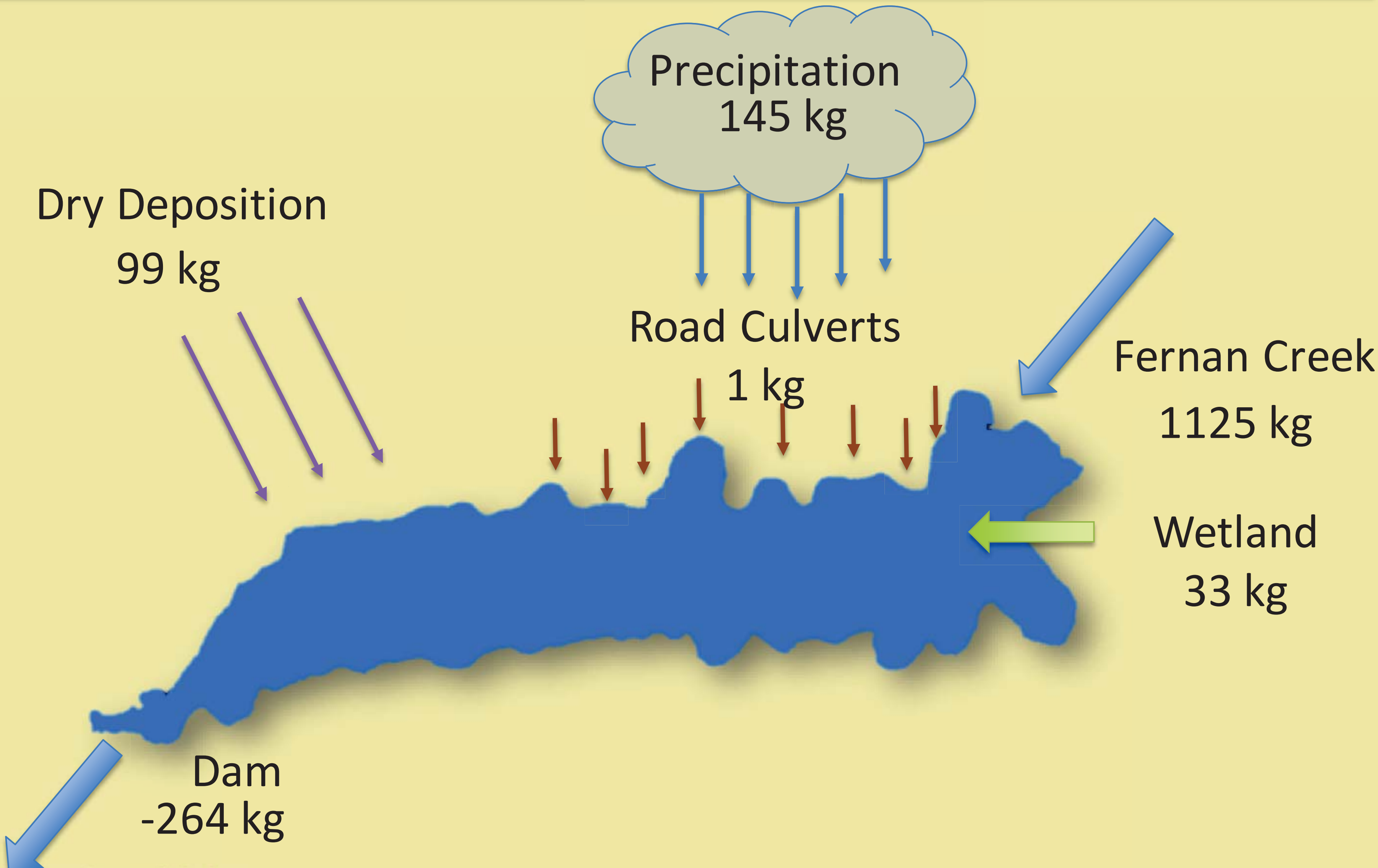
Inputs = 1.4 tonnes

- Output = 0.3 tonnes

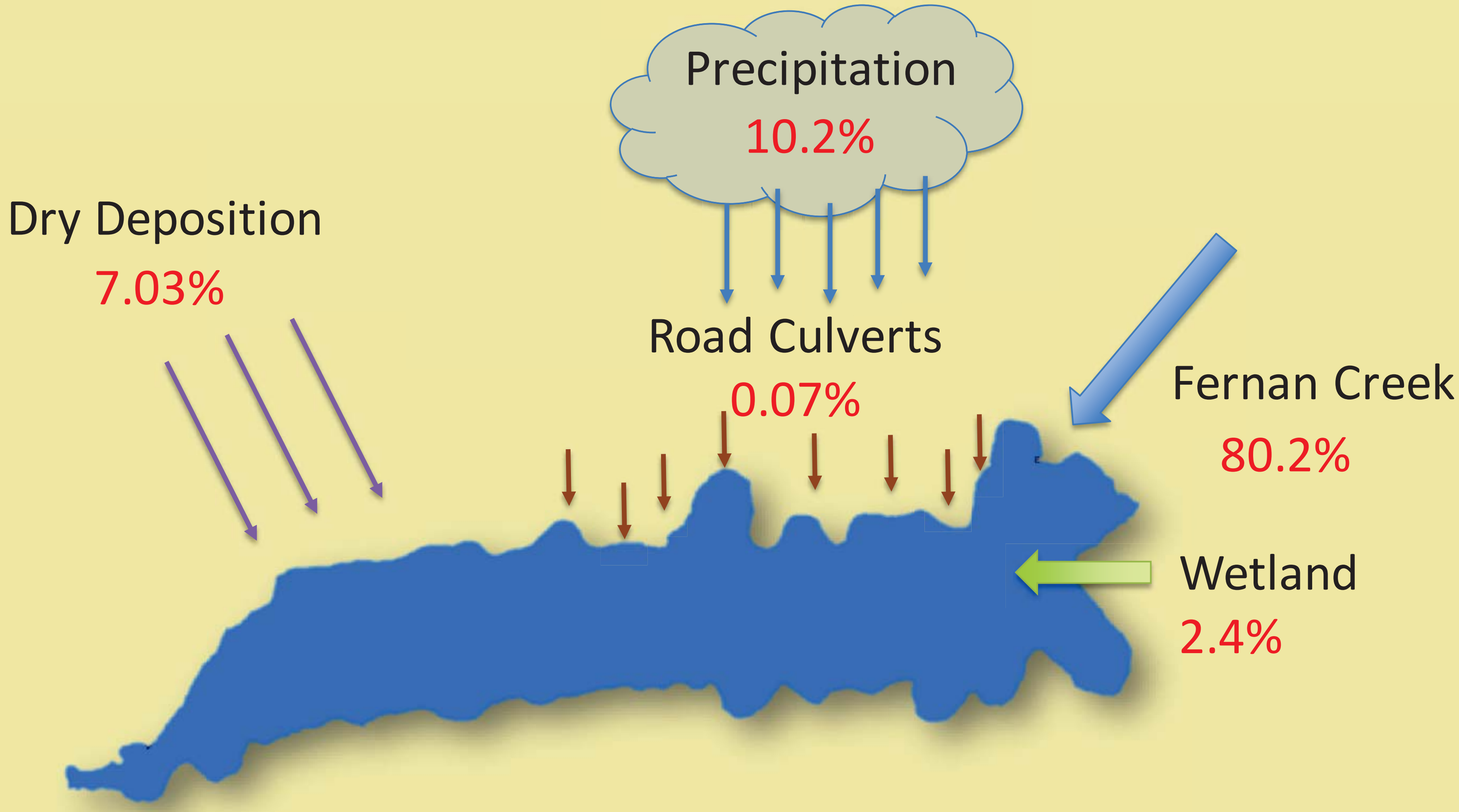
Δstorage = 1.1 tonnes

(81%)

Annual P budget



Inflow P percentages



Total Residue (sediment)

Input - Output = ΔStorage

Inputs = 2298 tonnes

\- Output = 760 tonnes

Δstorage = 1538 tonnes

(67%)

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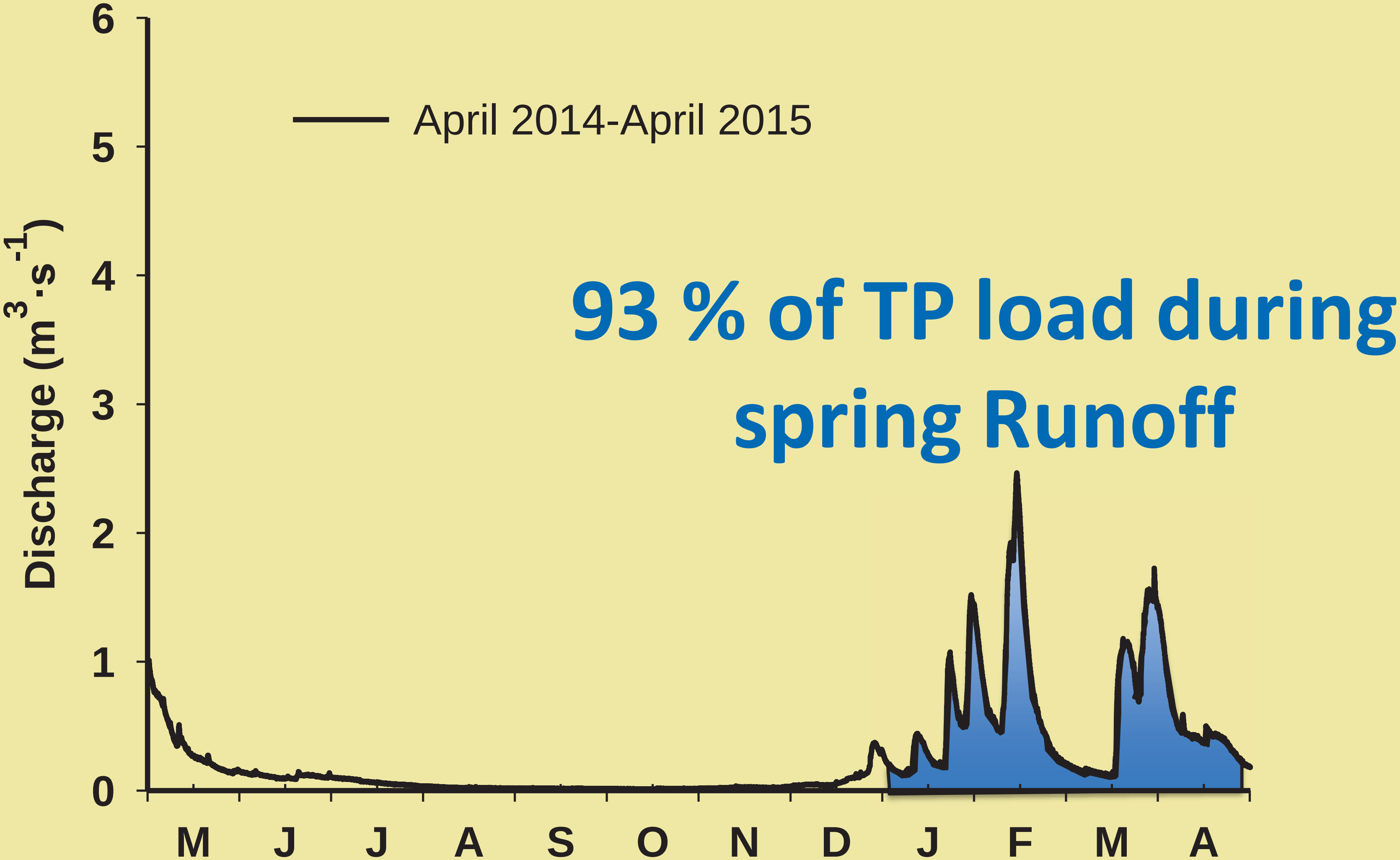

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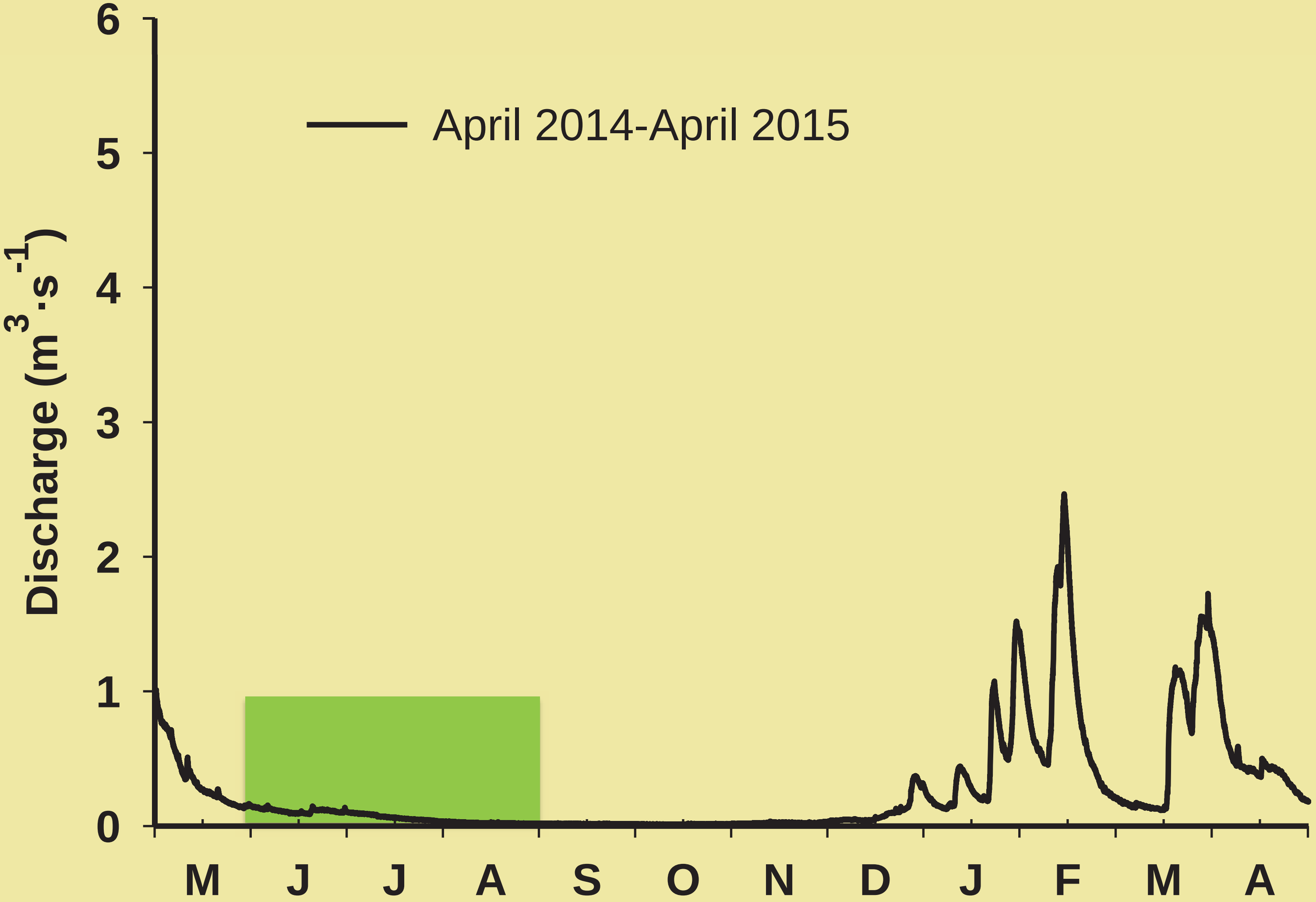
Problem is in the summer months



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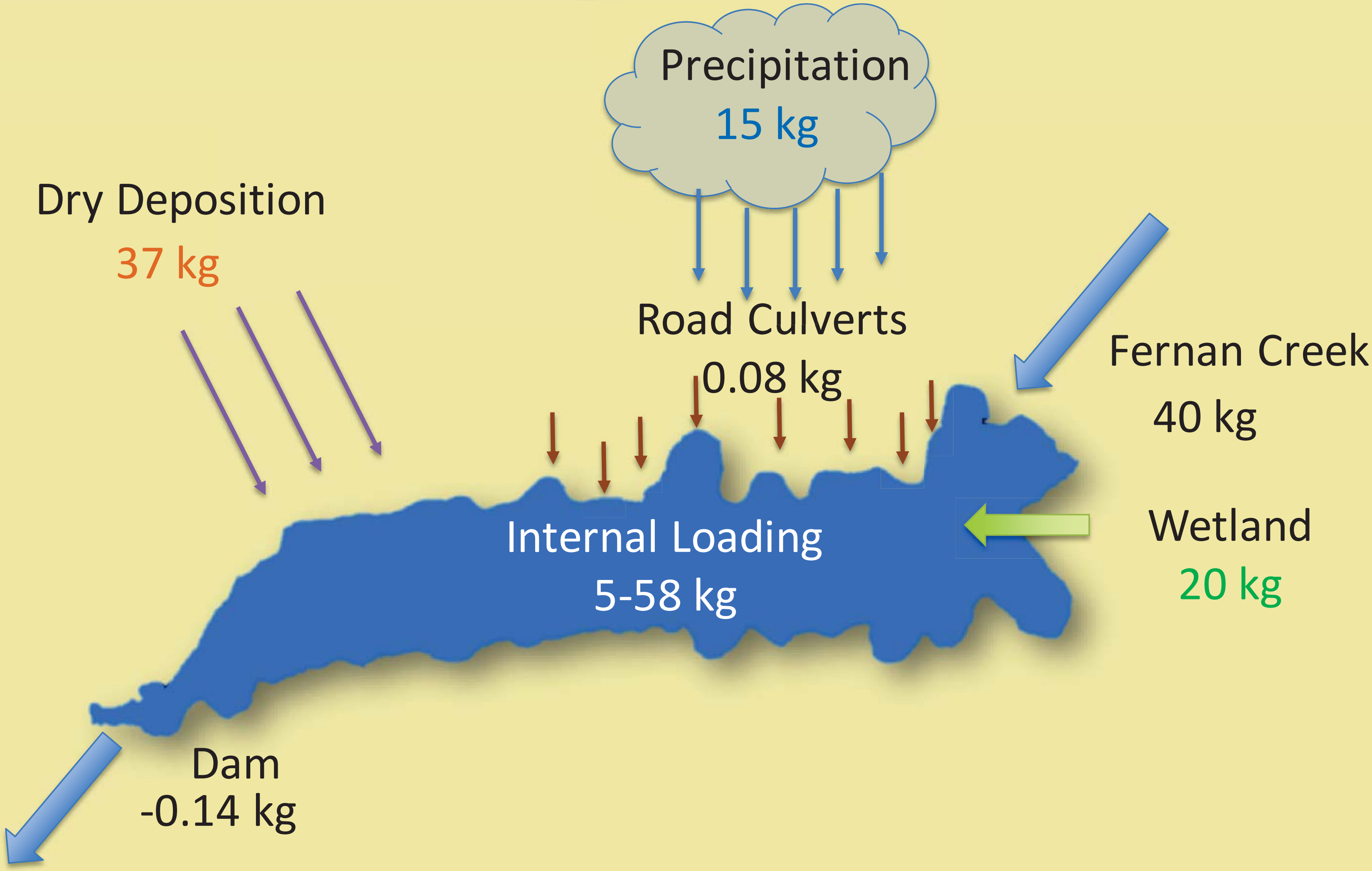
Calculate summer internal load

$$\text{in-out-}\ \Delta\text{in lake P} = L_{internal}$$

(Welch and Jacoby 2001)

***This assumes that all external P is readily available**

Summer P budget



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Summer internal load

In - out - Δin lake P = $L_{internal}$

93 - 0.14 - 88 +20 = 25 kg (21%)

93 - 0.14 - (88-15)+20 = 40 kg (30%)

93 - 0.14 - (88-15-38)+20 = 78 kg (46%)

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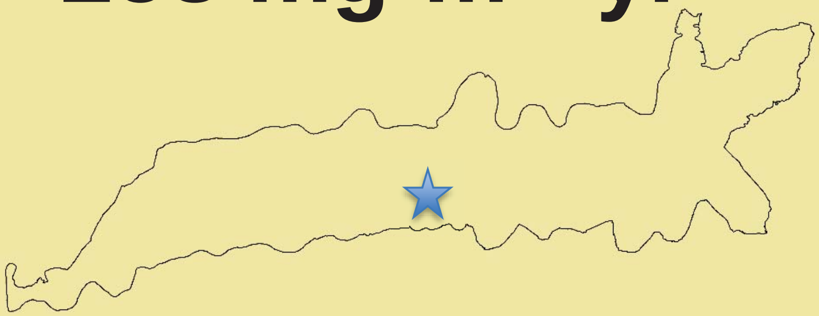
Internal loading

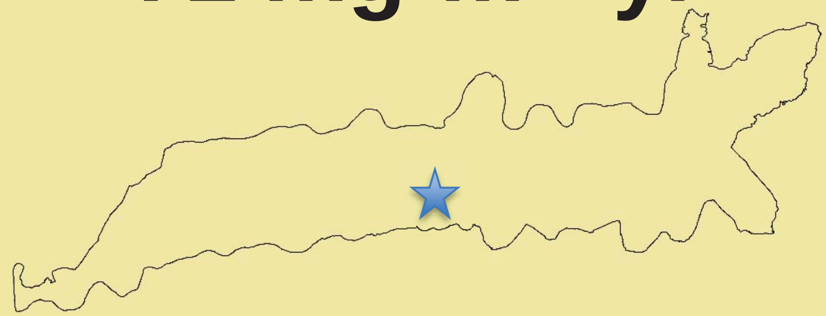
2014

$258\ mg \cdot m^{-2} \cdot yr^{-1}$



2015

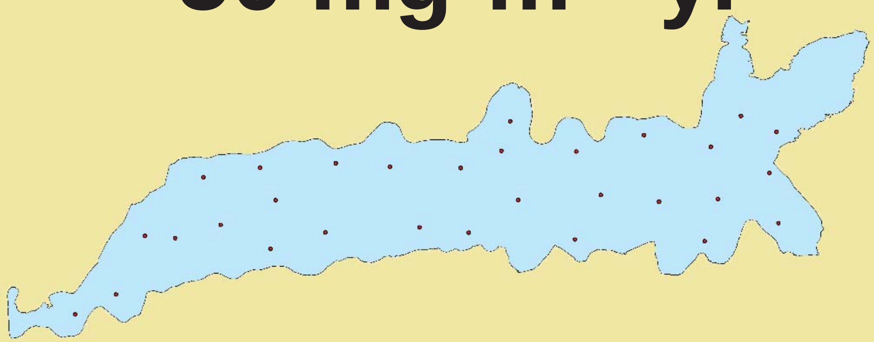
$71\ mg \cdot m^{-2} \cdot yr^{-1}$



2015

30 sites

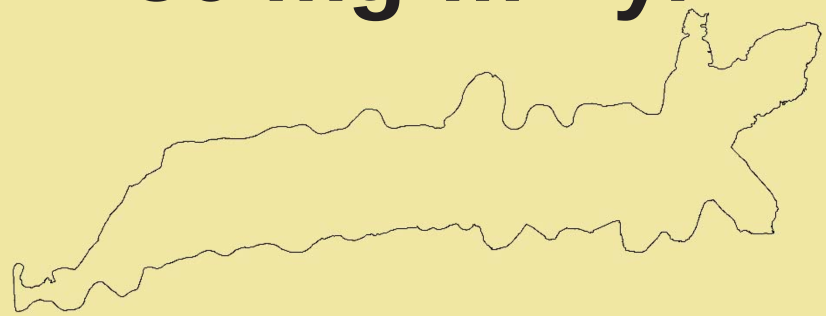
$50\ mg \cdot m^{-2} \cdot yr^{-1}$



29 % lower than deep site

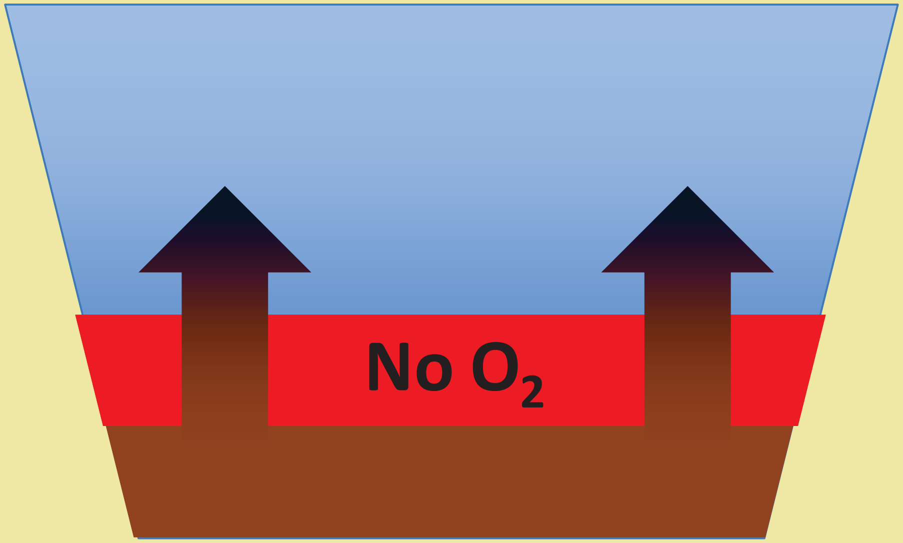
Internal loading

2014	2015
183 $mg \cdot m^{-2} \cdot yr^{-1}$	50 $mg \cdot m^{-2} \cdot yr^{-1}$



What is the source?

- Internal loading via anoxia / redox reactions



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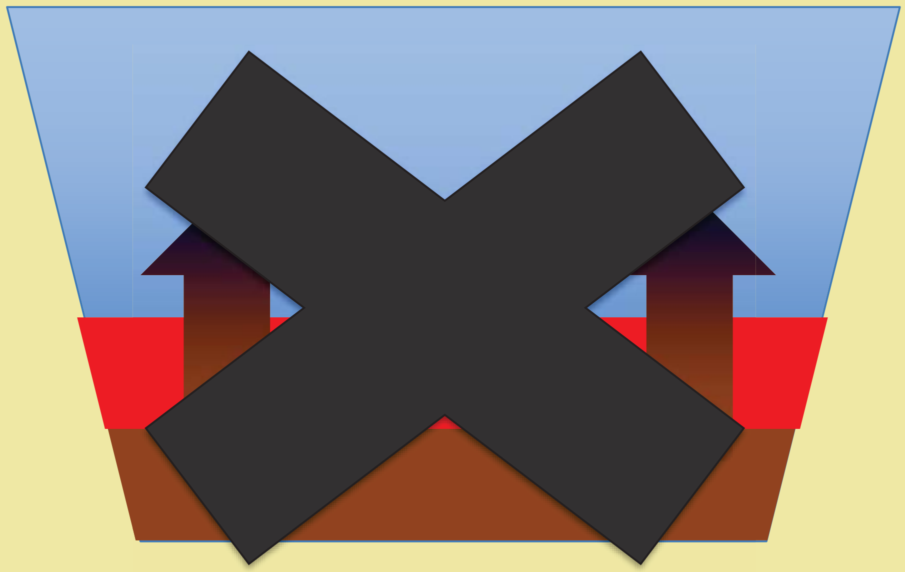
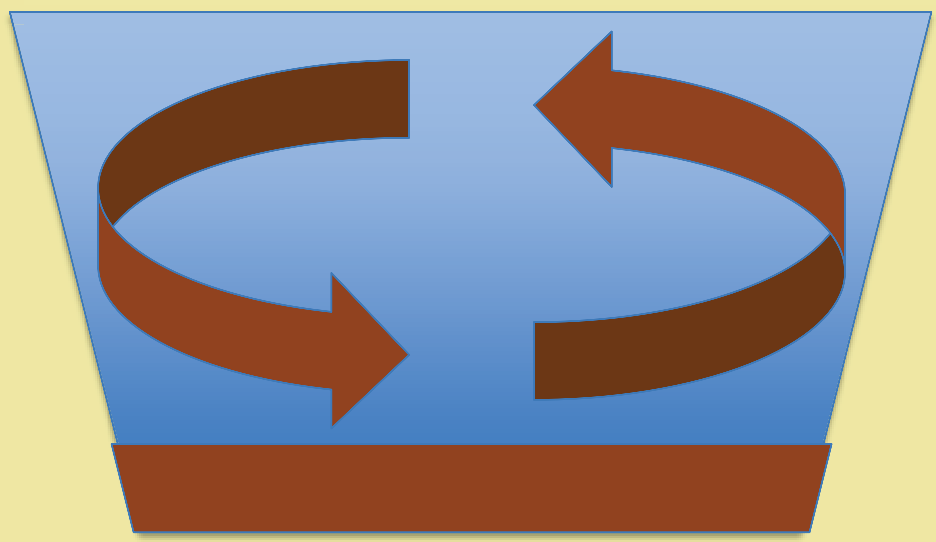
What is the source?

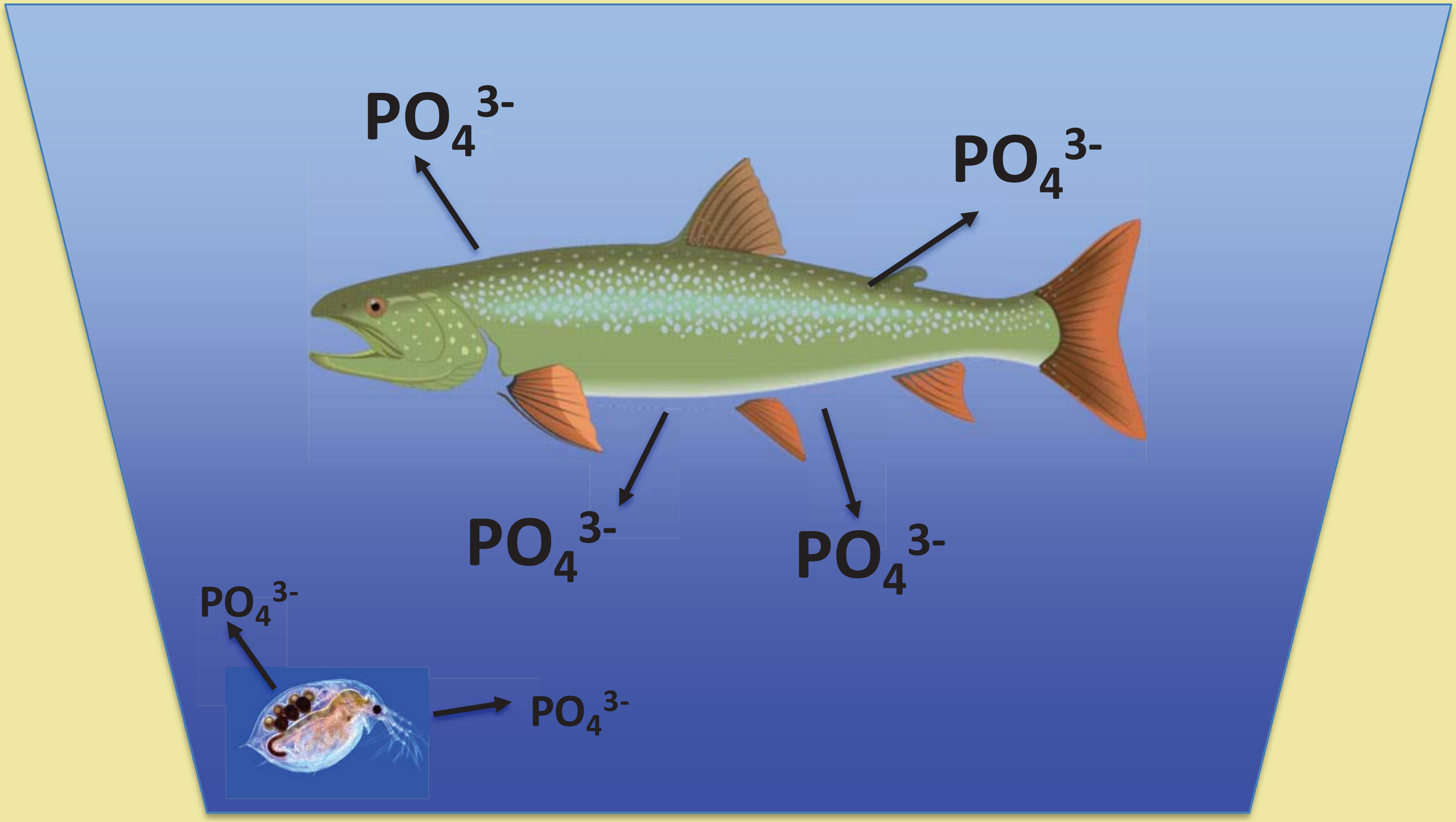
- Fernan is well mixed throughout the year



Wind induced mixing



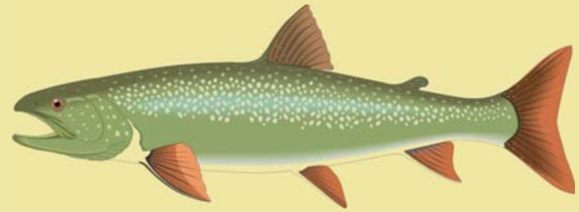
Biotic community recycling



Literature data

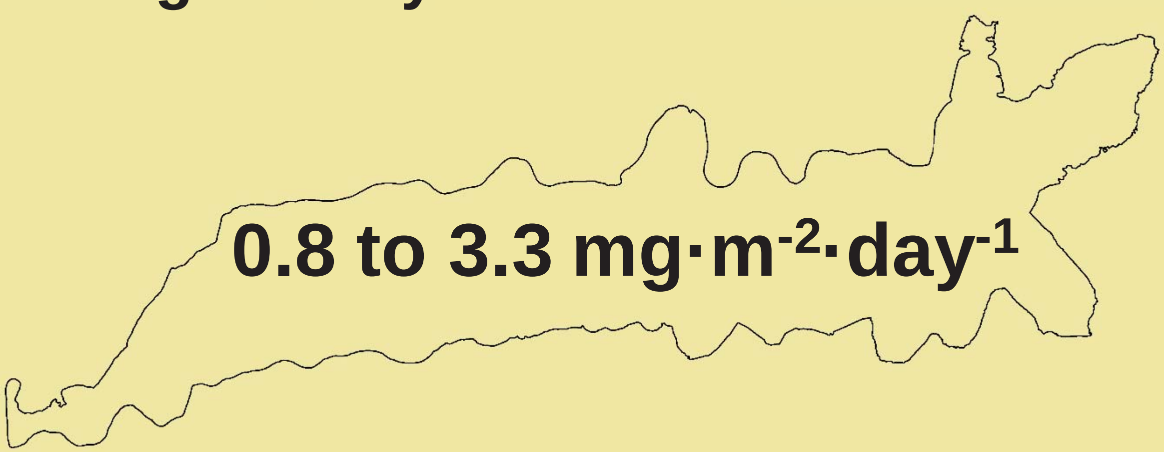
- **11 publications**
- **rates ranged from**

0.01 to 37 mg·m^{-2}·day^{-1}



- **11 publications**
- **rates ranged from**

0.02 to 5.46 mg·m^{-2}·day^{-1}



Summary

- Majority of P and sediment come in during spring runoff
  - However this is not the problem time period
- Internal loading contributes 21-46% of the available P in summer
  - Investigate internal loading further

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Summary

- Inter-annual variability in runoff and loading

- Wind mixing or biotic community

- In-lake strategies in concert with whole-watershed remediation

Future directions

- Wetland function
- Dry deposition
- Internal loading

- Restoration/remediation

Remediation options

Whole-watershed/external

- Headwater to lake (sed. delivery)
- Examine Fernan Creek

In-lake/internal

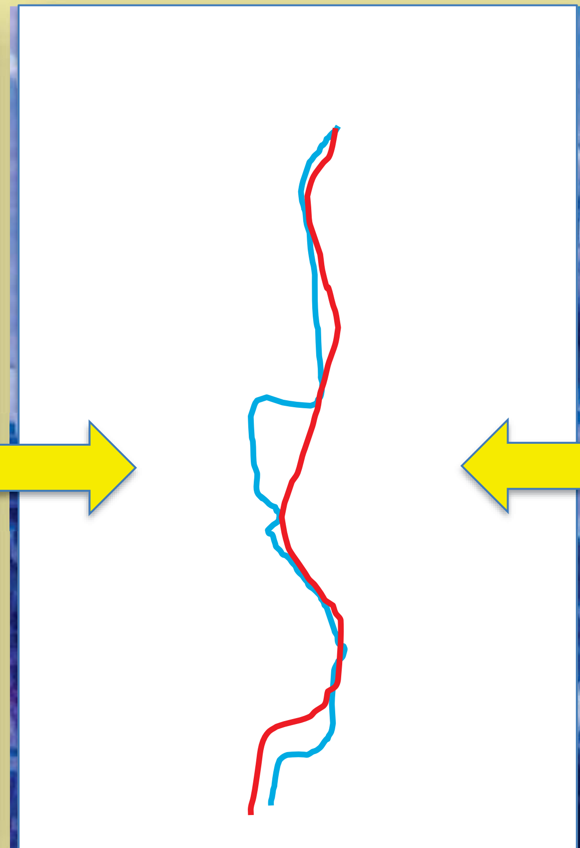
- Dredging
- Alum addition
- Nitrogen addition

In-lake remediation

- Treat symptoms, not the source
- Expensive – commitment

Fernan Creek changes

1954



1974

Today

Historic Fernan Creek

Photos from USGS

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Alum addition

- Precipitates P from the water column
- If alum is buried by sediment, it becomes ineffective

- Whole lake application for Fernan Lake would cost between $22,500 - $560,000

Dredging

- Remove P-rich seds
- Need someplace for removed sediment

Geotubes to dewater sediment

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Nutrient rebalance

- **Add N to re-balance TN:TP ratio**
- **Allows beneficial algae to flourish**
- **Reduces cyanobacteria abundance and toxins**

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Questions?