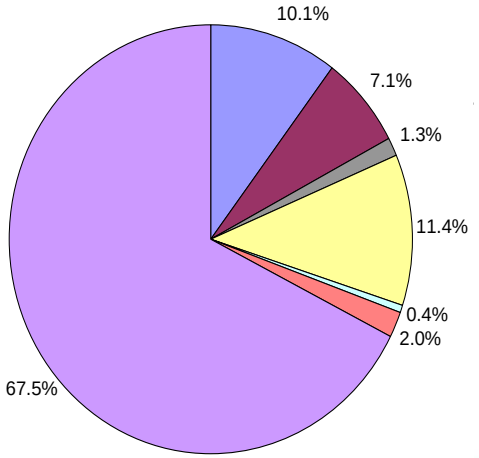
Associated Environmental

CANADA'S BEST MANAGED COMPANIES Platinum member



Phosphorus Budgets – What do and what don't they tell us?

Dörte Köster, Ph.D.

ALMS Workshop, Chestermere, September 18, 2019

Questions

- What is a Phosphorus Budget?
- How to estimate external and internal sources of Phosphorus to a lake?
- What does and what doesn’t the Phosphorus budget tell us?
- Where do we go from here?

What is a Phosphorus Budget?

Family Budget

- Breakdown helps make decisions on managing expenses
- Sources……and losses of money

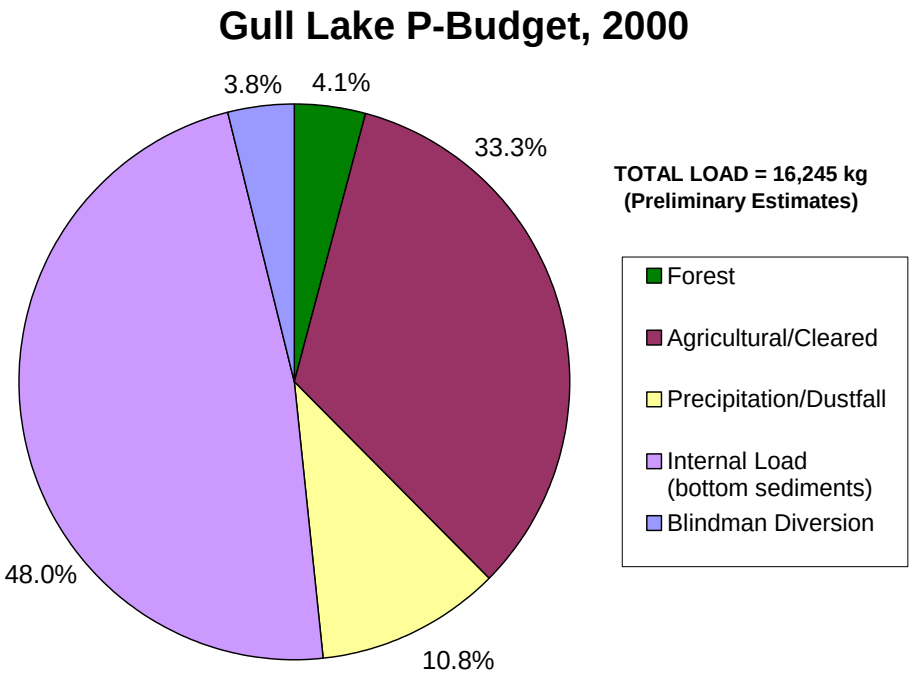
- Work

or

- Lottery?!?

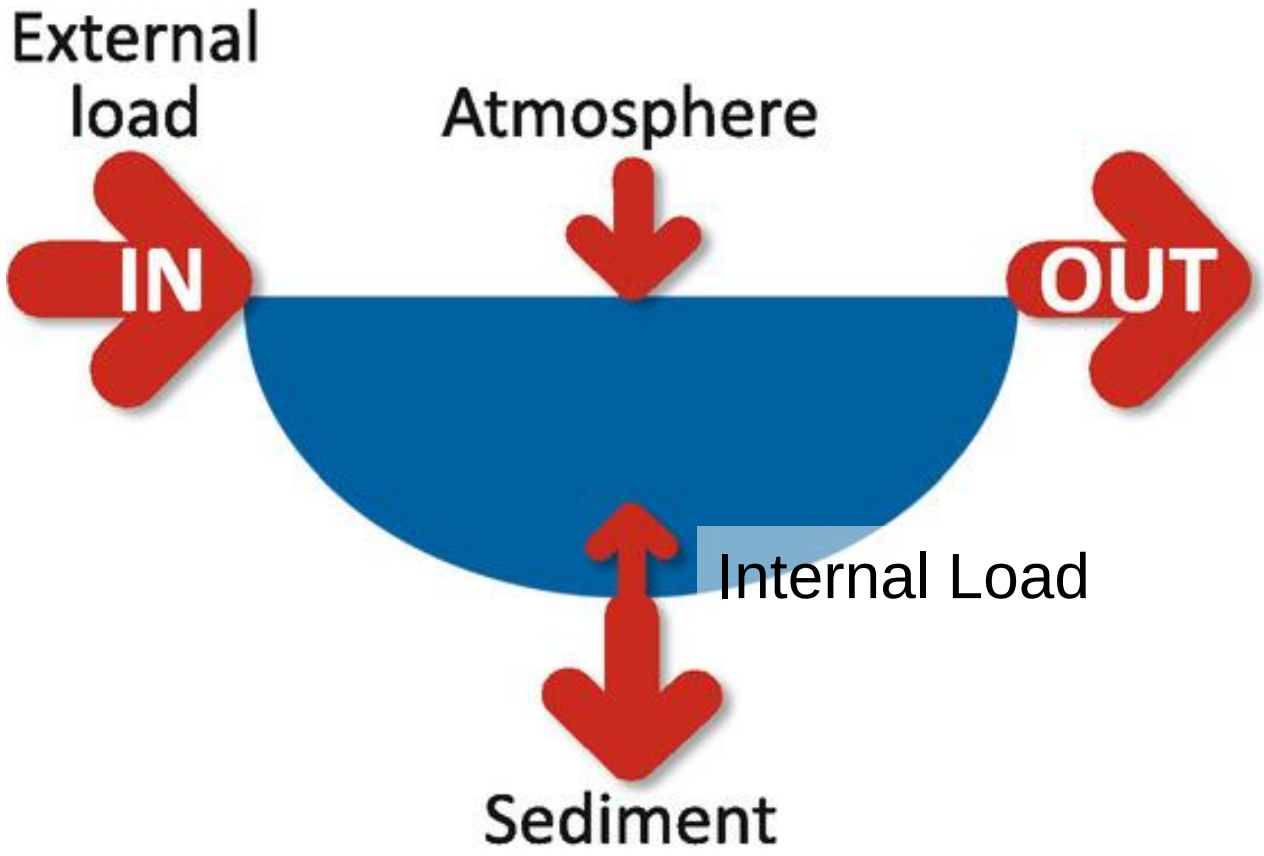
Phosphorus Budget

- Breakdown helps make decisions on managing phosphorus that enters the lake and that algae use to bloom
- Sources……..and losses of phosphorus to/from a lake



Outflow

Phosphorus (P) Budget

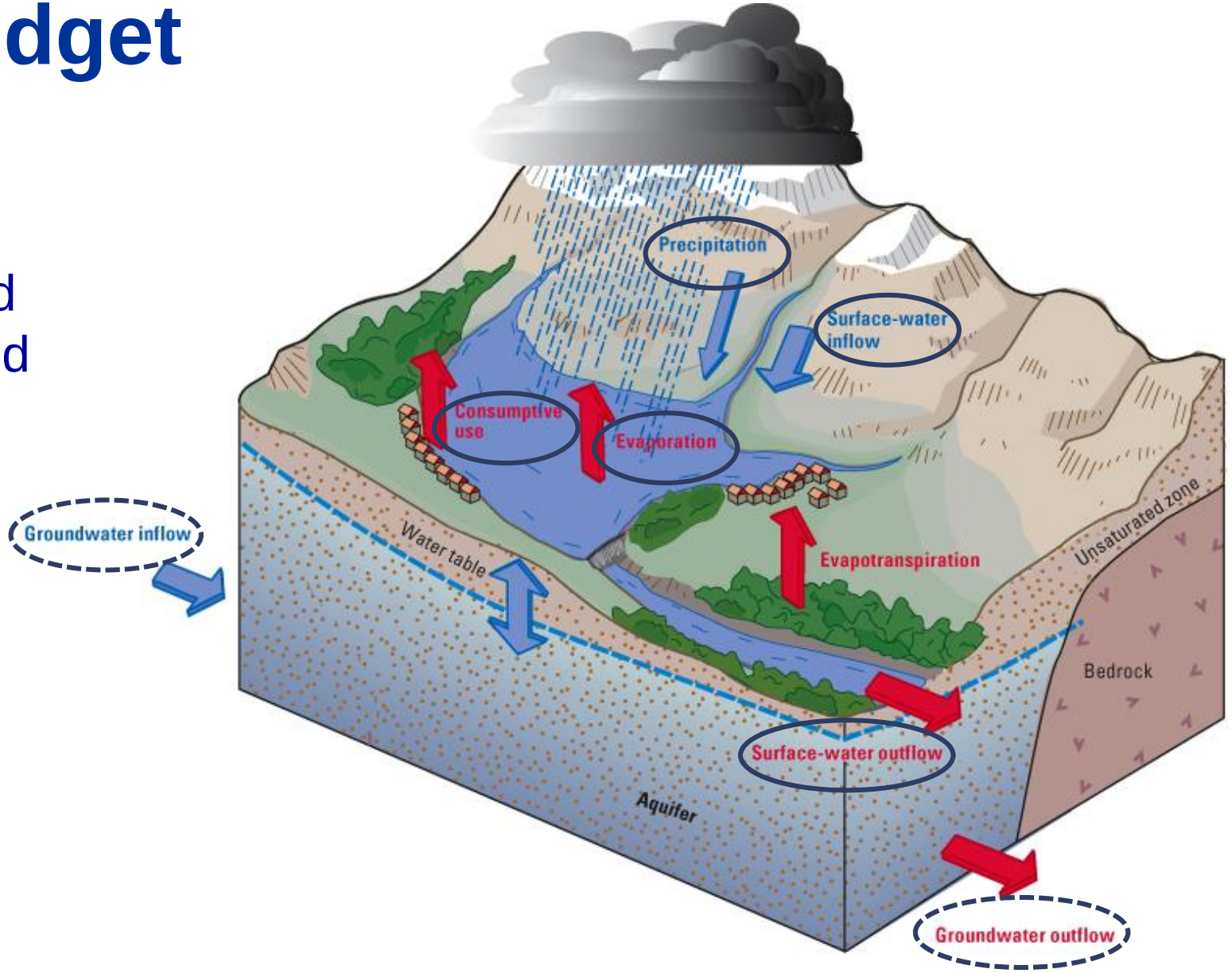


Modified from: Hamilton et al. 2007 Lake Restoration Handbook

Water Budget

Measured

Calculated



U.S. Geological Survey 2013. Water Budgets for Coeur d'Alene Lake, Idaho, Water Years 2000–2005

External Sources of P

External Phosphorus Sources

Atmosphere

Wikimedia

Arenadust.com

Forest

2dadstravel.com

Agriculture

agcanada.com

cattlefeeders.ca

Residential

Travelalberta.com

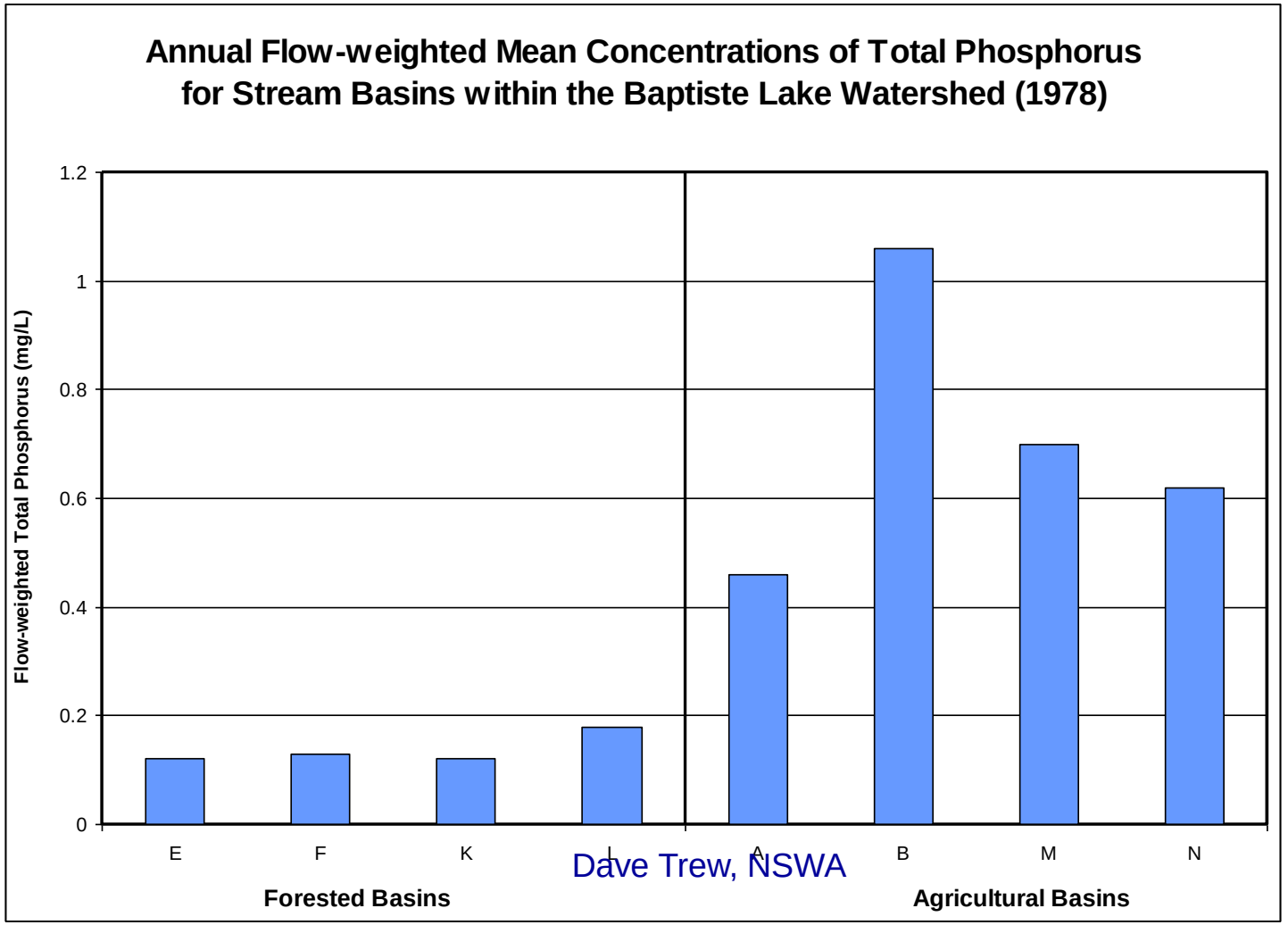
Waterfowl

Steinbachonline.com

How to Estimate External P Sources

- Watershed:
  - Export coefficients
  - Stream sampling (flow and water quality)
  - Watershed Modeling (e.g., ABMI P Runoff Model, SWAT)
- Groundwater: sampling and water budget
- Sewage, birds: estimates from literature, multiplied by population
- Atmospheric: measured or estimated

Stream Sampling Results Baptiste Lake



Dave Trew, NSWA

External P Load in AB Lakes

- Agricultural lands: largest loads
- Atmospheric load often important: (e.g., Pigeon: 20%)
- % of total load (D. Trew, Median of 1980-1990):

Precipitation	Agriculture	Forest
5%	6%	3%

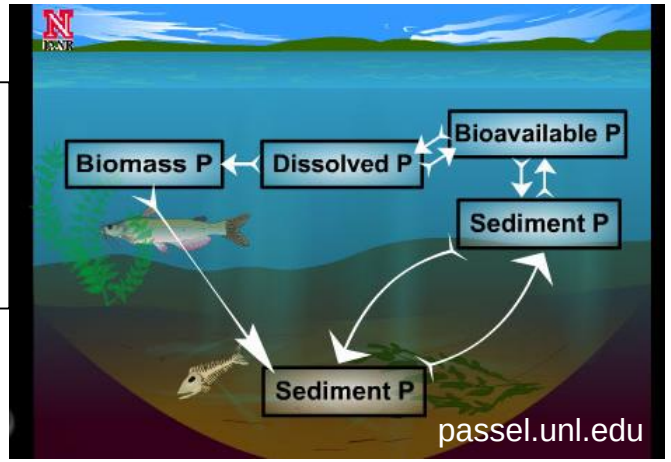
ALMS 2013

Alberta Lake	Time Period	Runoff (%)	Atmospheric Deposition (%)	Sediments/Other (%)	Domestic Sewage (%)	Diversions (%)	Ground-water * (%)	Mean Chlorophyll-a (mg/L)
Burnstick	1995	90	6	-	4	-	-	2.6
Gull	1999-00	31	11	52	7	-	-	7.5
Isle	1996	49	2	42	7	-	-	38.6
Lesser Slave	1991-93	28	7	65	-	-	-	40.3
Lower Mann	Various	12	1	69	18	-	-	96.5
Moose	Various	61	6	32	1	-	-	20.6
Pakowki	1996	9	2	90	-	-	-	34.6
Pine	1992	36	4	55	6	-	-	22.2
Ste. Anne	1996	36	4	55	5	-	-	43.8
Sandy	Various	21	6	73	1	-	-	82.5
Sylvan	2005	32	20	11	13	-	24	4.4
Thunder	1992-96	13	8	55	-	24	-	28.8
Upper Mann	Various	21	1	55	24	-	-	37.0
Wabamun	1980-82	23	13	55	1	6	2	11.3
Wabamun	2008	3	44	43	1	3	5	11.3
Wizard	Various	35	4	46	15	-	-	22.7
Mean	-	31	8	50	8	2	-	32.9

Internal Sources of P

In-Lake Sources

Sediment Release



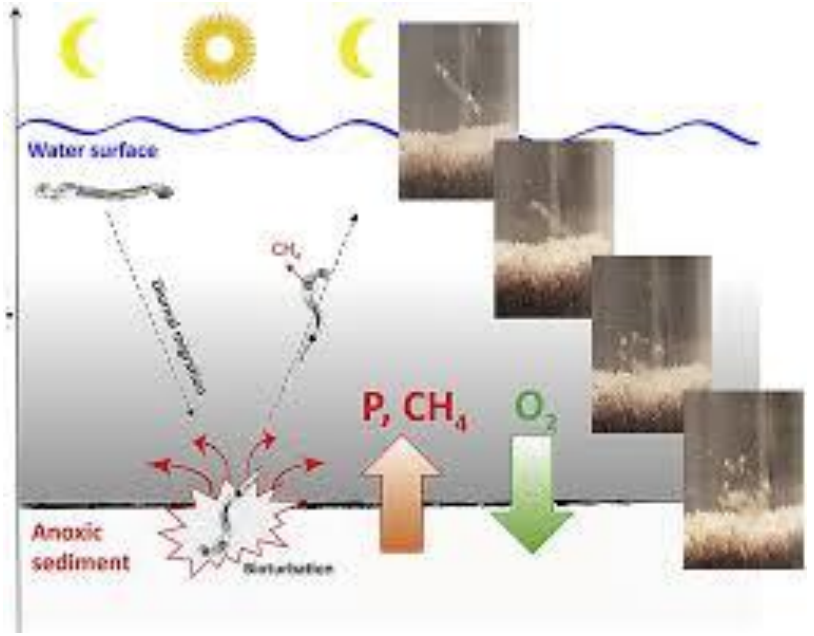
Sediment Resuspension

Arne Diercks, ECOGIG, flickr.com

Attached algae, cyanobacteria

Bouma-Gregson et al. 2018, PLOS

Bioturbation



Tang et al. 2018, Water Research

How to Estimate In-Lake P Sources

1) Mass Balance

$$\Delta M = (I_R + I_P + I_G + I_A) - (O_G + O_D + O_O) - (LS)$$

Mass change Inputs Outputs **Sediment Flux**

Most AB Data

2) Model based on empirical data (after Nürnberg)

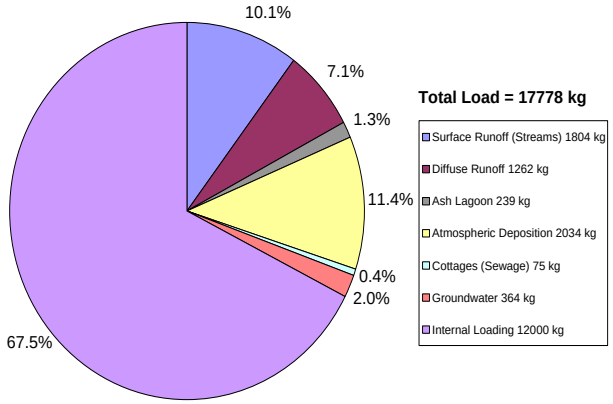
3) Release Experiments

People.vcu.edu

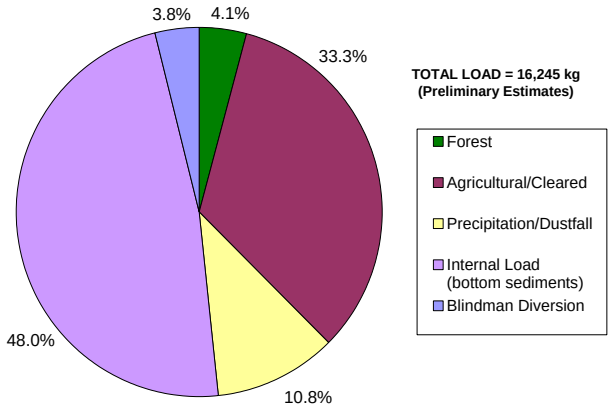
Internal P load in AB Lakes

- Median % of total load 1980-1990 (33 lakes): 82% (D. Trew)

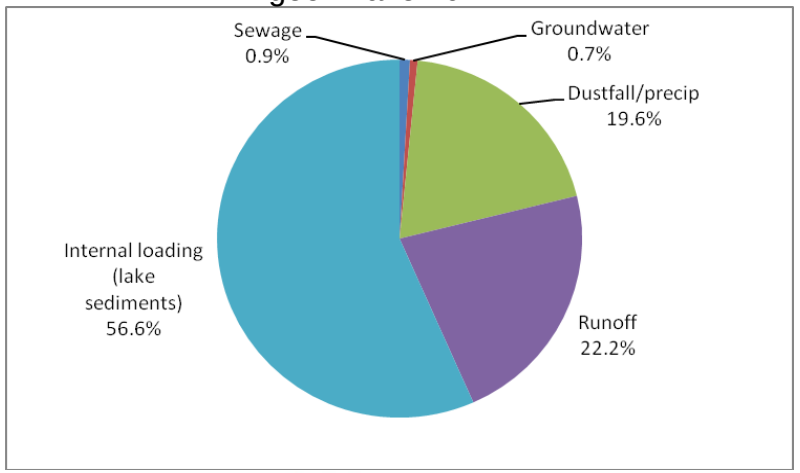
Wabamun Lake P-budget, March 4, 1981 to March 3, 1982



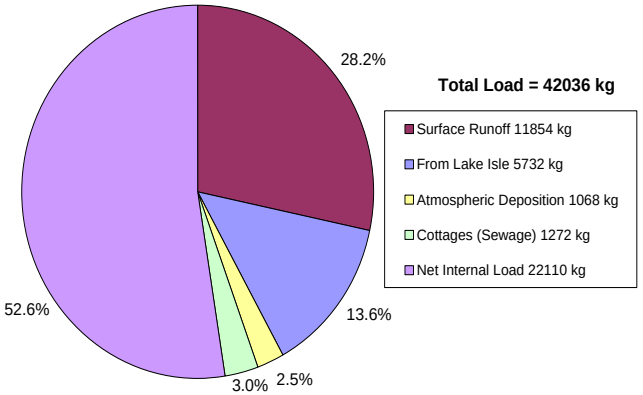
Gull Lake P-Budget, 2000



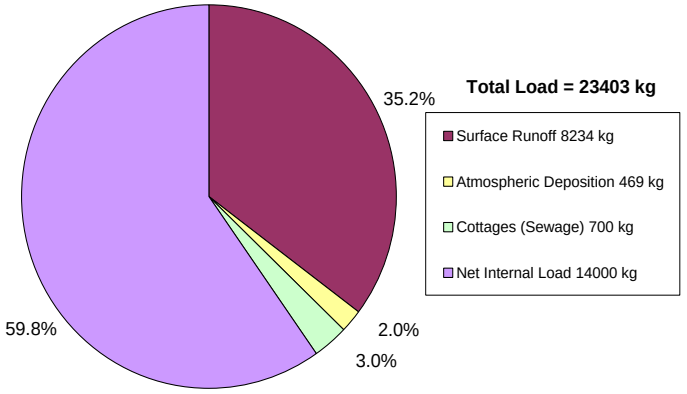
Pigeon Lake 2012

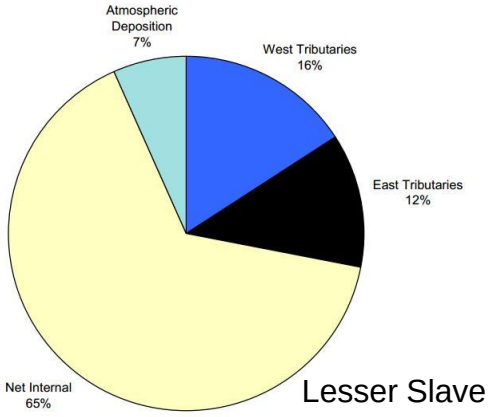


Lac Ste. Anne P-budget, March 1 to October 31, 1997



Isle Lake P-budget, March 1 to October 31, 1997





Lesser Slave 1991-1993

Internal Load in Canadian Lakes (Orihel et al. 2017)

- Common phenomenon in Canadian freshwaters
- Highest rates under anoxia, at slightly elevated pH and in P-rich lakes (hypertrophic)
- Prairie lakes have the largest internal load
- Climate change exacerbates internal load
- Relative importance of different internal load mechanisms poorly understood

What does and what doesn’t it tell us?

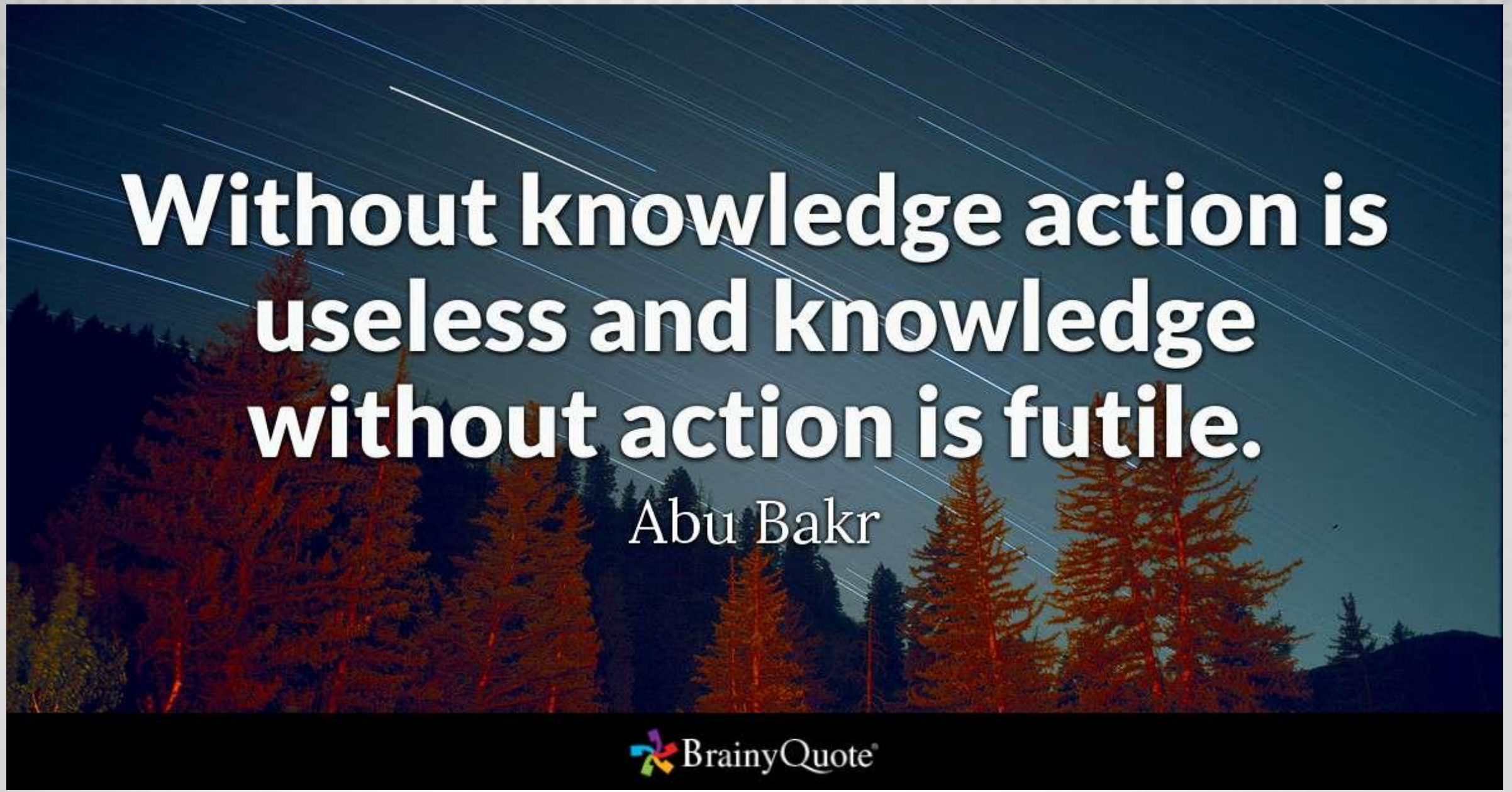
	What does it tell us?	What doesn't it tell us?
Phosphorus Budget	• Relative importance of different P sources	• How nutrients move within lake • Reason for individual algae blooms • What portion of the P load is from human sources
Stream Sampling	• Seasonal P loads from sub-watersheds in sampling year(s)	• Where exactly in the watershed is the Phosphorus from? • Storm event contribution
Export Coefficients	• Long-term average P load from runoff from land parcels	• What actually gets to the lake • Watershed specific load data
Mass Balance	• Net P load from internal sources	• Gross internal load • Contribution of sediment P release to algae blooms
Watershed Modeling	• Seasonality and range of years • Simulates land use scenarios	• Where exactly in the watershed is the Phosphorus from?

How can we improve P budgets?

- Keep sampling many lakes ☺ (i.e., support ALMS!)
- Apply simplified watershed models to more lakes
- Study internal P load processes and their role in algae blooms in AB lakes
- Work with hydrologists to develop good water budgets
- Study groundwater contribution to lake water budgets
- Develop AB-specific lake models

How can P budgets inform lake management?

- Prioritize P sources for management
- Education
- Focus stewardship and education on key sources
- Provide confidence in decisions about lake and watershed management strategies
- Support land conservation efforts
- Support decisions on development applications


Without knowledge action is useless and knowledge without action is futile.
Abu Bakr
BrainyQuote

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