Removal of nitrate-nitrogen from City wastewater will cost millions and achieve little

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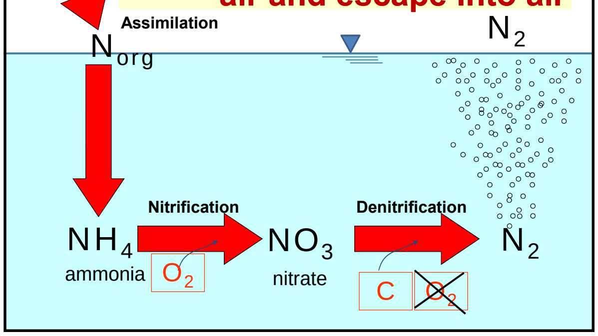
25.XI.2009
Breakfast on the Frontier

UNIVERSITY OF MANITOBA

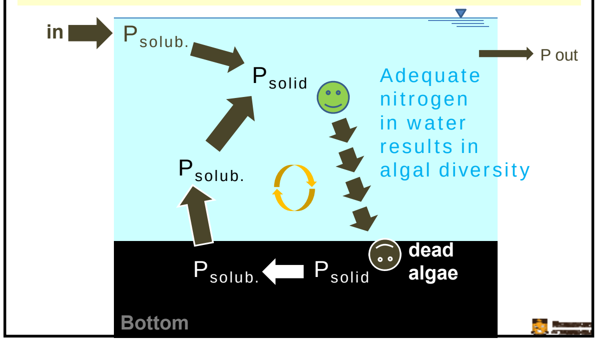
The goal is to show

- what is critical to protect the Lake
- consequences of the effluent N:P ratio
- that nitrate removal not helpful to the Lake
- that nitrate removal best left to incidental processes at the plant
  - Better for: the Lake; the rate-payers; the carbon footprint; $ for what matters most
- that large portion of the $350M expense may fuel the dangerous blue-green algae

In the lake nitrogen cycle is open. N can get in from air and escape into air

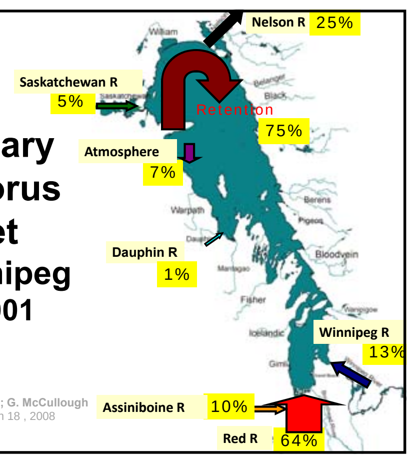


In the lake phosphorus P takes decades to flush or immobilize



Low nitrogen favors growth of "bad" blue-green algae BG (cyanophytae bacteria). "Good" algae may be a nuisance but they are food. BG are not and they kill:

Preliminary Phosphorus Budget Lake Winnipeg 1994 - 2001

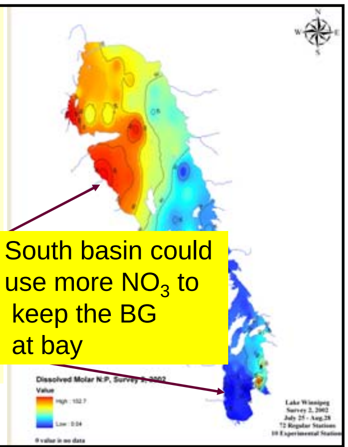


R. Hesslein; S. Page; M. Stainton; G. McCullough Freshwater Institute. LWRC March 18 , 2008

Lake molar N:P

High 100

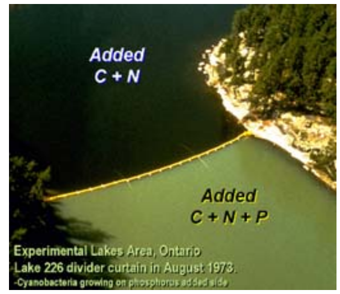
Low 0.04



South basin could use more NO_3 to keep the BG at bay

Data from M. Stainton – Freshwater Institute

Evolution of Phosphorus Limitation in Lakes
Natural Mechanisms Compensate for deficiencies of Nitrogen and Carbon in Eutrophied lakes (1977)
D.W. Schindler, SCIENCE, **195**: 260-262



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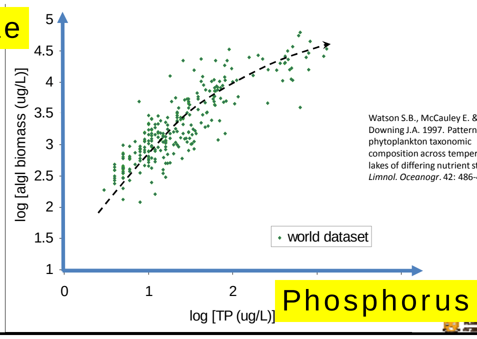
Algae mass proportional to TP. No correlation to N found



Watson S.B., McCauley E. & Downing J.A. 1997. Patterns in phytoplankton taxonomic composition across temperate lakes of differing nutrient status. *Limnol. Oceanogr.* 42: 486-495

Eutrophication of lakes cannot be controlled by reducing nitrogen input: results of 37-year whole-ecosystem experiment. PNAS 105: 11254, 2008

DW Schindler, RE Hecky, DL Findlay, MP Stainton, BR Parker, MJ Paterson, KG Beaty, M Lyng, SEM Kasian

- **Constant P**
- **Decreasing N**
- **Increased BG fraction & BG blooms**

Case study: One of the water reservoirs for Pretoria SA. WWT Plants continued to remove N but neglected P removal

D. Wolmsley: Reservoir Rietvlei, Pretoria's water supply, after the wastewater plants stopped removing phosphorus

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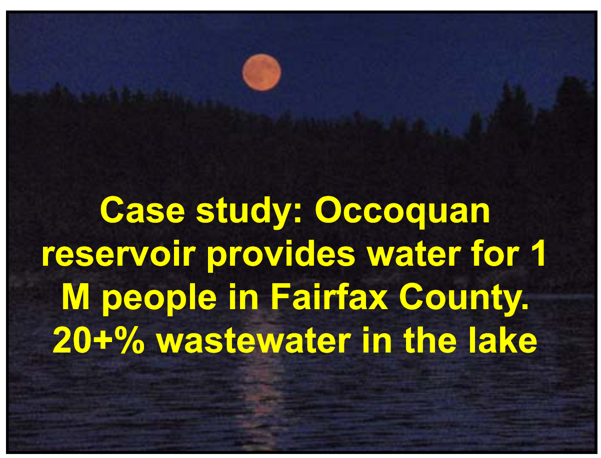
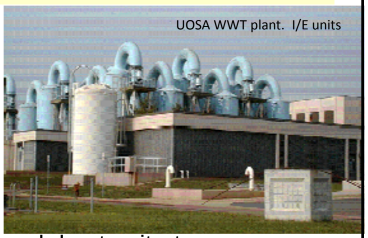


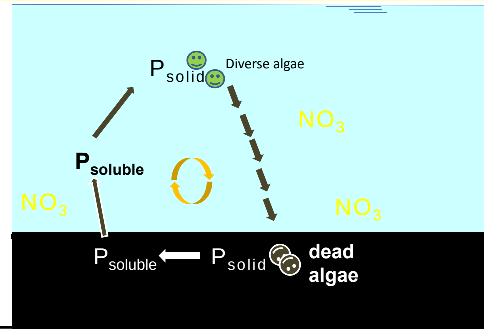
Activated Sludge → CaO + reCarb → GAC → I/E → Cl_2



- **I/E** failed
- $NH_4 \rightarrow NO_3$
- Reservoir improved due to nitrates
- Obtained permit to nitrate discharge

Info. from Dr C. Bott HRSD Virginia; Dr J. L. Barnard B&V, Kansas City

Occoquan: Presence of nitrates decreased release of P from sediments and stopped the blooms



CEC recommended

- Remove P to 1 mg/L
- Remove ammonia to less than toxic loads
- Remove total nitrogen TN to 15 mg/L
- Keep effluent N/P mass ratio at 15/1
- Use BNR **and** do not use chemical phosphorus removal. Recover phosphorus

What this eutrophic Lake needs to control excessive blooms

- Phosphorus as low as humanly possible
- Nitrogen presence to keep the “good” algae competitive against the “bad” BG algae
- Some **nitrate** presence to mitigate the phosphorus recycle from sediments

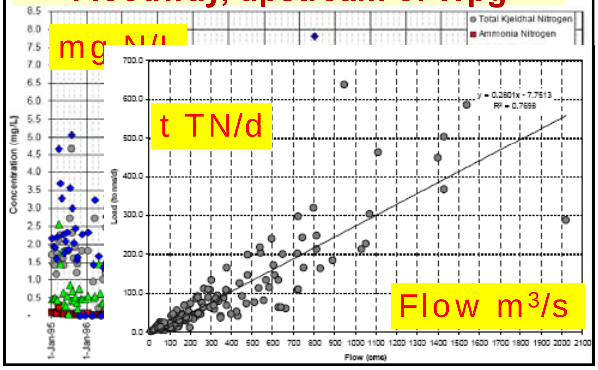
What CEC implies

- Deep removal of total nitrogen
- N : P = 15: 1 means 0.3 mg P/L → 5 mg N/L
- 5 mg N/L →**Limit of Treatment Technology LOT**
  - methanol
  - increased carbon footprint
  - increased emissions of nitrous oxide N_2O
  - no benefit to the river; potential harm to the Lake
- Plants must be oversized to meet requirements during high flows and cold temperatures of Spring melt

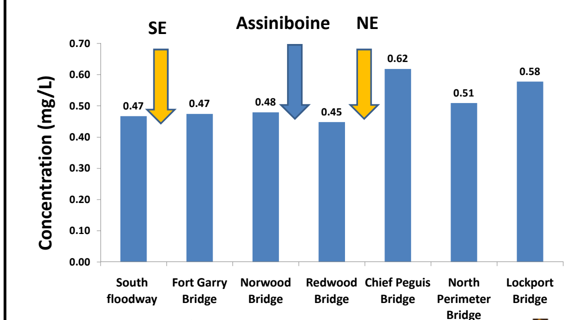
Nitrogen is not a problem in the Lake – in fact it is needed. But what are the Red River needs?

- Ammonia may affect the river
  - No impact of ammonia on oxygen at all found
  - Potential toxicity in the river mitigated by permit
- Nitrates in the river should be well below the drinking water standards (10 mg N/L)

Nitrogen in the Red 1995-2009 Floodway, upstream of Wpg

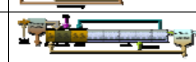


Nitrates < 1 in the Red
(drinking water limit 10 mg/L)



Data collected bi-weekly by City of Winnipeg

N. End capital and future costs

Option and Description	Process Schematic	Effluent Performance Targets (mg/L)	Capital Cost (Million)	Future Cost 20 yrs @ 6 % (Millions)
Centrate N and P Removal No Change to Main Plant		TP ~ 3.0 NH_3 ~ 17 TN ~ 25	$ 30	$ 85
Bioaugmentation, Increase Main Plant SRT, Split stream Partial Nitrification, Chem. P		TP ≤ 1.0 NH_3 ≤ 3.0 TN ~ 25	$ 130	$ 350
BNR Main Plant		TP ≤ 1.0 NH_3 ≤ 3.0 TN ≤ 15	$ 430	$ 1100
LoT – BNR Main Plant		TP ≤ 0.3 NH_3 ≤ 1.0 TN ≤ 5.0	$ 730	$ 1500

N. Szoke City of Winnipeg

The CEC proposed TN permit and N:P requirement

- Are not just incremental DN cost increase
- Prevent flexible/sustainable approach to design that would allow for:
  - Multi-stage add-on processes
  - Minimal disruption of the current infrastructure, which mostly works well
  - Lesser tank volumes for critical cold/wet period of Spring thaw

Two examples of other, thus defeated, lower cost options preserving the existing infrastructure and providing protection of the Lake and the River

- **Phoredox → MBBR**
- **HPOAS with PhoStrip → N-BAF or DN/N 1-stage BAF**

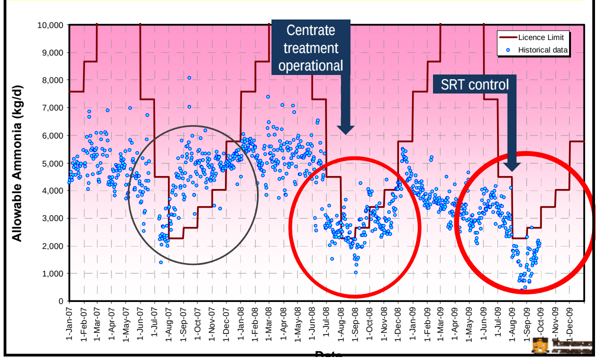
P recovery (struvite) can be from streams other than centrate. With or without BNR. It is a chemical process

1. Benisch, Baur, Britton, Oleszkiewicz, Neethling (2009) *Proceed. IWA Nutrient Removal Conf., Krakow PL*
2. Yuan, Zurzolo, Oleszkiewicz (2009) *Proceed. IWA . Conf. on Nutrient Recovery, Vancouver BC*

So what should be done to protect the River, the Lake and the Public Purse?

- Effluent P as low as possible e.g. 0.1-0.3 mg/L
- Combine P removal with P recovery upstream of the sludge train. Mind the economics!
- Allow the 15:1 = N:P ratio to increase.
- Remove ammonia from centrate, bioaugmentation and process upgrade
- Leave nitrates to "incidental" removal within the plant processes (e.g. O_2 or alkalinity recovery)

After start-up of centrate treatment and SRT control, N. End met NH_4 licence



Summary

- P rules. Remove till it hurts and recover P
- Meet load permit for ammonia with the centrate facility and process upgrades
- TN effluent limits detrimental to the Lake, rate payer and the main goal
- Drop N:P ratio; it pushes us into the Limits of Technology for N removal
- Put money saved where it matters most to the Lake: radical watershed P control

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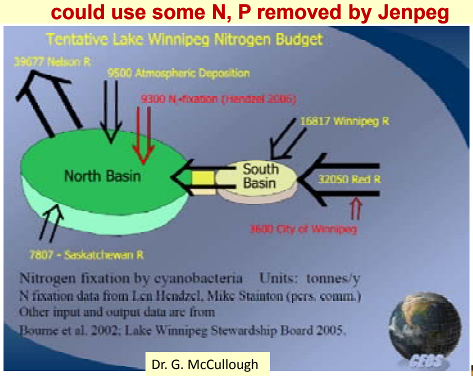
Acknowledgement

- NSERC Canada
- Manitoba Conservation: Sustainable Development Innovation Fund SDIF
- City of Winnipeg: Water and Waste Dept
- AECOM Winnipeg
- M. Stainton, Freshwater Institute;
- D. Schindler, U of Alberta
- J. L. Barnard B&V, Kansas City
- G. Daigger CH2MHill, Denver CO
- J. Husband Malcolm Pirnie, New York

END

Jenpeg removes a large portion of exported load. Hudson Bay shows decreasing productivity and could use some N, P removed by Jenpeg



31 Dr. G. McCullough

Receiver impact of pollutants

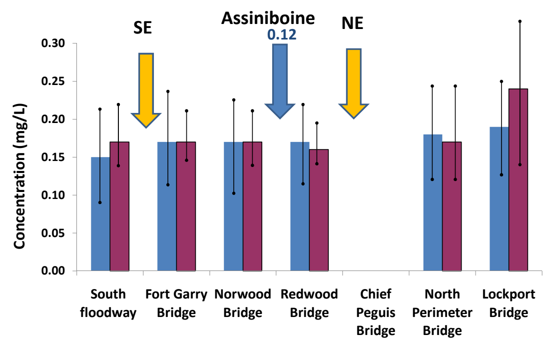
1. Oxygen depletion from C, N √
2. Pathogens √
3. Toxicity (of ammonia) √
4. Eutrophication P √
5. Chronic impact of endocrine disrupting and bio-accumulating compounds ?

Lake Winnipeg

- 6.6 M people
- 210 M population equiv.= animal waste
- 1 M km² fertilized agricultural watershed

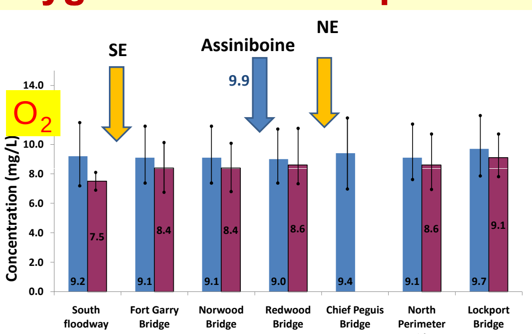
Sources	Total Nitrogen		Total Phosphorus	
Non-Point	71,100	74.1%	6,500	81.3%
Point	6,000	6.3%	1,000	12.5%
Other	18,800	19.6%	500	6.3%
Total	**95,900**	**100%**	**8,000**	**100%**
North End Plant	***2,300***	***2.4%***	***310***	***3.9%***

Soluble phosphorus in the Red



Data collected bi-weekly by City of Winnipeg

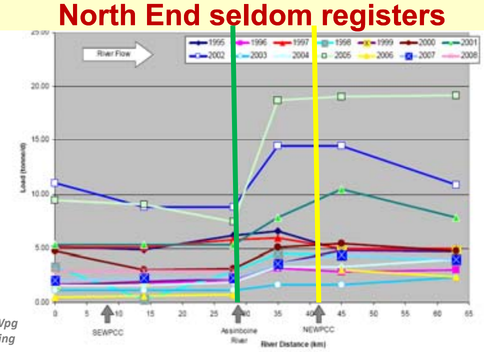
Oxygen was never a problem



2009

Data collected bi-weekly by City of Winnipeg

P load in Red R in August. Assiniboine's load large at times North End seldom registers

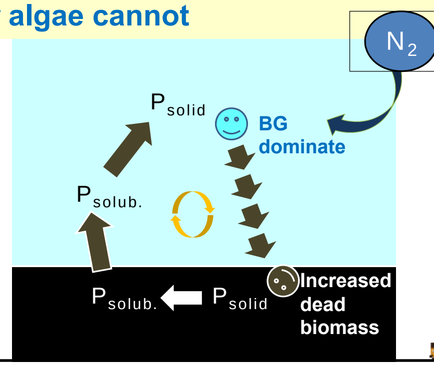


City of Wpg monitoring N. Szoke

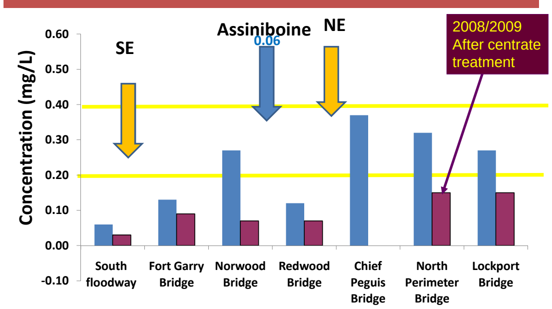
N_2O gas emissions are by aquatic species and/or by treatment processes

- N_2O is formed during nitrification and during denitrification
- Denitrification to low TN employs petrochemicals with large carbon footprint
- Treatment plant nitrification/denitrification has not been shown to decrease N_2O emissions, when compared to N_2O emissions by aquatic species

When nitrogen low then blue-green (BG) "algae" assimilate N_2 from air. Other algae cannot



Ammonia may be a problem for a month only. Permit defines plant loads



Nitrogen: N_{org}· NH_4 · NH_3· NO_3· NO_2. TN = sum of all

- $N_{org} \rightarrow NH_4^+$ Ammonia
- Ammonia NH_3 may be toxic in summer
- NH_4^+ uses up oxygen to form nitrates
  $NH_4 + O_2 \rightarrow NO_3$
- Nitrates must be below 10 mg N/L in drinking water. Persist in groundwater
- Nitrites may be toxic