Phosphorus losses in surface runoff and tile drainage from agricultural fields using multiple conservation strategies for phosphorus management

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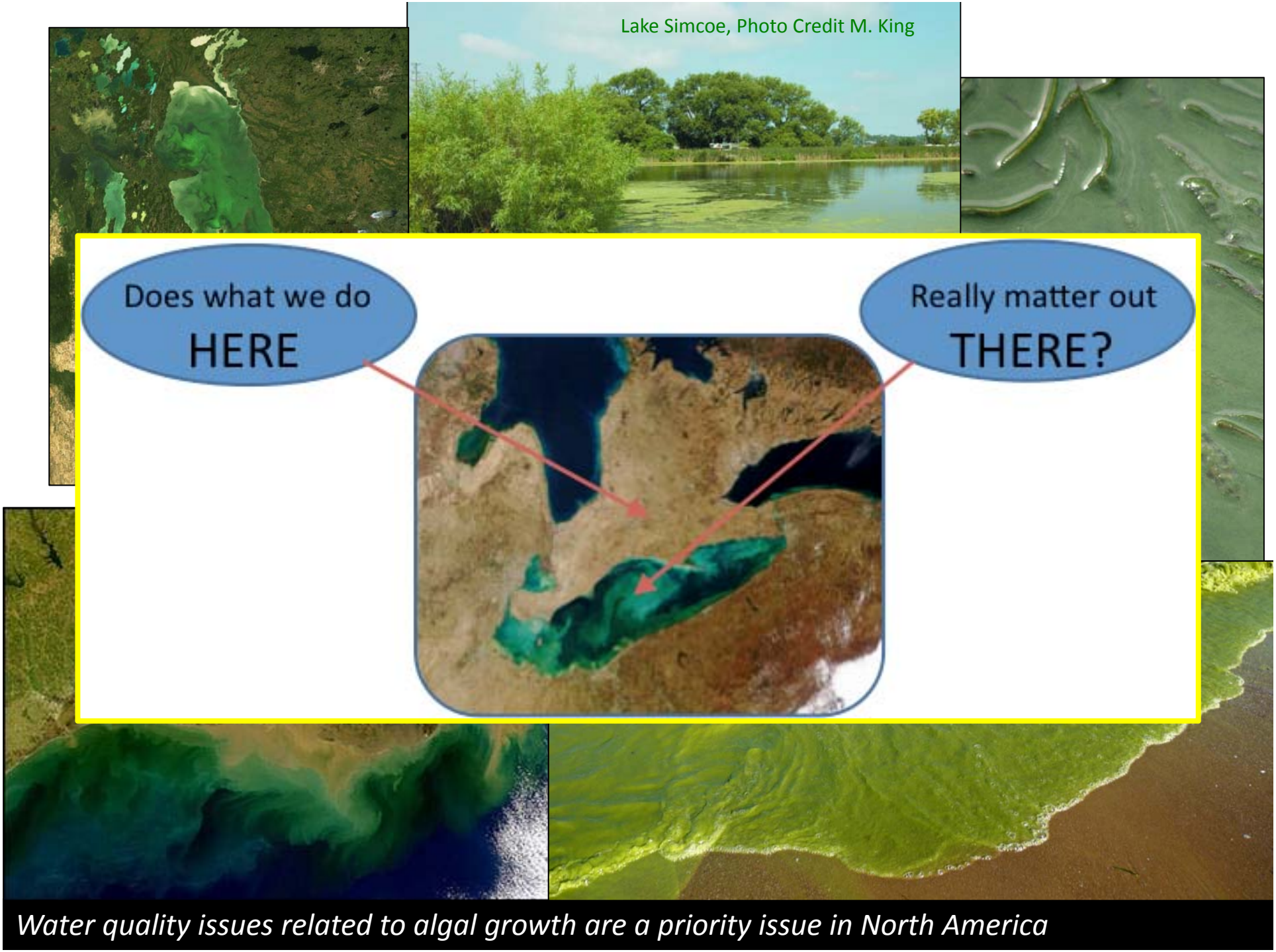
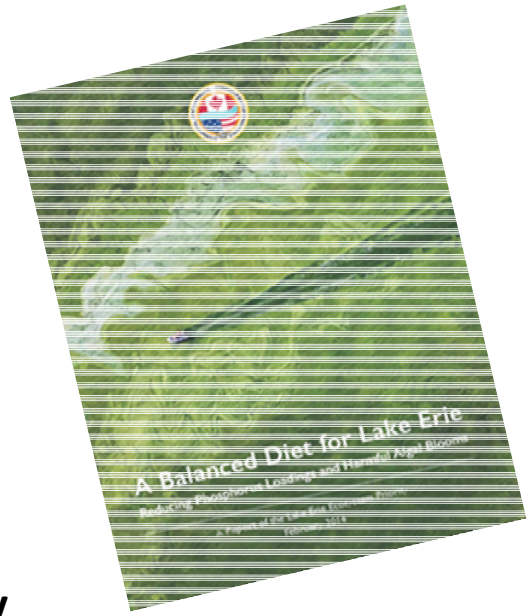


Water quality issues related to algal growth are a priority issue in North America



IJC LEEP Report

February 2014


Lake Erie, 2009. T. Archer NOAA

History

- In '70s, serious eutrophication due to excess P loadings
- Mid-80s, loads cut in ½ (mainly sewage upgrades and reduced P in detergents)
- Early 2000's, symptoms of excess P appear again
- 2011 - 5000 km^2 algal bloom (3X any previous) = 10 on the severity scale
- Today rural/urban runoff (non-point) is dominant source of P load to lake (>50%)
- Bulk of loading occurs during snowmelt and heavy rains

Report's Objective

To provide advice to help restore the lake's ecosystem by reducing nutrient loads

- Significant efforts to reduce P loads recently
- 2015 – largest on record – "broke the scale" → 10.5 on severity index
- How do we deal with this issue?

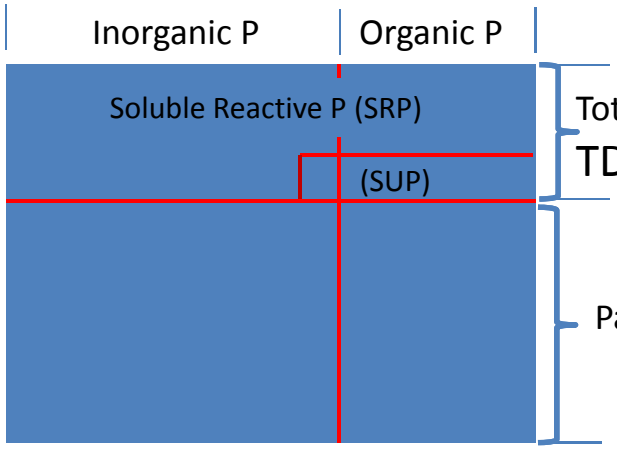
Overview

- What is causing the blooms? Discussion of contaminants, sources and pathways
- How is P lost from agricultural watersheds? Surface and subsurface processes
- What are some of the BMPs that we are using to try to stop this? How do they work?
- Importance of seasonality in the Great Lakes Region
- Are selected BMPs working to reduce P loads from Ontario fields? Overview of recent research findings in Ontario

What is causing the algal blooms?

- **Lakes: Phosphorus (P) = limiting nutrient but N contributes**
- **Algal productivity related to P *concentrations* in lakes**
- **Excess P "fertilizes" algae → blooms**

"Forms" of Phosphorus

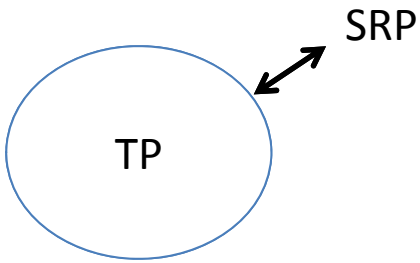


Total Dissolved P (TDP)

TDP = SRP + SUP

SUP = Soluble Unreactive Phosphorus

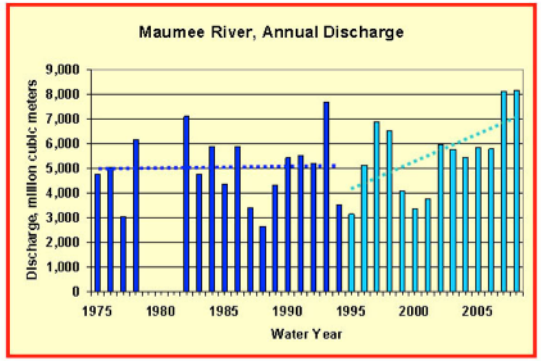
Particulate P (PP)



TP = PP + TDP Total Phosphorus (TP)

How is NPS P Loading Estimated?

Runoff (L/year) X P Concentration (mg/L) = P Load (mg or kg or T)



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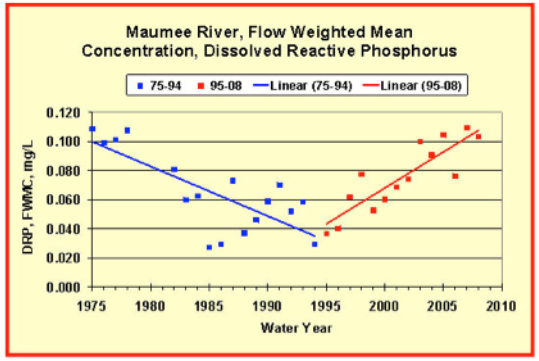

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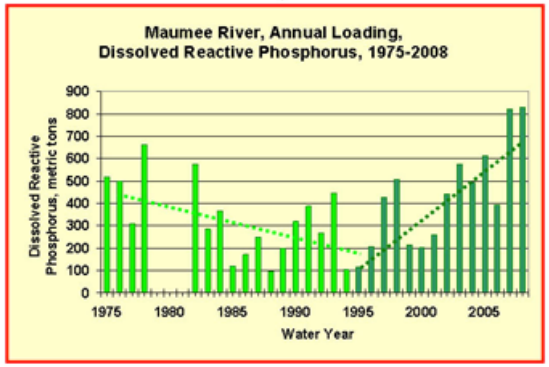
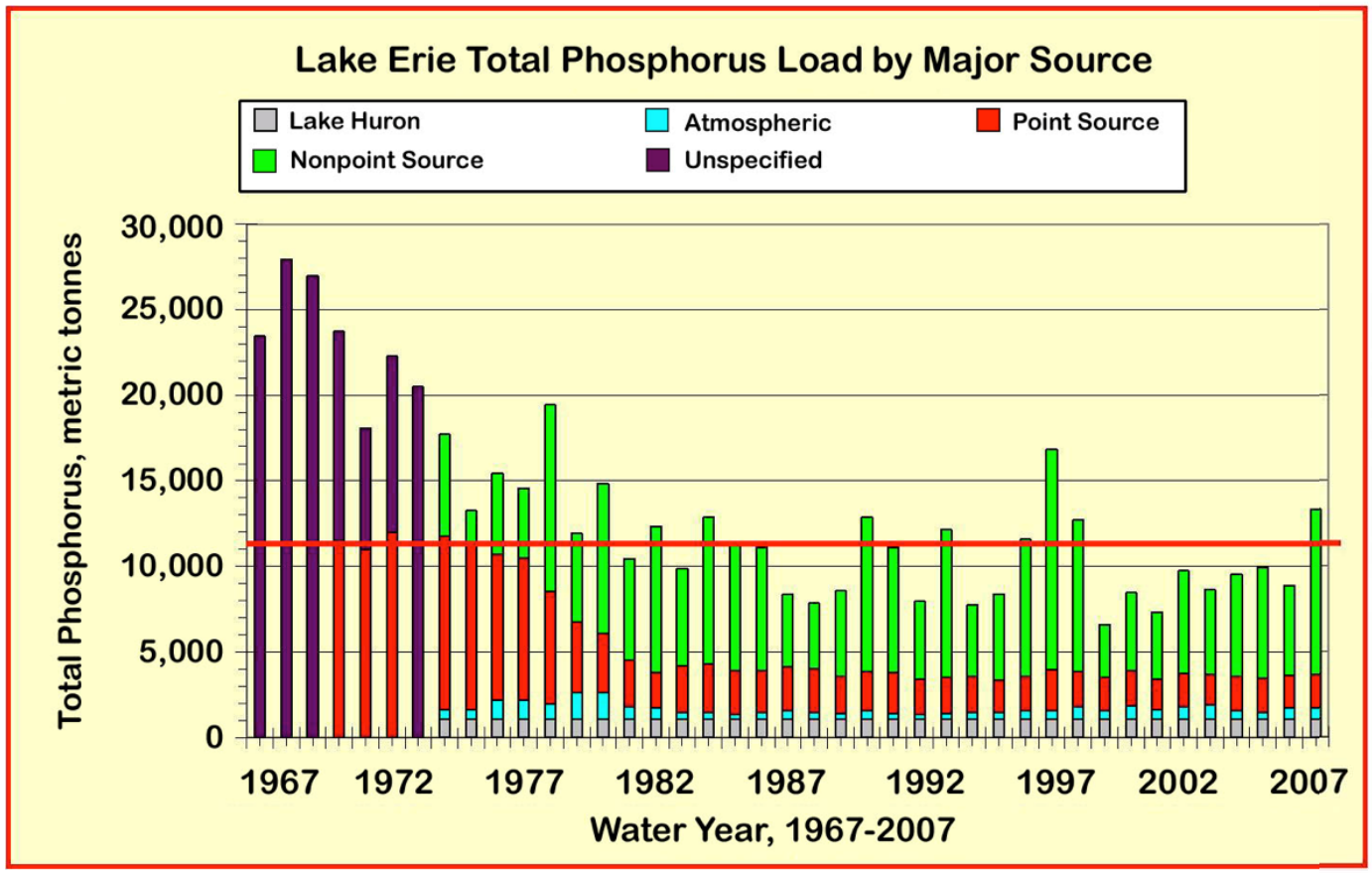


Source: Baker and Richards – Heidelberg University

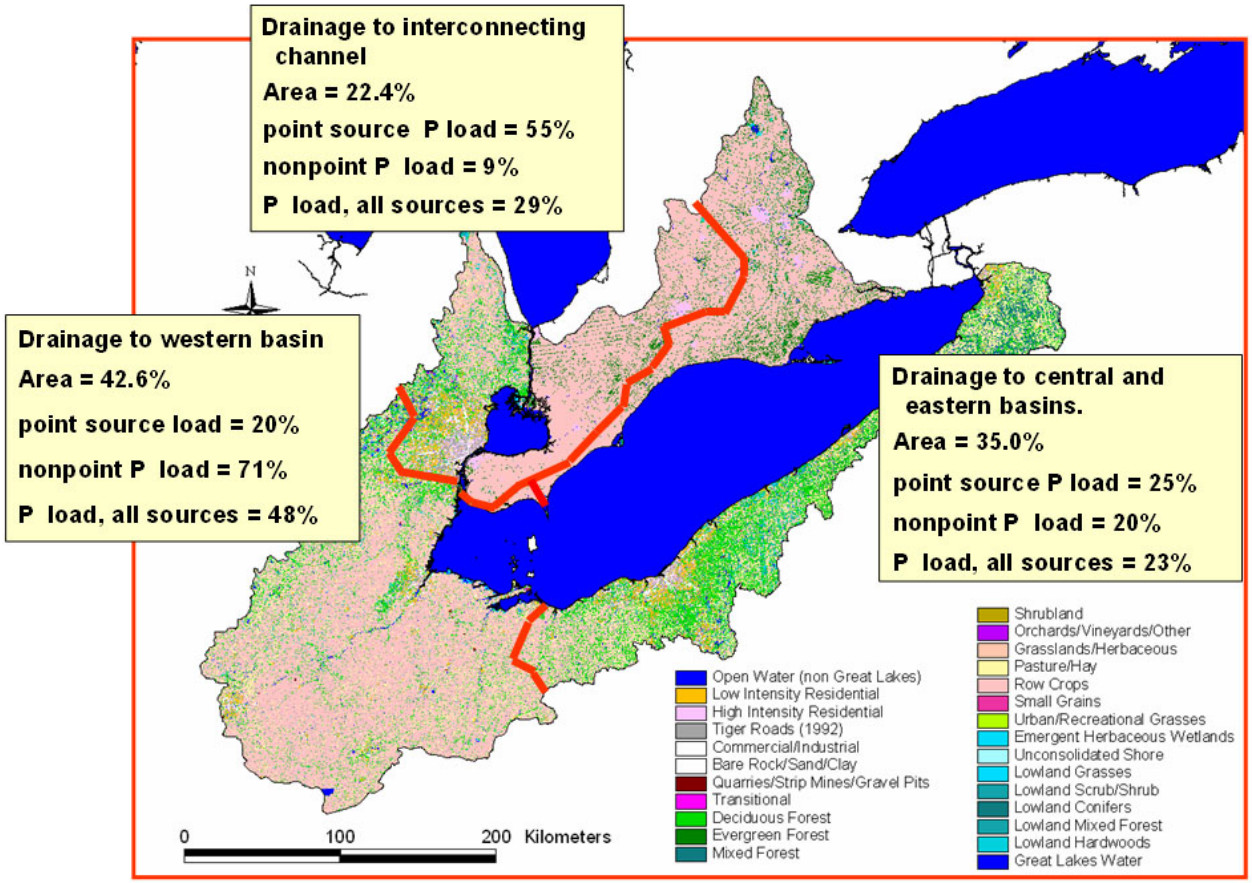
Where is the P Coming From?
Breakdown of P Load By Major Source



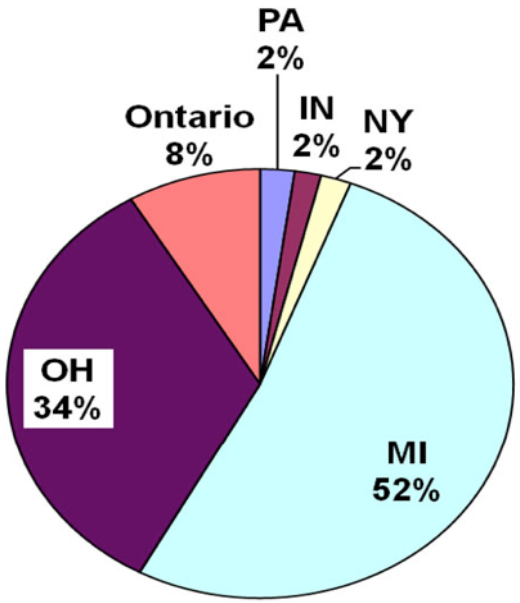
Source: Ohio EPA, April 2010 (Ohio Lake Erie Phosphorus Task Force Final Report)

Where is the Phosphorus Coming From?

By Major Lake Erie Basin



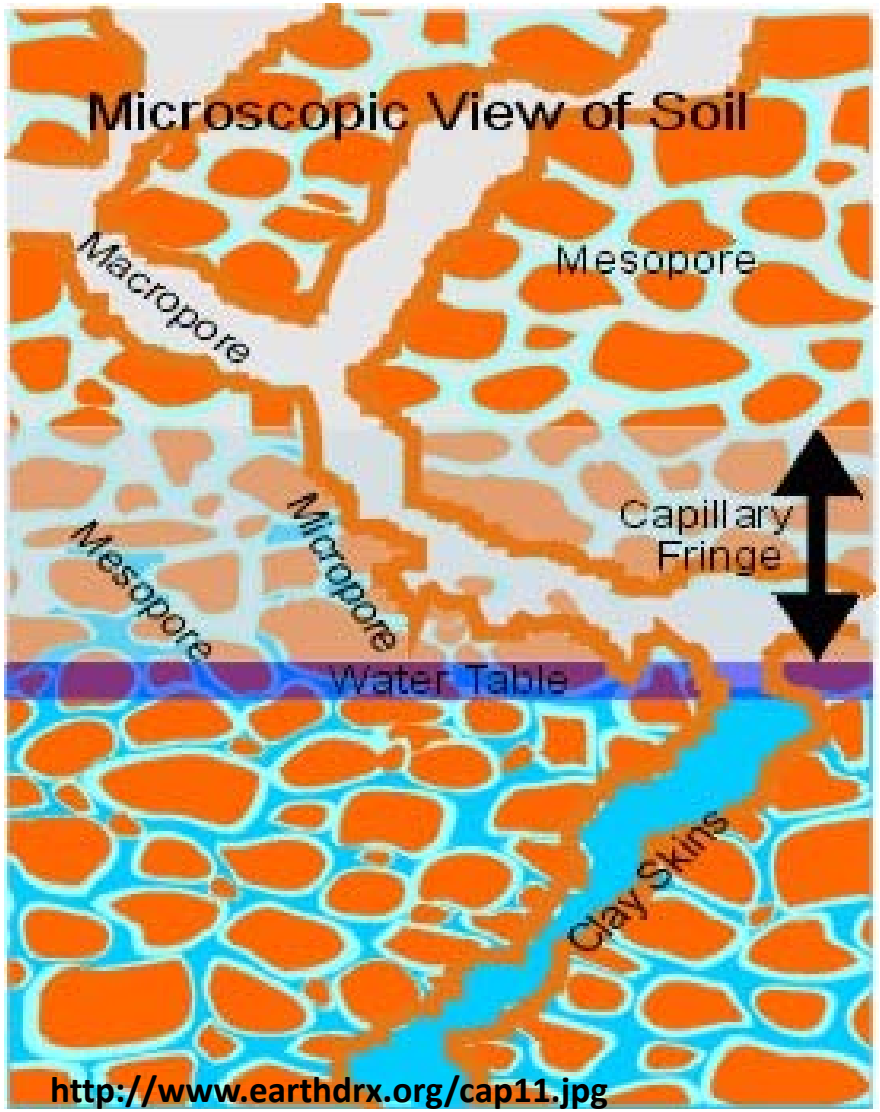
By Major Jurisdiction



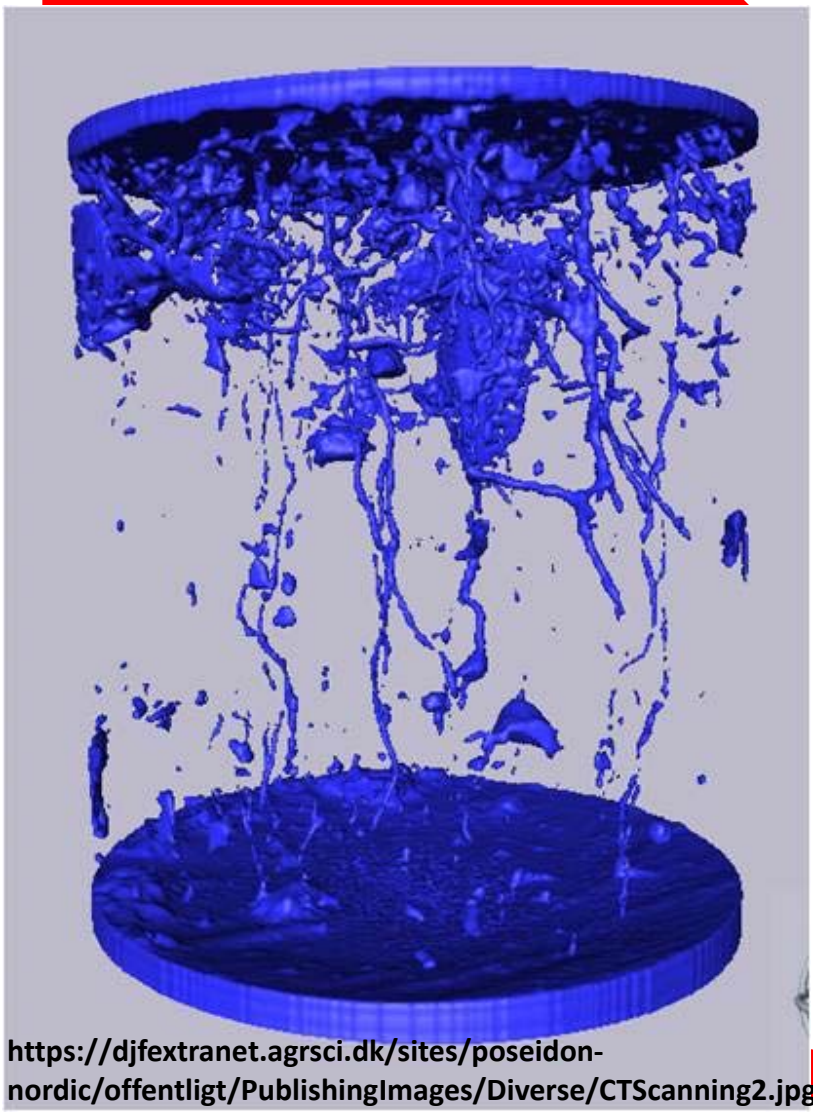
Source: Ohio EPA, April 2010 (Ohio Lake Erie Phosphorus Task Force Final Report)

How is P Lost From Agricultural Fields?

Understanding P in Subsurface Runoff



http://www.earthdrx.org/cap11.jpg



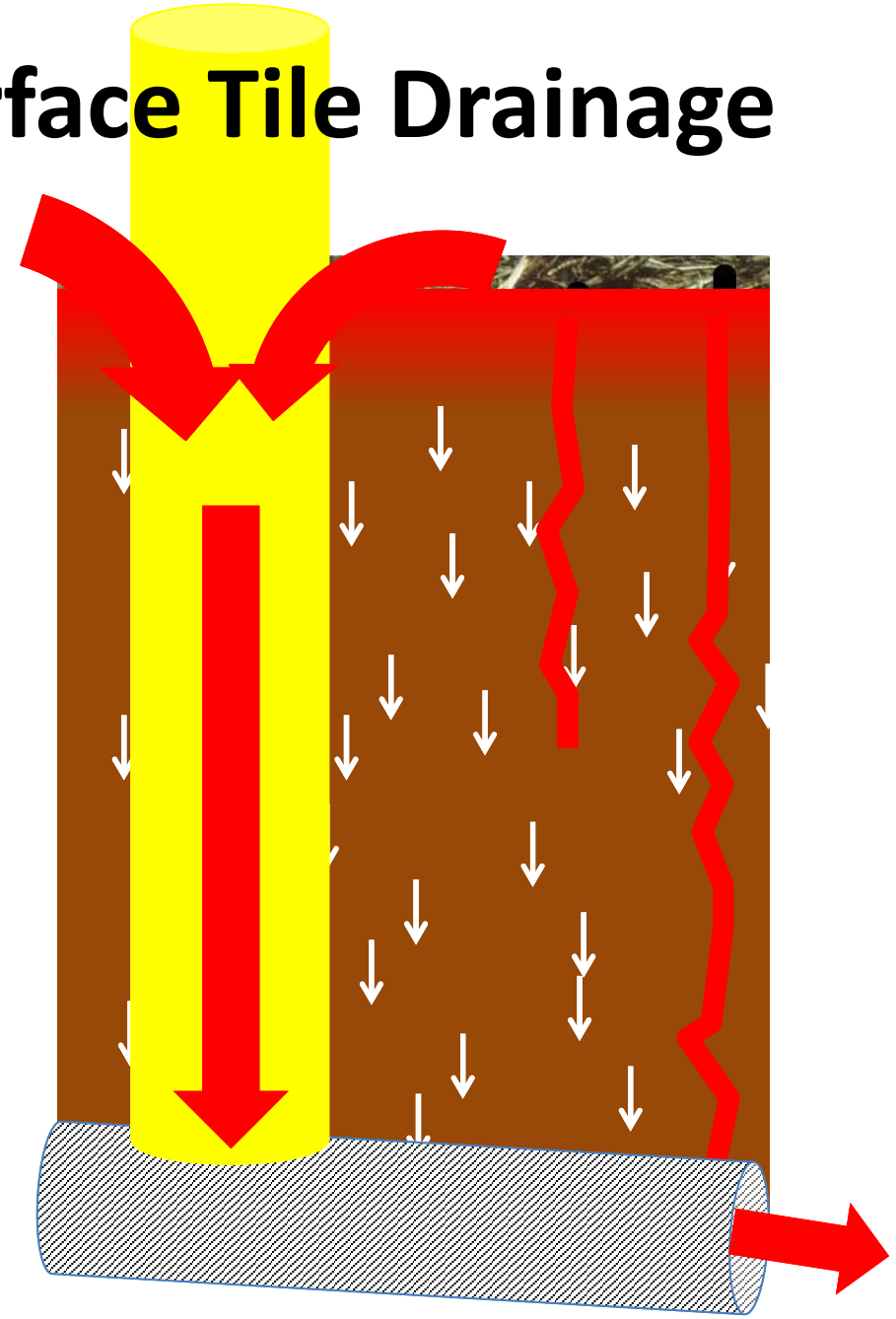
https://djfextranet.agrsci.dk/sites/poseidon-nordic/offentligt/PublishingImages/Diverse/CTScanning2.jpg

Surface vs. Subsurface Tile Drainage

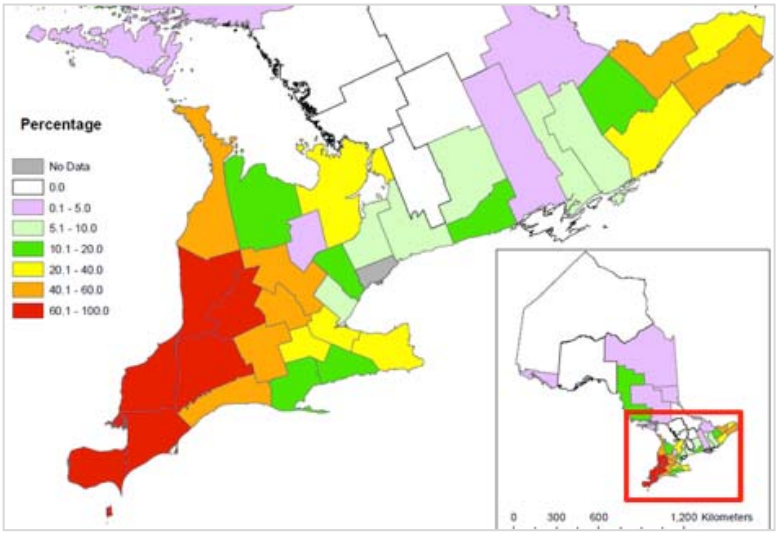
It is Important to Make the Distinction!

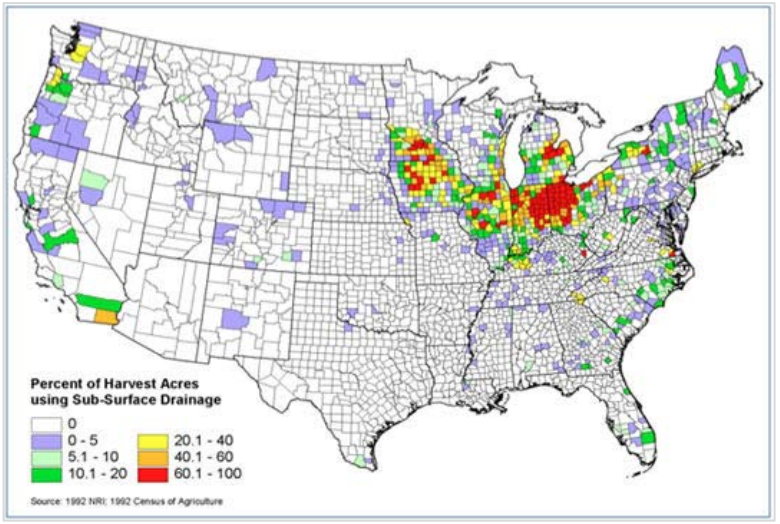
Surface Drainage

Subsurface Drainage



Extent of Tile drainage in Great Lakes Region





Removal of tile drains is not an option…

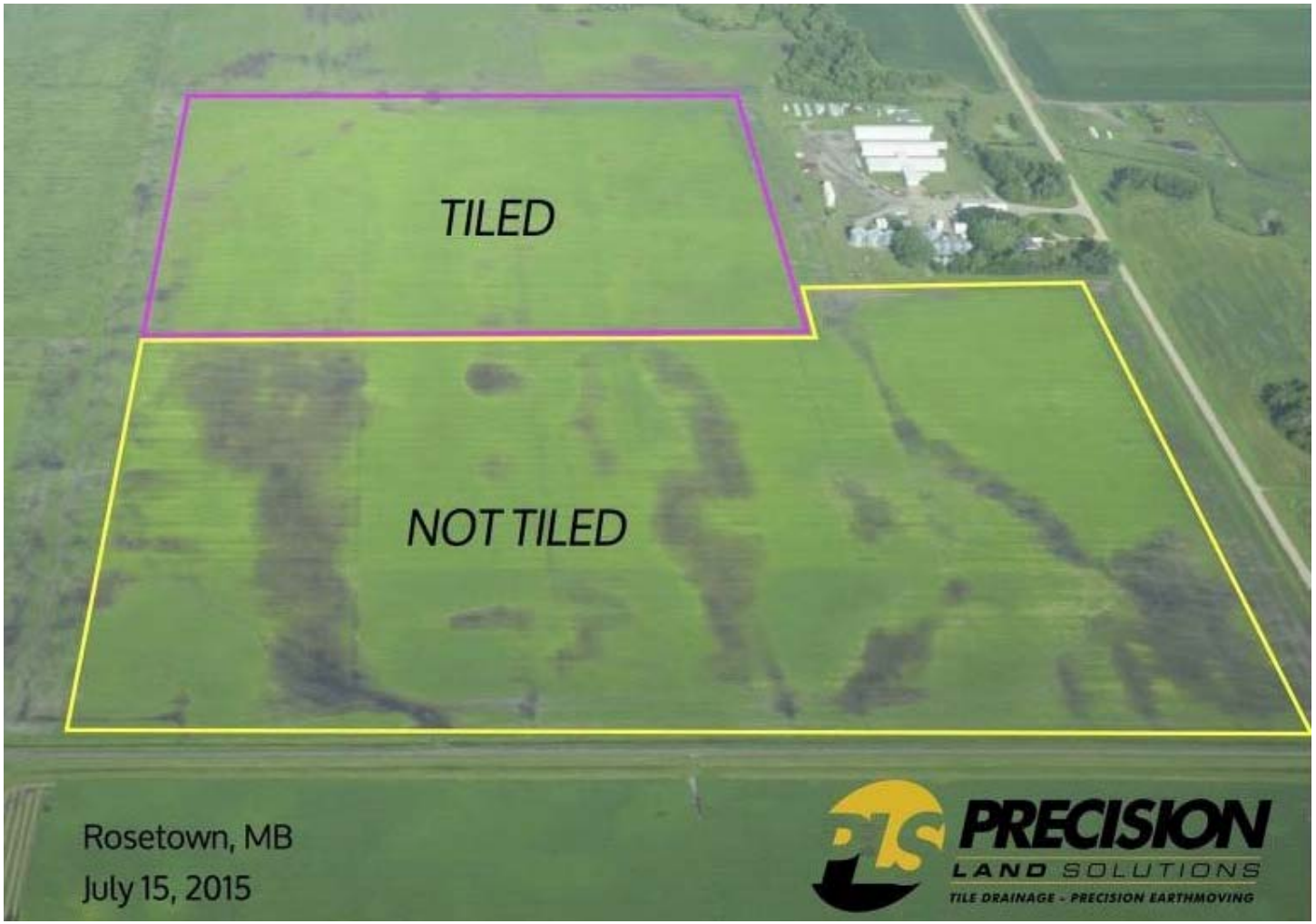
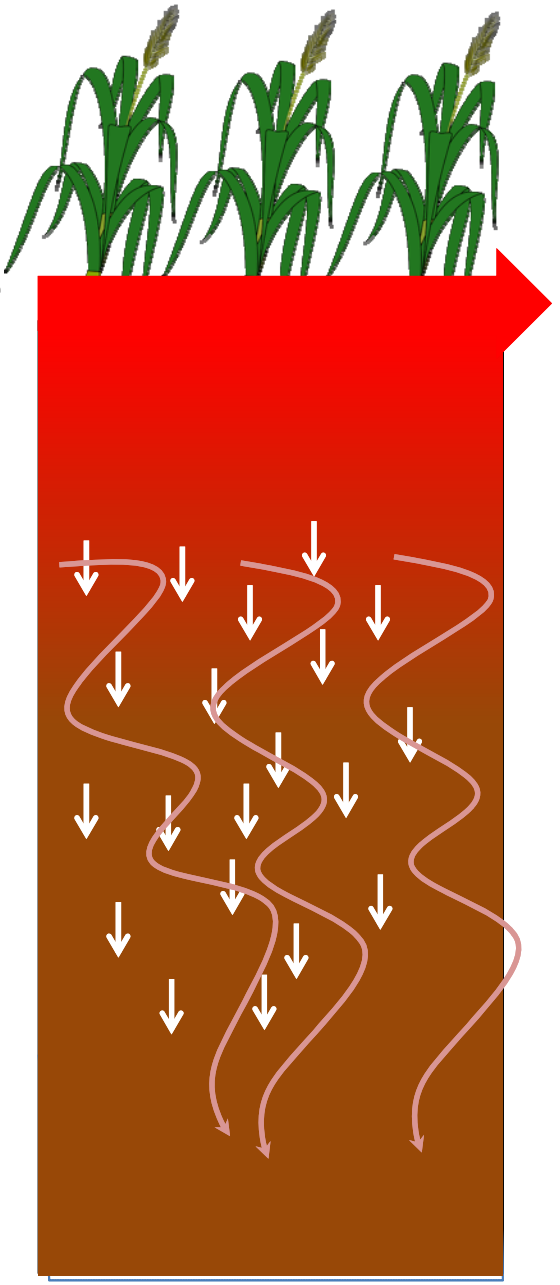


Image provided by D. Lobb, U of M

Some Current BMPs…

No-till Vs Tillage:

- **No till can lead to "stratified" P and more macropores → more P in tile drainage, maybe more dissolved P in surface flow but less PP**
- **Tillage breaks up pores, mixes in P → may lessen load to tile drains, *but* more erosion in surface runoff**
- **4Rs *e.g.* Nutrient management & subsurface placement may help this**



Some Current BMPs…

Cover Crops, Riparian Buffer Strips, Grassed Waterways, WASCoBs

- **Build soil OM**
- **Slow surface erosion**
- ***But* may not work in winter, and may supply dissolved P**

Importance of Seasonality?

→*Sediment entering Lakes Erie & St. Clair, March*

To develop and apply effective strategies to reduce P loss, we first need to know when most P is lost
→ target these periods!
Need BMPs to work year round

Source: NOAA

Research on P Loss in Ontario 2011 – 2015

Research Questions:

(1)When is most P lost during the year? What form is it in (sediment or dissolved)?

(2)What pathway(s) are most important for P loss? Tiles or surface runoff?

(3)Do our management practices impact these losses? If so, which ones are most important?

→ Examples of practices studied: tillage, nutrient management, subsurface P placement (banding), cover crops

Collaborators & Partners

Farmers & Farming Organizations

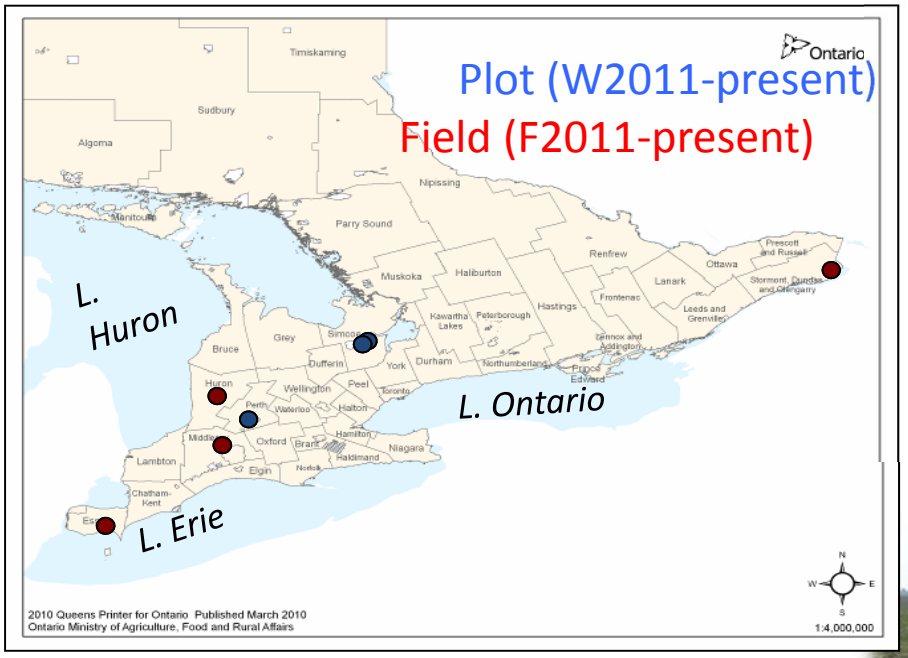
ANSWERS (D. Lobb, K. Eisses, B. McIntosh, K. Nixon, S. McRae, L. Taylor)
Innovative Farmers of Ontario (IFAO)
Land Improvement Contractors of Ontario (LICO)
Ontario Soil and Crop Improvement Association

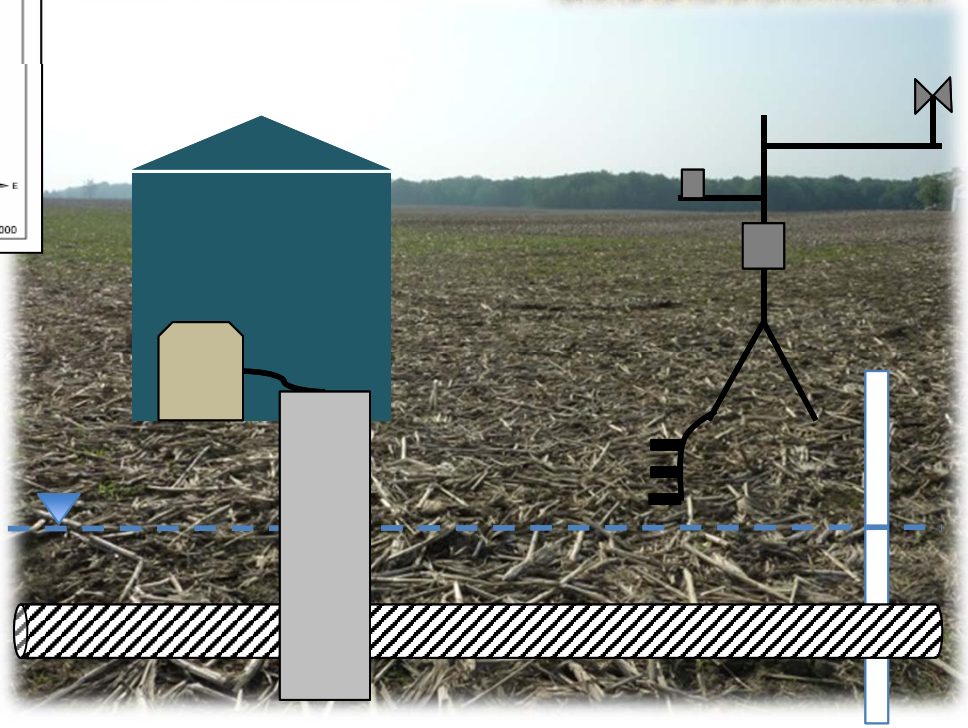
Universities

Waterloo, Guelph, Wilfrid Laurier Universities

Government

Ontario Ministry of Agriculture, Food and Rural Affairs
Essex Region and Upper Thames Region Conservation Authorities
Agriculture and Agri-Food Canada





7 sites instrumented with runoff monitoring equipment, automated water samplers and weather stations (year–round, 2011 to present)

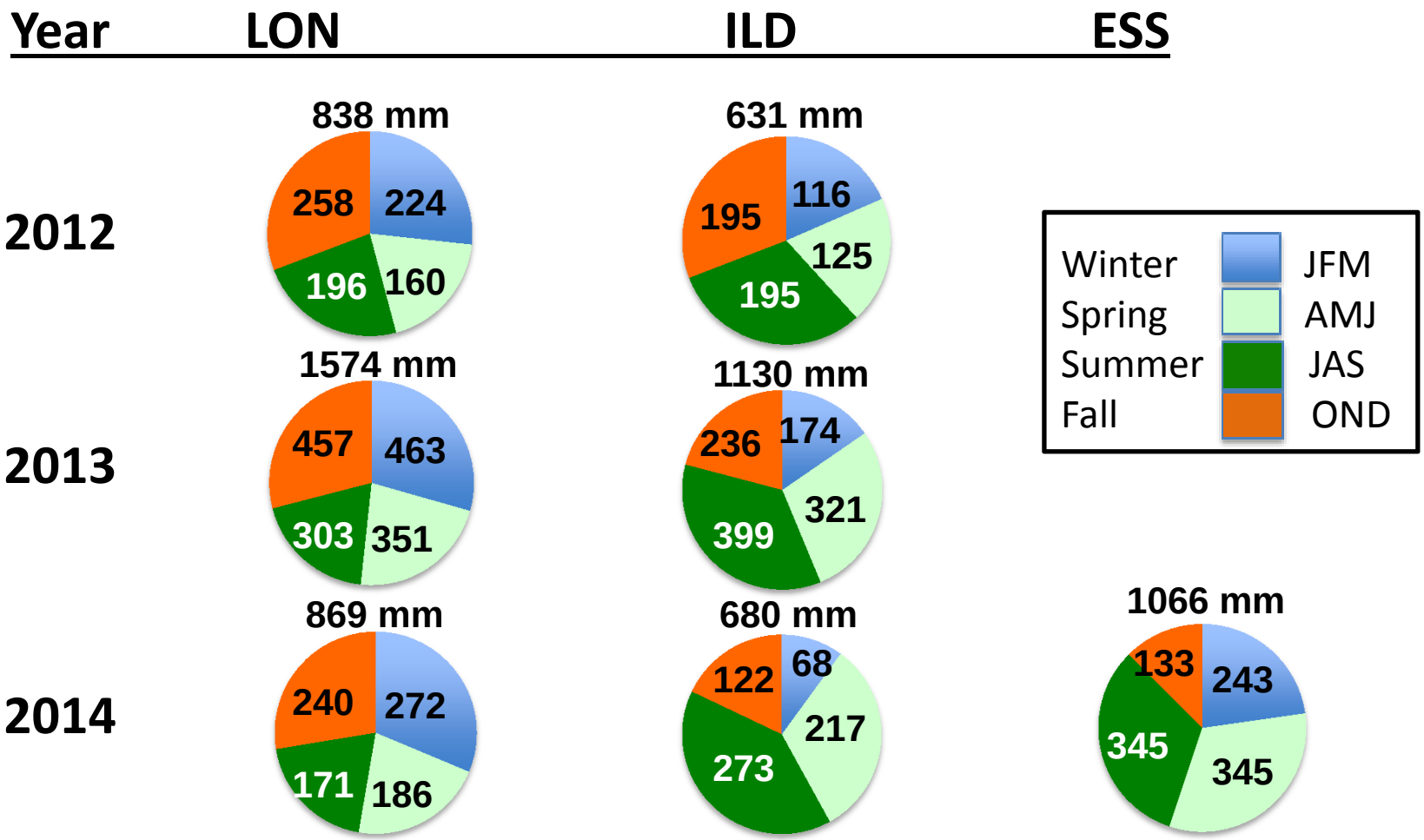
Research Sites…

	Contrib. Area (ha)	Land Slope (%)	Soil Name (texture)	Soil P (ppm) Olsen	Tile Drain Depth (m)	Tile Space (m)	Rotation	Tillage
LON	~8	0.5-3.5 uniform	Perth/Listowel (SiL)	10	~0.9	13.9	Cg-Sb-WWcc	Rotational Vertical till
ILD	~8	0.5-3 hummocky	Thorndale/Embro (SiL)	16	~0.9	9.1	Cg-Sb-WW	Rotational Strip Till
BVL	~4	0.5 - 3.6	Bainsville (SiL)	15	~0.9	12	Cg-Sb-WW	Rotational Ridge Till
ESS	~7	0-0.5 ~ level	Brookston (C)	13	0.7	10.7	Cg-Sb	Fall chisel/plow
INN1	~0.3	1.5	Bondhead/Guerin (SL)	25	1	12	Cg-Sb-WW	Rotational Disk Harrow (shallow)*
INN2	~0.3	0.5	Bondhead/Guerin (SL)	5	1	12	Cg-Sb-WW	Rotational Disk Harrow (shallow)*

- Working farms, volunteer cooperators
- Aside from Essex, most are silt loams or sandy loams
- P is carefully managed → low STP, reduced till, subsurface P placement (banding)

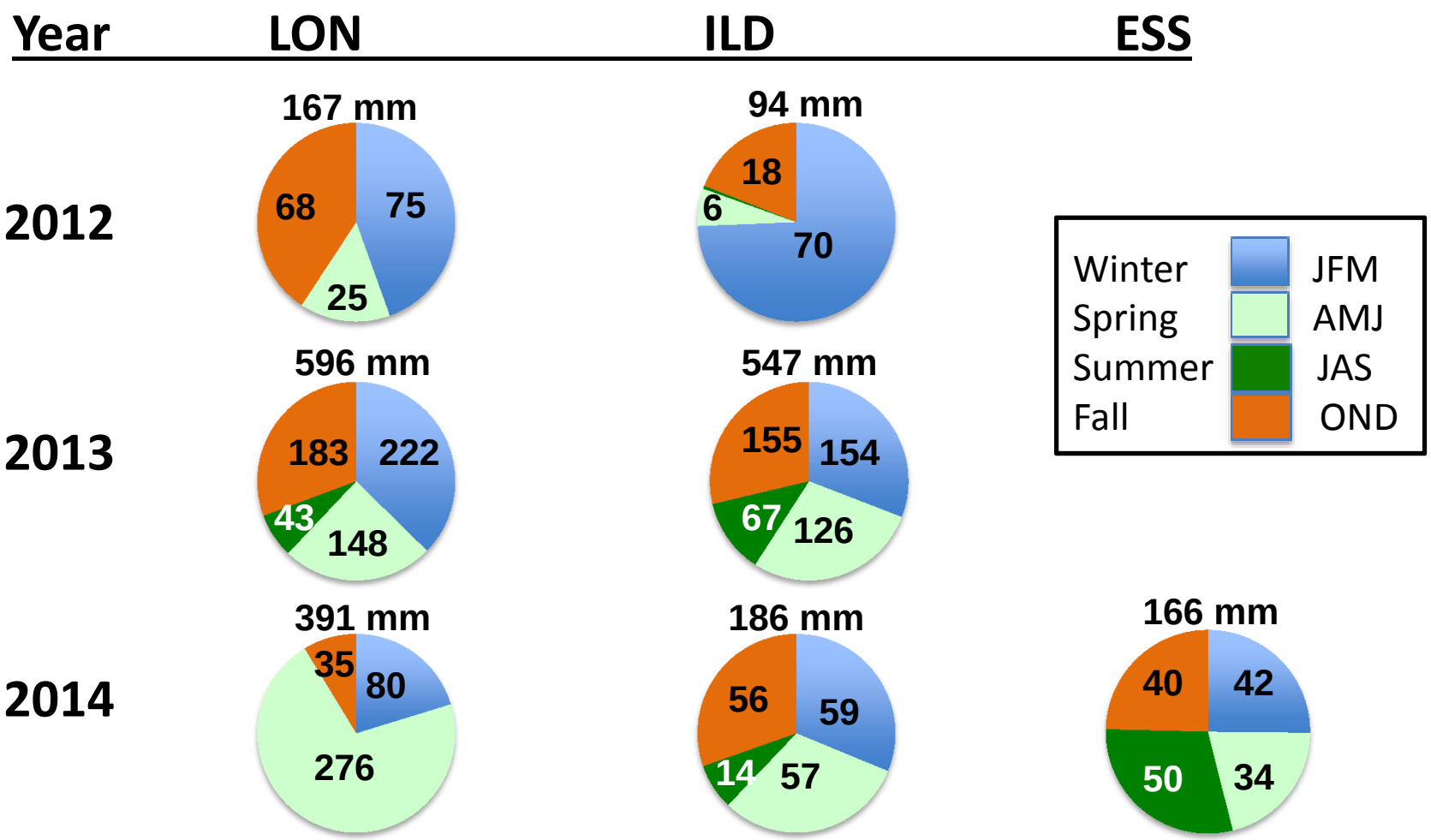
General Field Observations: Precipitation

1. Seasonal Distribution of Precipitation
2. Year-to-Year Variability of Precipitation/Seasonal Distribution



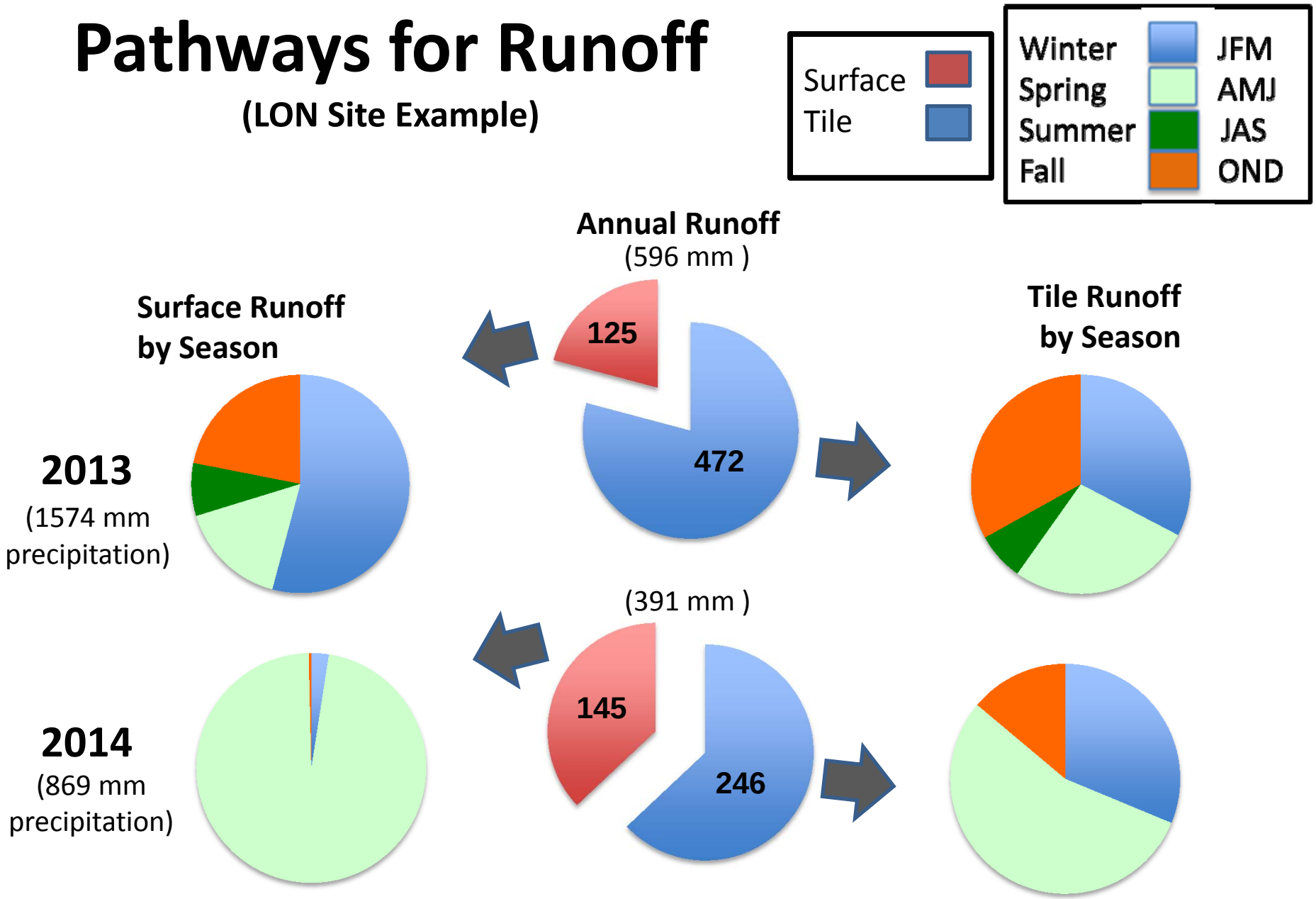
General Field Observations: Runoff

3. Inter-annual Variability in Seasonal Runoff (Combined Surface + Tile)



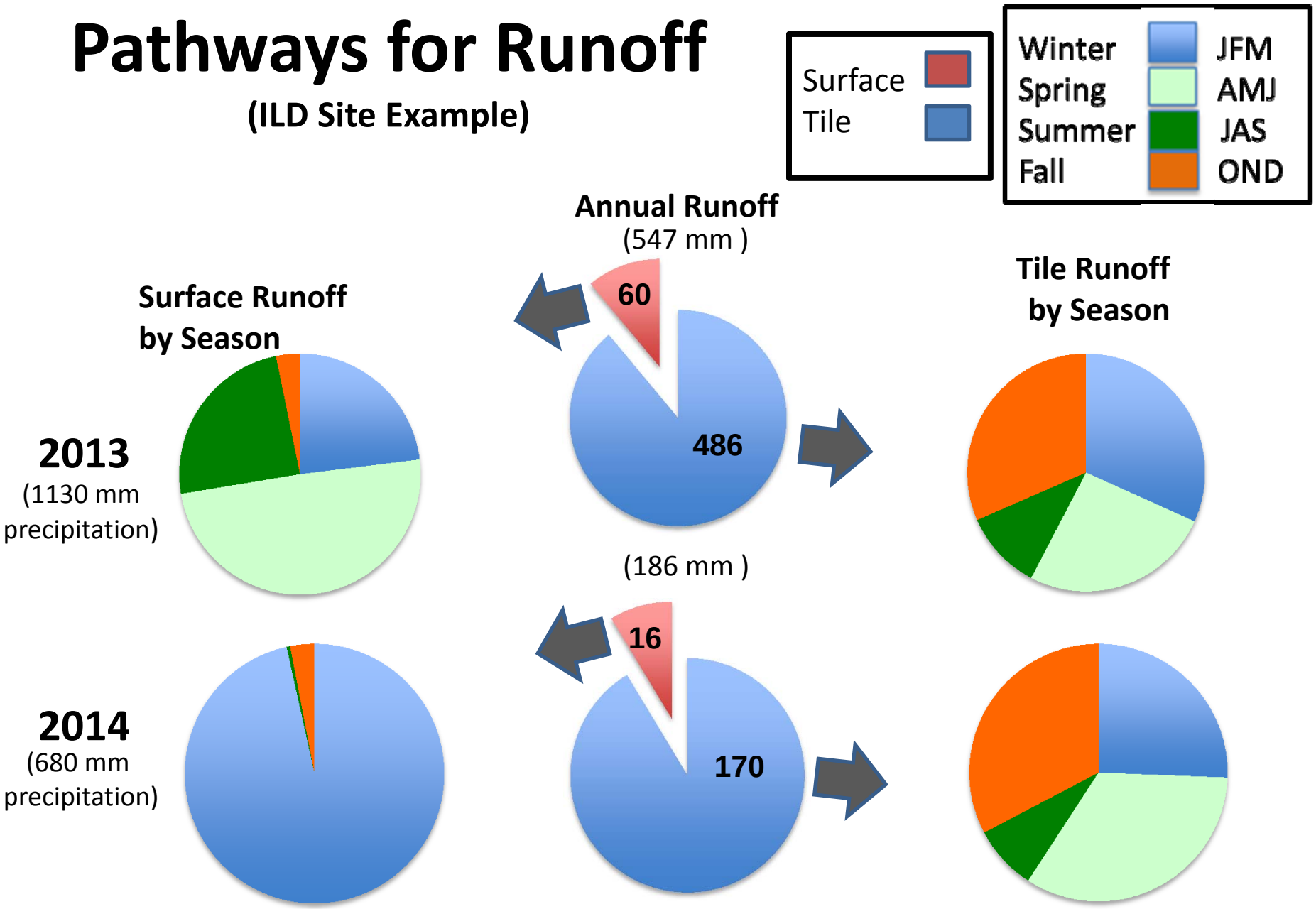
Pathways for Runoff

(LON Site Example)



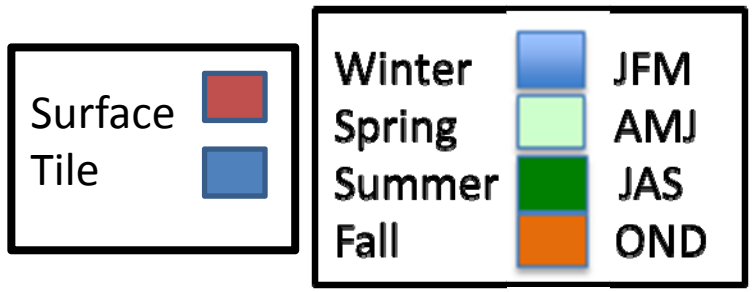
Pathways for Runoff

(ILD Site Example)



Pathways For Runoff

(ESS Site Example)

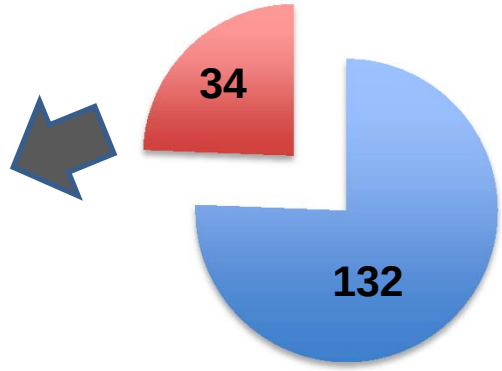


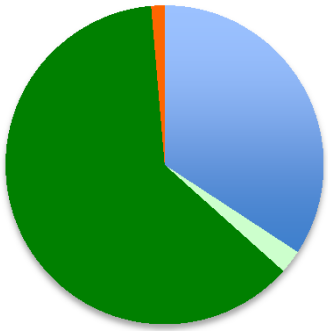
2014

(1039 mm precipitation)

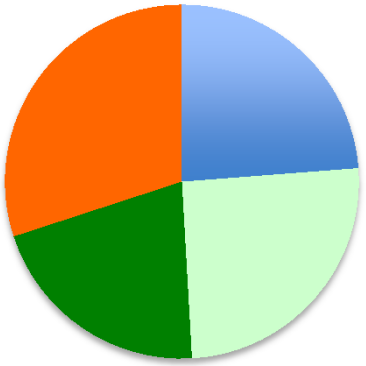
Annual Runoff

(166 mm)



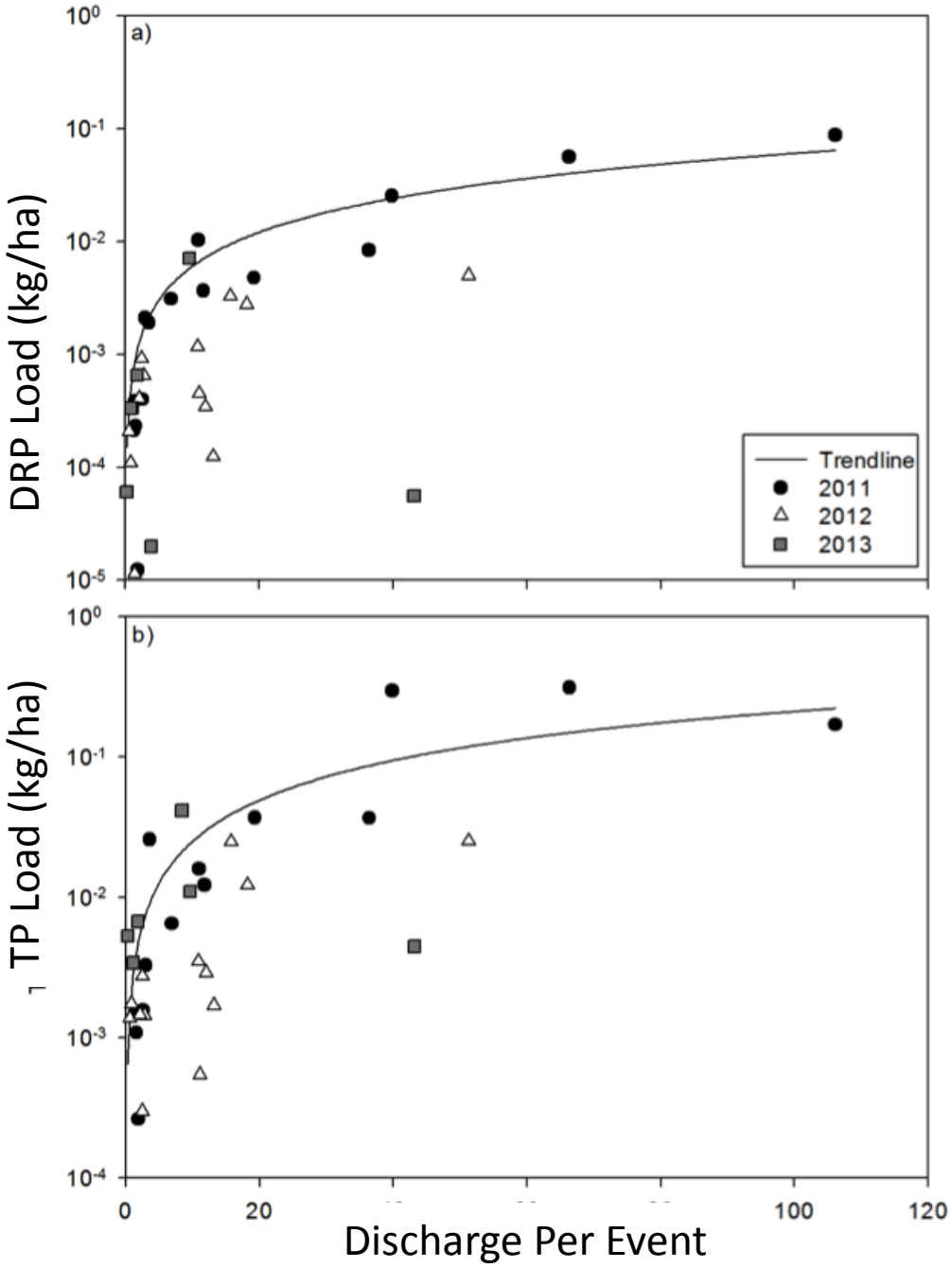


Surface Runoff by Season



Tile Runoff by Season

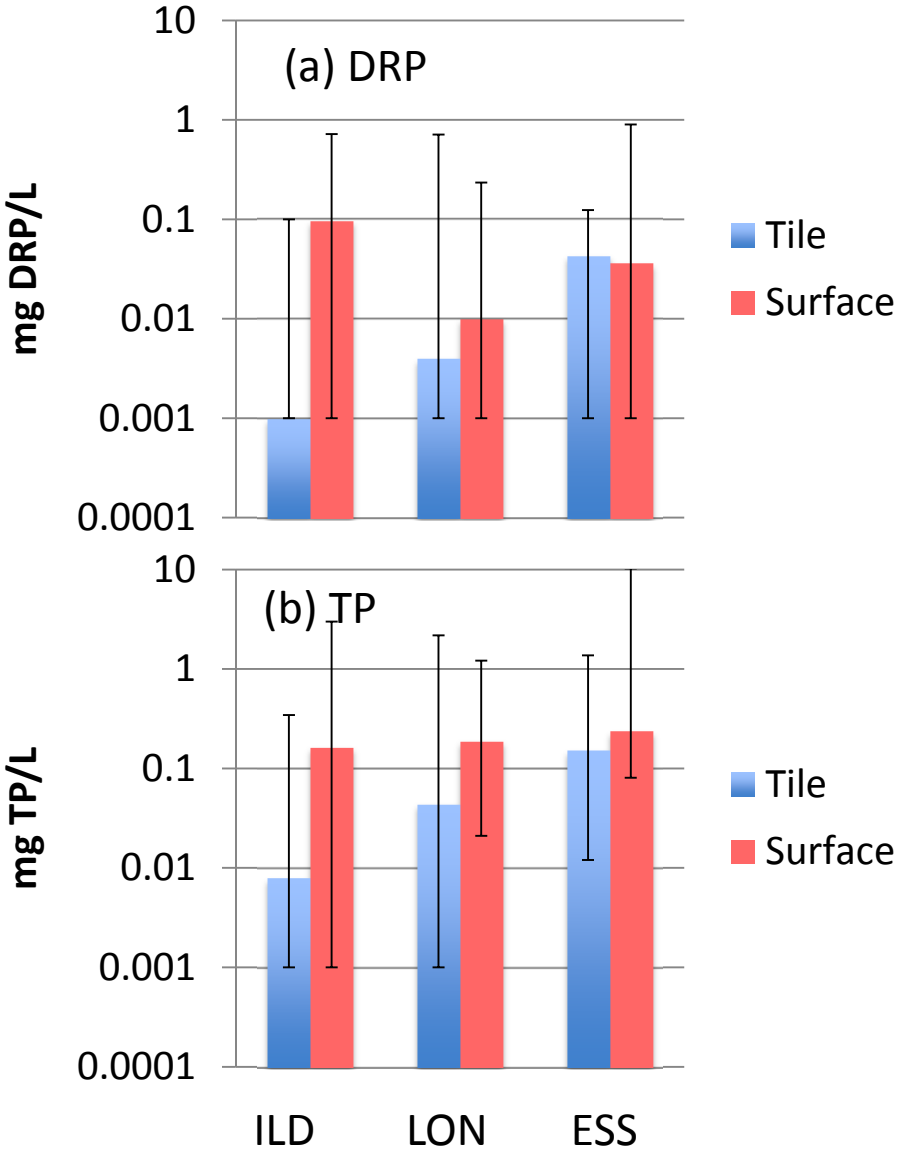
- **Most P is lost with runoff events!**
- **Given that most runoff is lost during non-growing season (NGS), most P loss also happens during NGS!**



Lam et al., 2016, INN1 site example

Median and range in P concentrations in tile effluent and overland flow during events

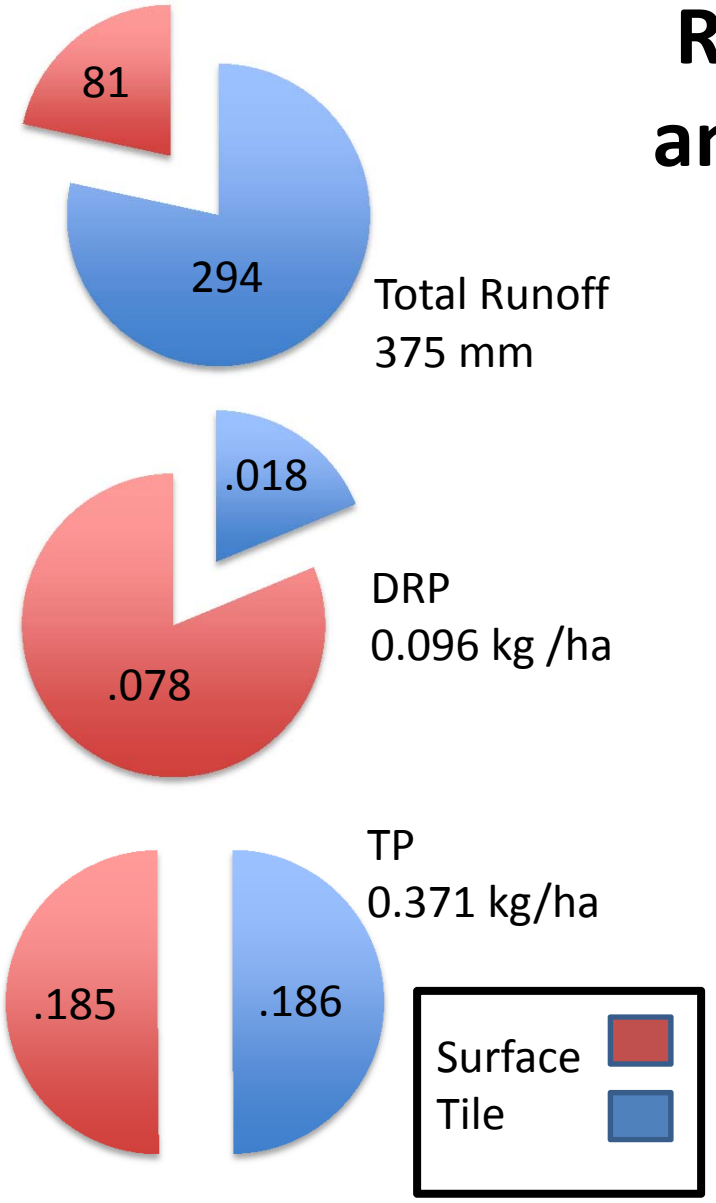
- Overland flow [P] > tile drain [P]
- More apparent in loams than clays



Macrae, Brunke and McKague, unpublished data

Relative Contribution of Tile and Surface Runoff to Annual P Load

(LON SITE: MAY 2012 – APR 2013)



Van Esbroeck et al., 2016

General Conclusions

Despite tile runoff contributing to the majority of the total runoff leaving a field:

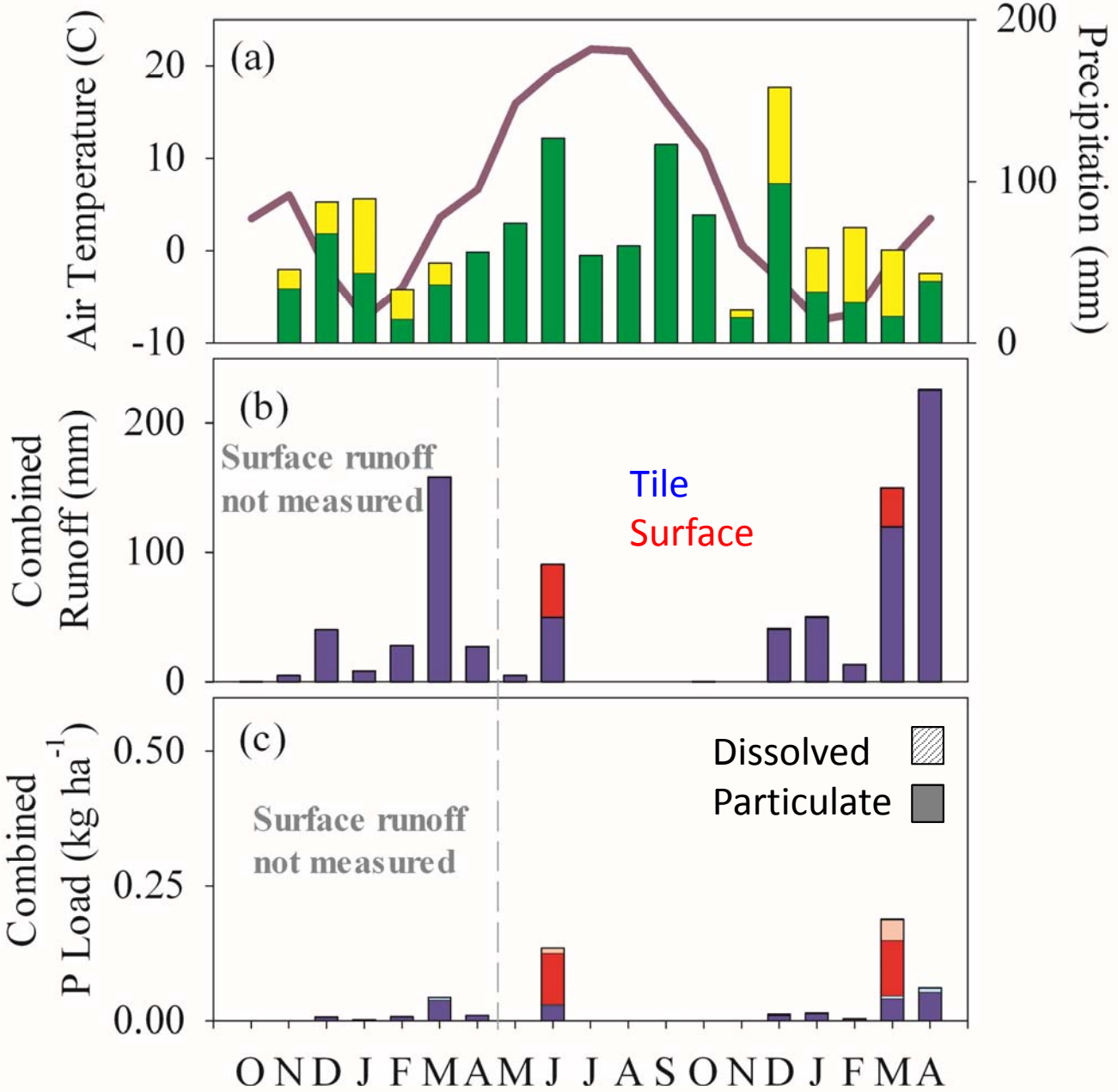
- Surface runoff contained the majority of DRP
- Surface = Tile for TP contribution

Therefore, surface runoff is a very important pathway for annual P loss .

- Erosion control
- Improving soil infiltration capacity (to reduce runoff)

are still key steps to reducing P loss from fields

When is most P lost and through which pathways?



Tiles =

- **78-90% of flow**
- **20-67% of DRP**
- **40-77% of TP**

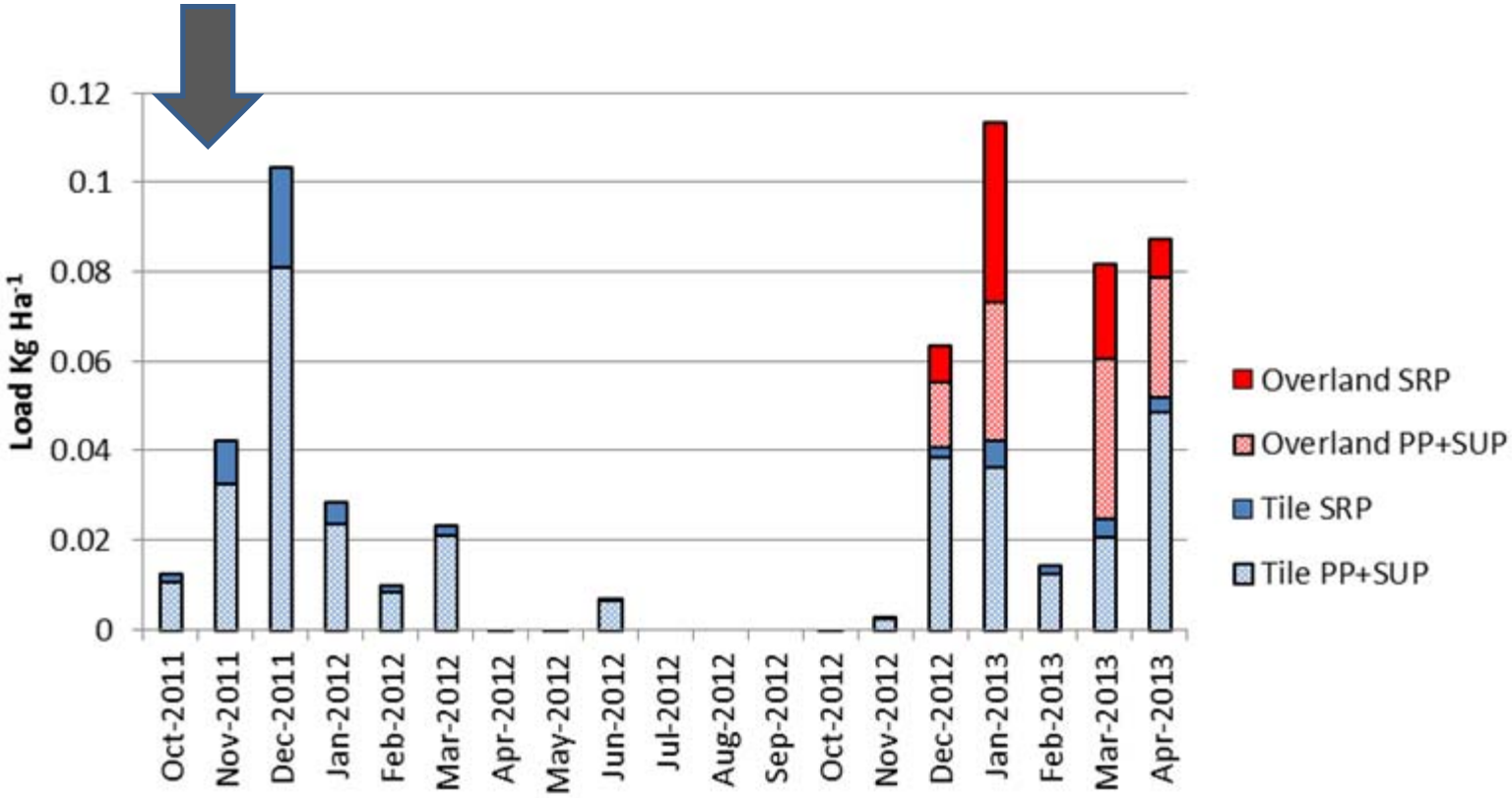
- **Most P lost as particulate (sediment)**

BVL Site

Van Esbroeck et al. 2016

Nutrient Application Timing and Placement Effects on P Loss

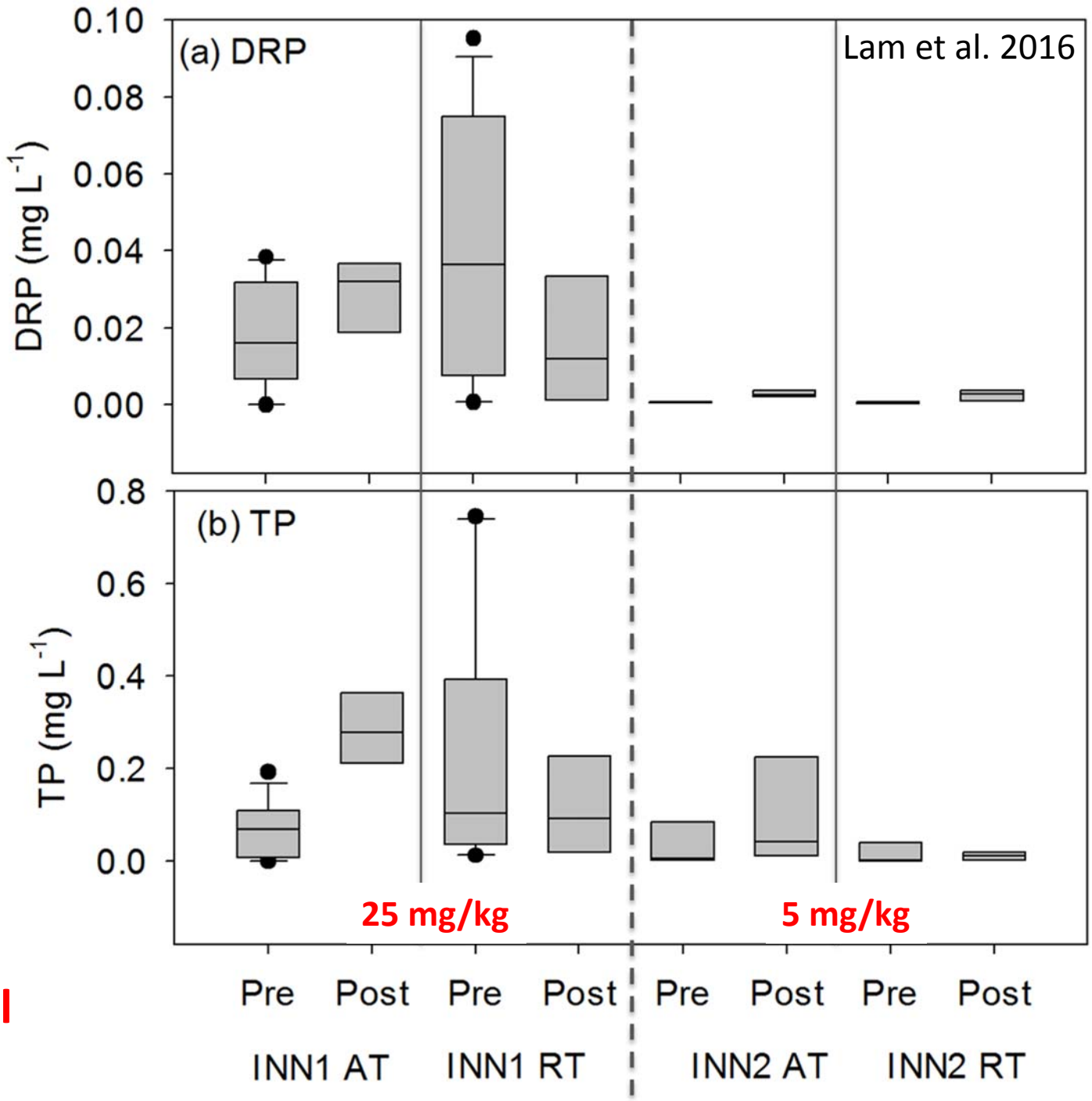
(LON SITE)



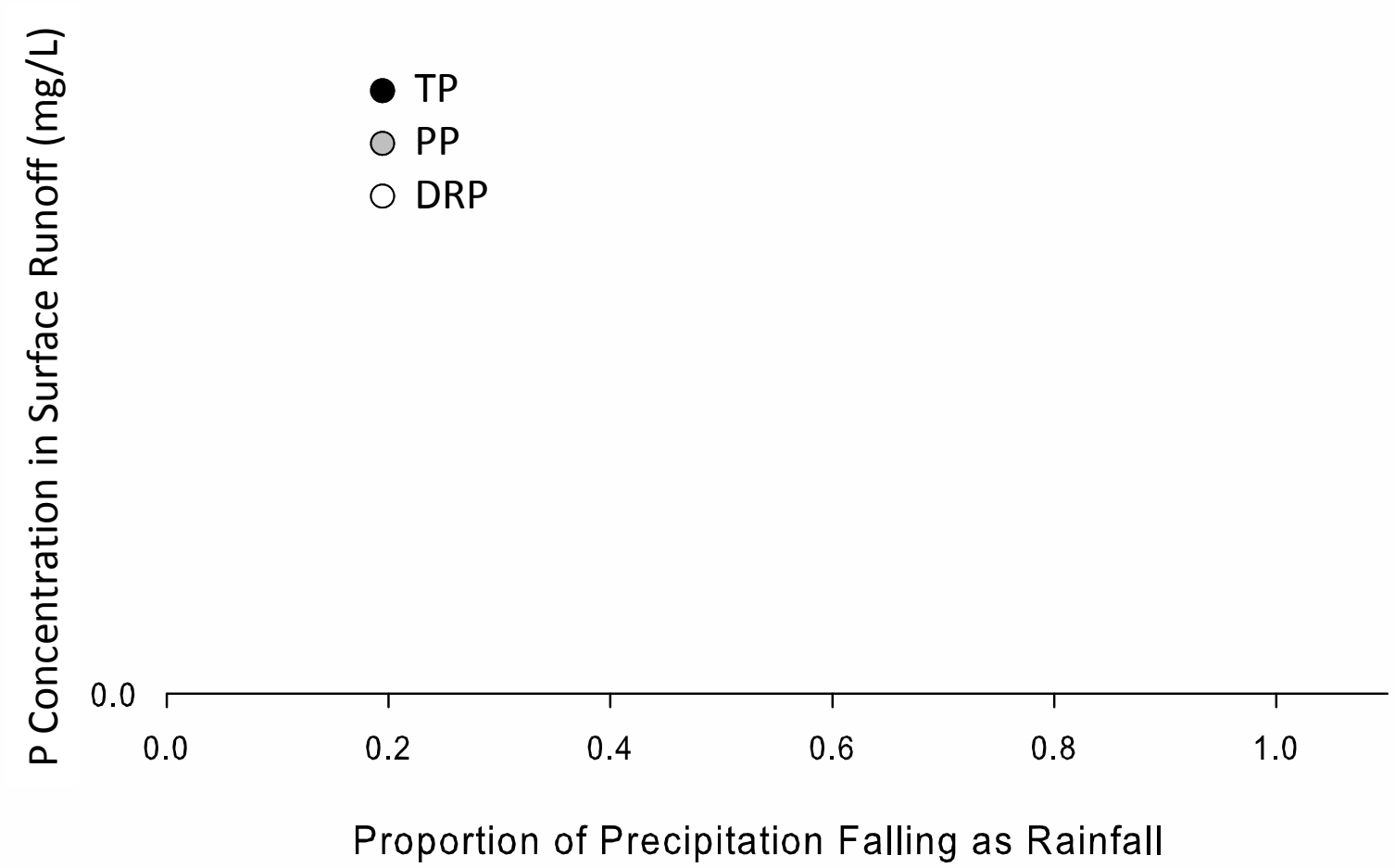
Source: C. Van Esbroeck – MSc Thesis, UW

Does Reduced Tillage Increase P Loss in Tile Drains?

- Tillage did not increase P loss when used with banding
- Lower losses from lower soil P site



Does Event "Type" Matter?



Crop/Cover Effects on P Loss

Cover Crop Erosion Control (P loss) Benefits (Chatham-Kent Example)

Visual Observations (erosion)

Field with Over-Winter Cover Crop

Field Without Cover Crop

Crop/Cover Effects on P Loss

Cover Crop Erosion Control (P loss) Benefits (Chatham-Kent Example)

Visual Observations (Soil Water/Structure)

Field with Over-Winter Cover Crop

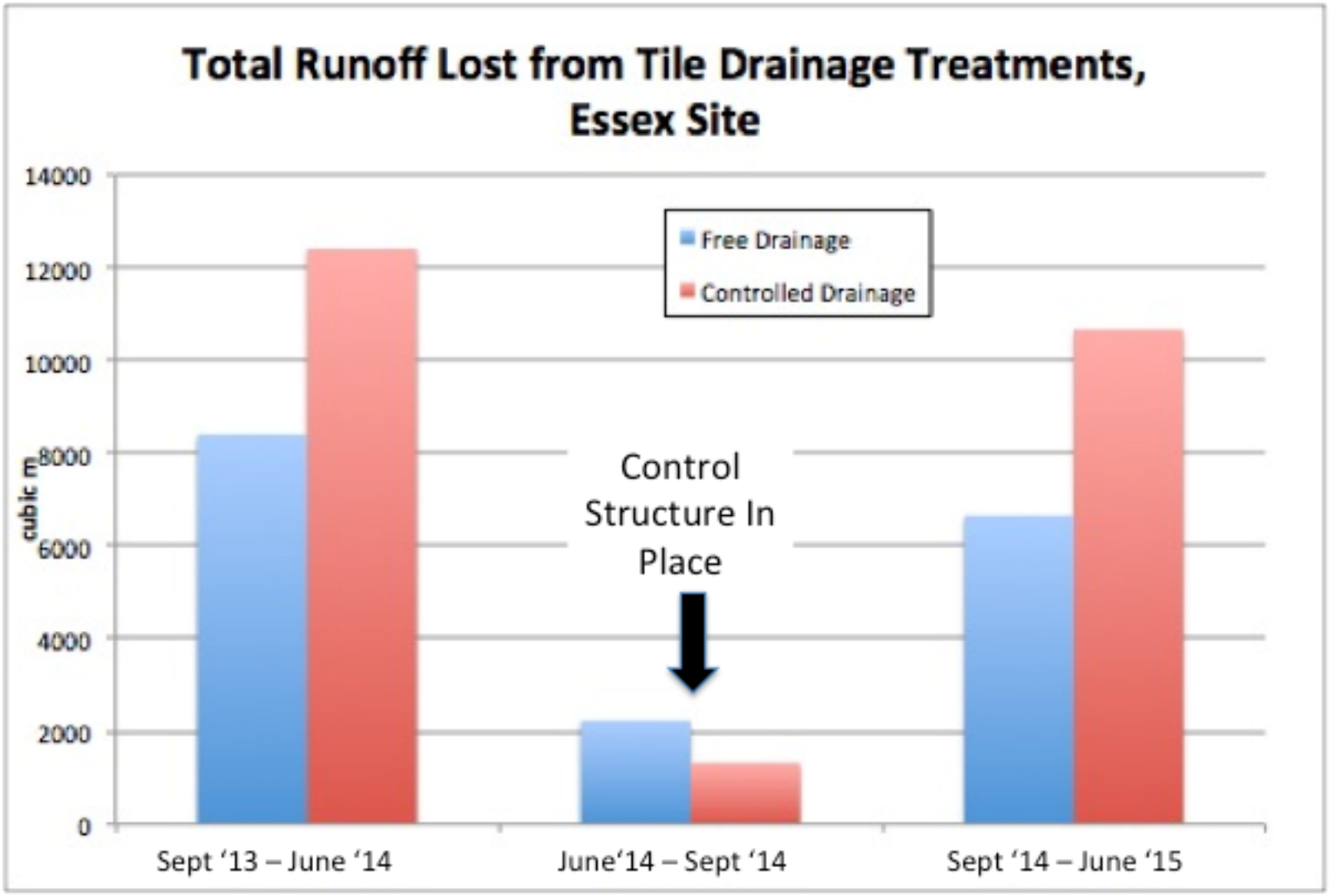
Field Without Cover Crop

Cover Crops & P Loss After Freezing

- ***Yes, cover crops can lose P after freezing***
- **But depends on crop type – we can use this to optimize cover crop choices!**
- **Most P lost after first freeze-thaw event – often occurs in late autumn in Ontario → most vegetation P may go into soil before winter hits!**
- **Rainfall pulls less P from cover crops than surface flooding – can we use this knowledge to optimize use of cover crops?**
- **Currently doing work on termination & winter P loss**

Lozier & Macrae, 2016; photo by @t_vollmer via Twitter

Will control structures in tiles work?



How effective can they be if they are not left in place during peak flow due to frost potential?

BMPs on our Corn-Soy-Wheat sites:

Data collected across our sites consistently shows field based loads <0.5 kg/ha TP (combined surface and subsurface runoff) → even in a very wet year!

- **Nutrient management (keep STP low)**
- **Subsurface placement of P (or incorporate if surface broadcast**
- **Crop rotation → Corn, soy, winter wheat**
- **Rotational, minimum tillage (after wheat) (esp. if P is surface applied - manure)**
- **Cover crops after wheat**
- ***Collectively, these appear to maintain low P loads in both tile drainage and surface flow → most of our sites are silt loams or clay loams***

- **Need more data in Ontario clay soils and direct comparisons with Ohio farms → currently working on this!**

Summary:

Can We Reduce P Loss from Cropped Fields?

- **Use of multiple (stacked) BMPs – need to manage in surface and subsurface**
- **Slow water flow down – force underground if possible (at least in silt loams and sandy loams) – clays are trickier!**
- **Build and maintain soil health**

Acknowledgements

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  - **Ontario Ministry of Agriculture, Food and Rural Affairs – Best Management Practices Verification and Demonstration Program, Lake Simcoe Program, New Directions Program**
  - **Environment Canada - Lake Simcoe Clean Up Fund**
  - **Growing Forward (Agricultural Adaptation Council Farm Innovation Plan [FIP]) and CAAP Programs**
  - **OSCIA, LICO**

- **Logistical & Technical Support: ANSWERS farmers (D. Lobb, K. Eisses, B. McIntosh, K. Nixon, S. McRae, L. Taylor); Innovative Farmers of Ontario (IFAO); Land Improvement Contractors of Ontario (LICO), A. MacLean, E. Thuss, I. Martin, J. English, J. Owens, C. Duke**