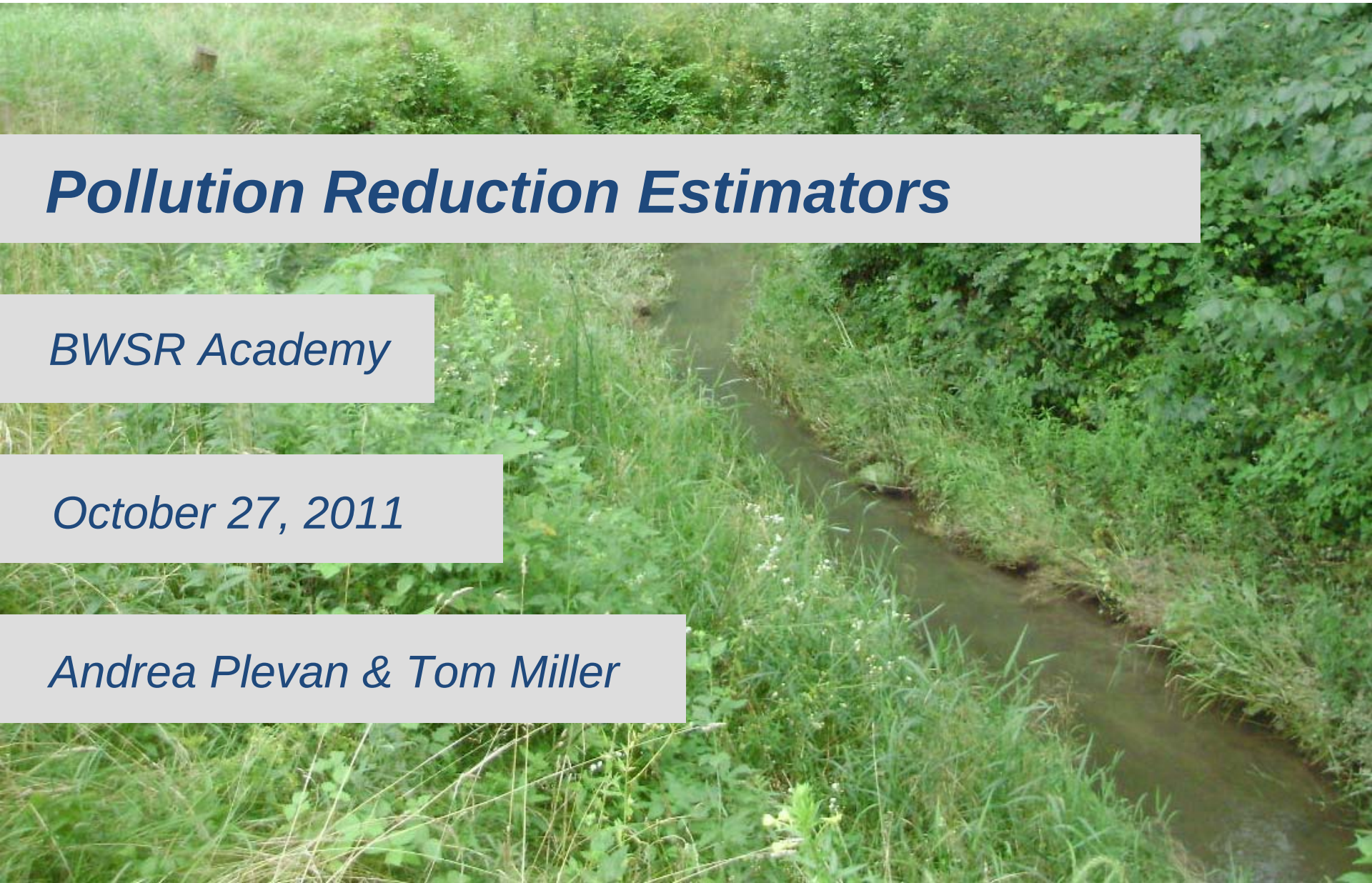
Emmons & Olivier Resources, Inc.

water ecology community

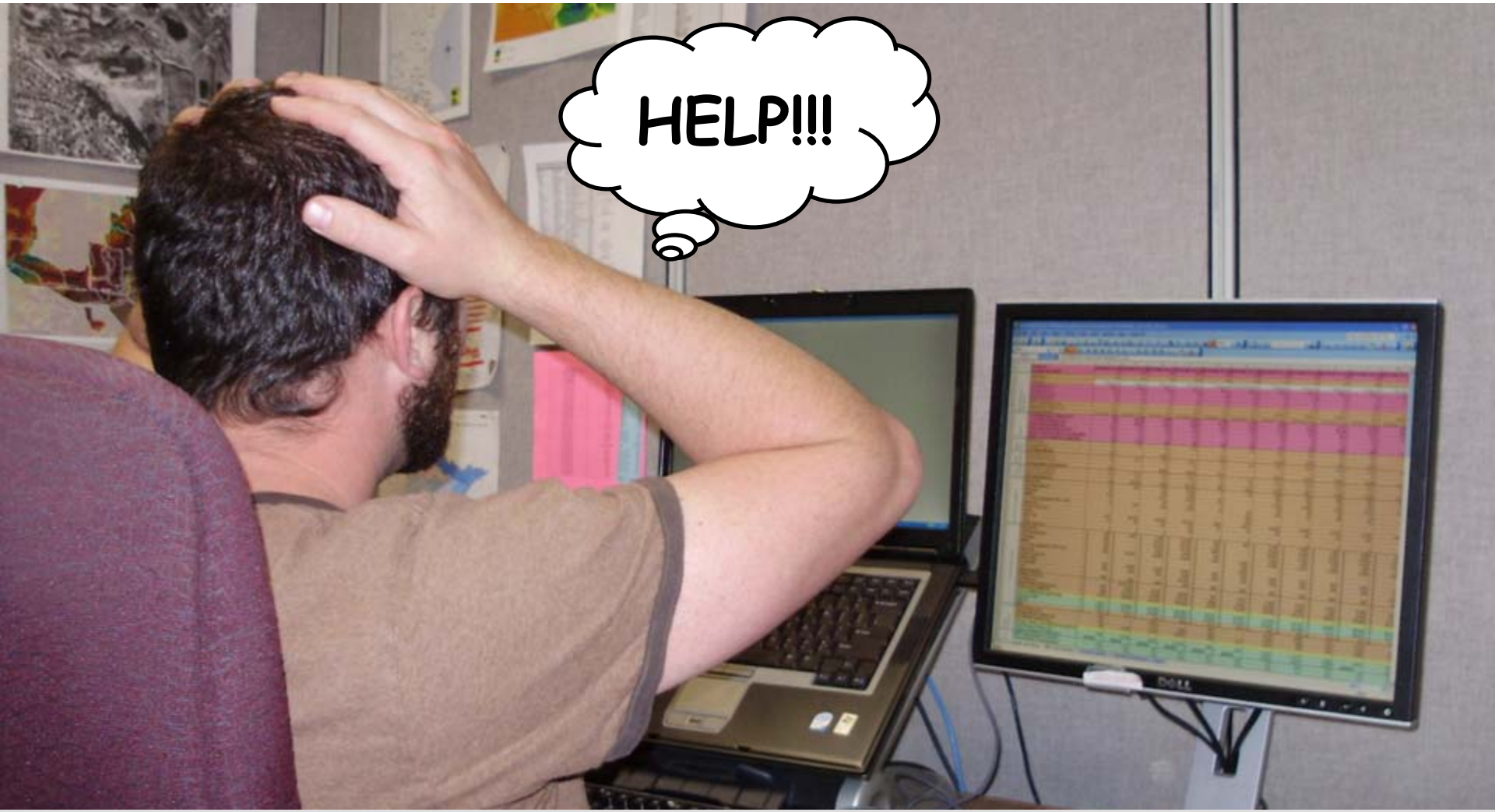


Pollution Reduction Estimators

BWSR Academy

October 27, 2011

Andrea Plevan & Tom Miller

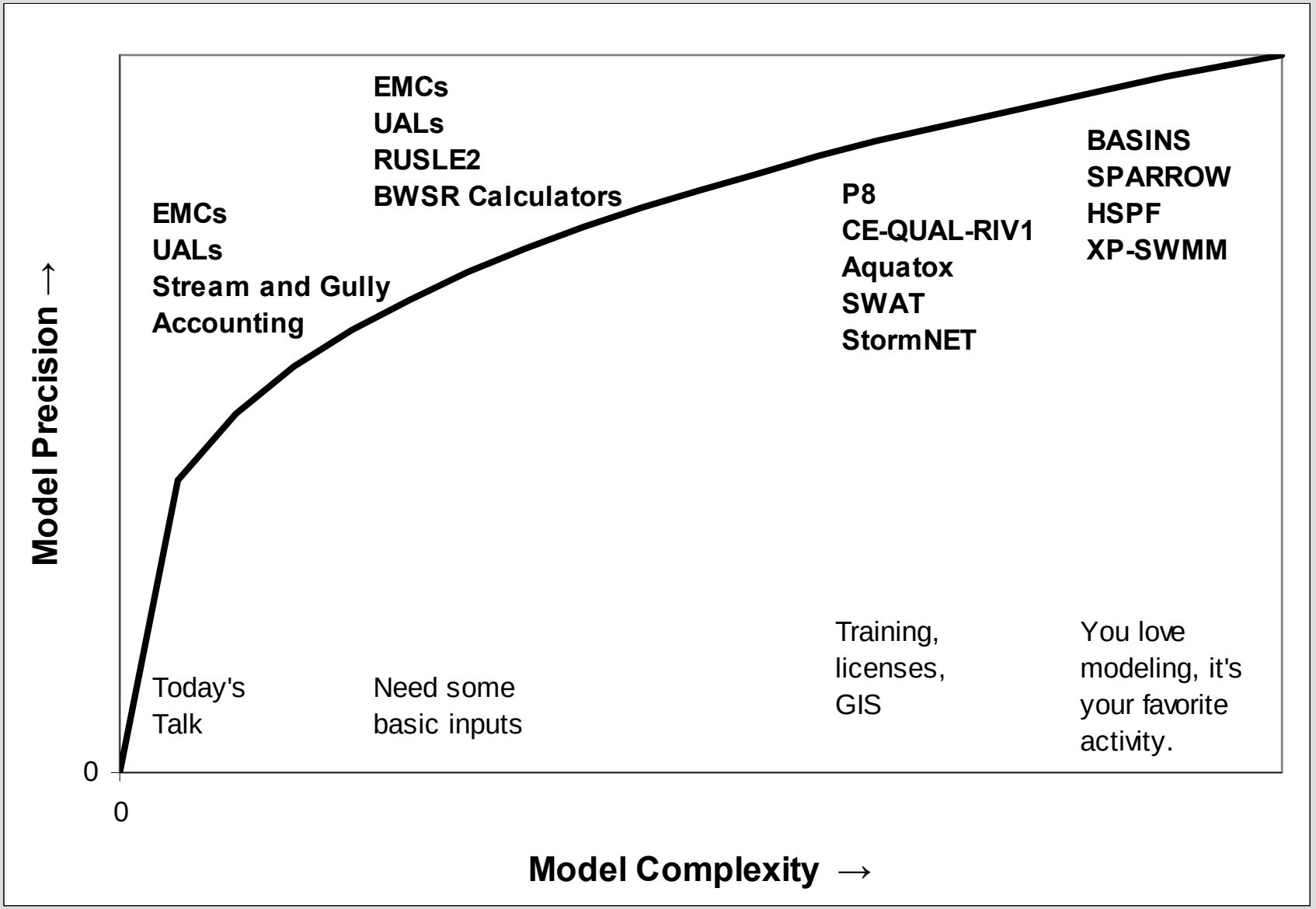


I need to estimate phosphorus reduction for this Clean Water Fund grant application I'm working on!

Goals

- **Familiarity with simple watershed loading models and pollutant removal models**
- **Understanding of when to use them and when not**
- **Provide tools for**
  - **Pollutant removal estimates: grant applications, tracking in eLINK, project benefit comparisons, etc.**
  - **Checking estimates by others**

Model Complexity Spectrum



Outline

- When is simple OK?
- 2 approaches for watershed runoff
  - Unit area load (UAL)
  - Event mean concentrations (EMC)
- Pollutant removals - watershed
  - Land cover change
  - Percent removals
- Pollutant removals - streambank and gully erosion
- Pollutant removals - septics
- Examples

When is simple OK?

- **OK**
  - Comparing benefits
  - Grant applications
  - Planning
- **Not OK**
  - BMP design, sizing
  - Apples to oranges comparisons

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Unit Area Loads (UALs)

Average loading rates (load per area) assigned based on land use or land cover

Land cover	UAL	
	TP (lb/ac-yr)	TSS (T/ac-yr)
Agriculture	0.40	1.7-2.6
Forest/grassland	0.08	0.10
Urban - high density	1.1	0.21
Urban - low density	0.80	0.10

Load (lb/yr) = Area (ac) x UAL (lb/ac-yr)

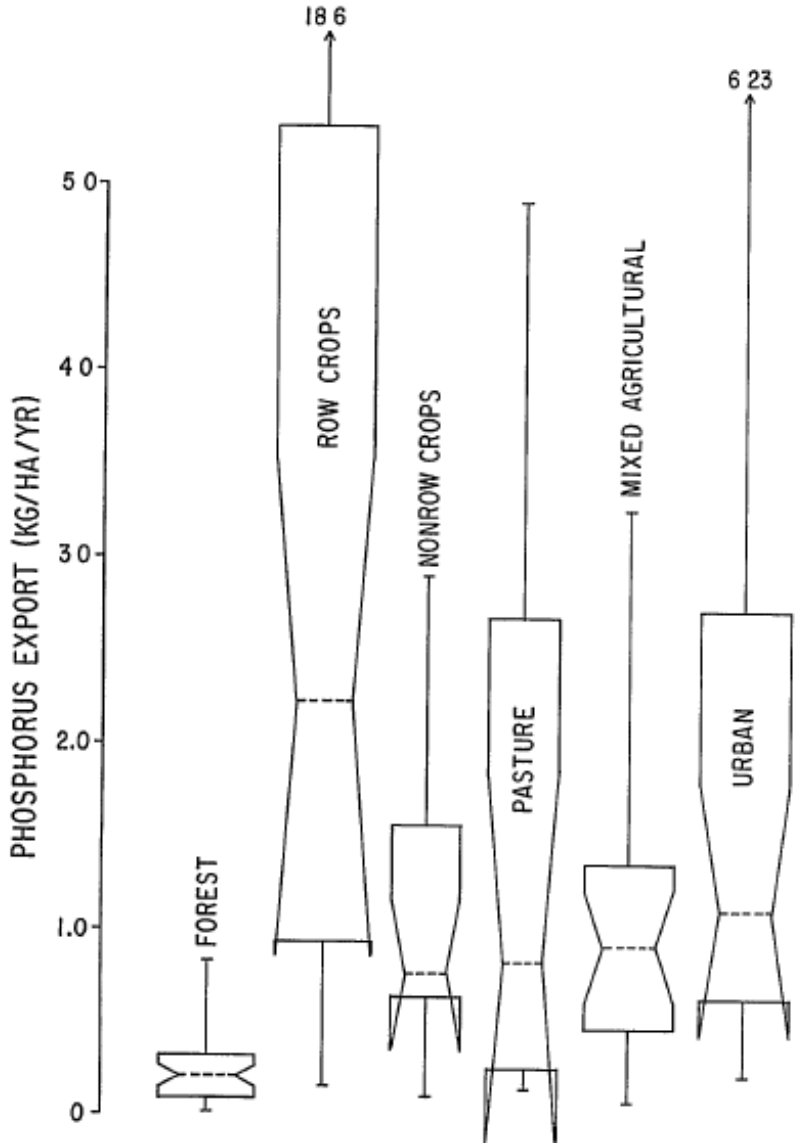
Unit Area Loads (UALs)

Example:

Land use or land cover	Area (ac)	UAL (lb P/ac-yr)	Load (lb P/yr)
Grassland	50	0.08	4
Agriculture	25	0.4	10
Low density developed	8	0.8	6.4
Total	*83*		*20*

*Tip: round numbers

Variability in UALs



From EPA 440/5-80-011: Reckhow et al. 1980

EMCs and Runoff Volume

- Average loading rates (load per runoff volume) assigned based on land use or land cover
- Takes into account runoff volume

Land cover	EMC			Runoff Factor*
	TP (mg/l)	TSS (mg/l)	TN (mg/l)	
agriculture	0.32	1362	2.68	30
forest/grassland	0.04	11	0.6	4
urban-high	0.3	81	2.4	80
urban-low	0.3	27	2.0	35

***For areas with imperviousness, runoff factor = % impervious. For areas without imperviousness, runoff factor is related to CN.**

EMCs and Runoff Volume

- **Input needs**
  - Annual precipitation (inches) = "precip"
  - Runoff factor
  - Pollutant concentration, or event mean concentration (mg/l) = "EMC"
  - Area (ac) = "A"

Land use or land cover	Precip (in)	Runoff Factor	EMC (mg/l P)	Area (ac)	Load (lb P/yr)
Grassland	32	4	0.04	50	1.1
Agriculture	32	30	0.32	25	16.4
Low density developed	32	35	0.30	8	5.6
Total				*83*	*23*

L (lb/yr) = precip x [0.05+(0.009 x runoff factor)] x EMC x area x 0.20

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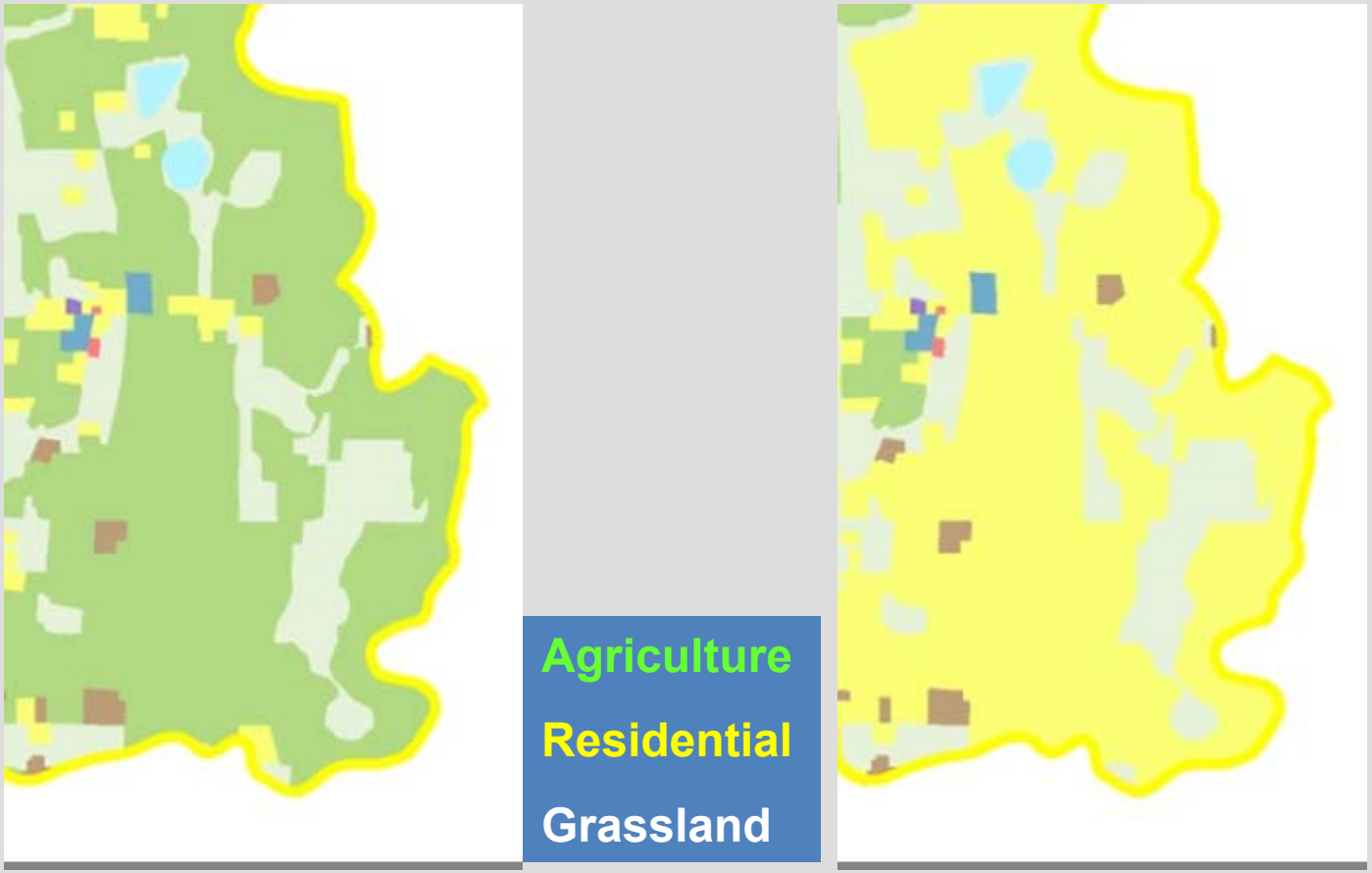
Pollutant removals

Land use / cover change



Conversion of agricultural to grassland and developed

Pollutant removals / changes

Land use or land cover	Area (ac)	UAL (lb P/ac-yr)	Load (lb P/yr)
Grassland	50	0.08	4
Agriculture	25	0.4	10
Low density developed	8	0.8	6.4
Total	*83*		*20*

Land use or land cover	Area (ac)	UAL (lb P/ac-yr)	Load (lb P/yr)
Grassland	60	0.08	4.8
Agriculture	0	0.4	0
Low density developed	23	0.8	18.4
Total	*83*		*23*

Conversion of agricultural to grassland and developed

Pollutant removals – by BMP type

BMP	TP Reduction (%)	TSS Reduction (%)
Bioretention/Rain Garden	50-100	85-90
Biofiltration	25-50	60-85
Infiltration Basin/Trench	25-100	85-100
Grassed Channel	15-50	50-87
Dry Swale	20-50	50-87
Wet Swale	20-50	69-87
Filter Strips	0-45	30-73
Wet Pond	40-75	70-90
Dry Pond	15-45	53
Vegetated Filter Strips	50-80	75
Forested Buffers	30-45	40-60
Agricultural Grass Buffers	30-45	40-60
Conservation Tillage	22	30
Continuous No-Till	20-40	70
Forest Harvesting	60	60

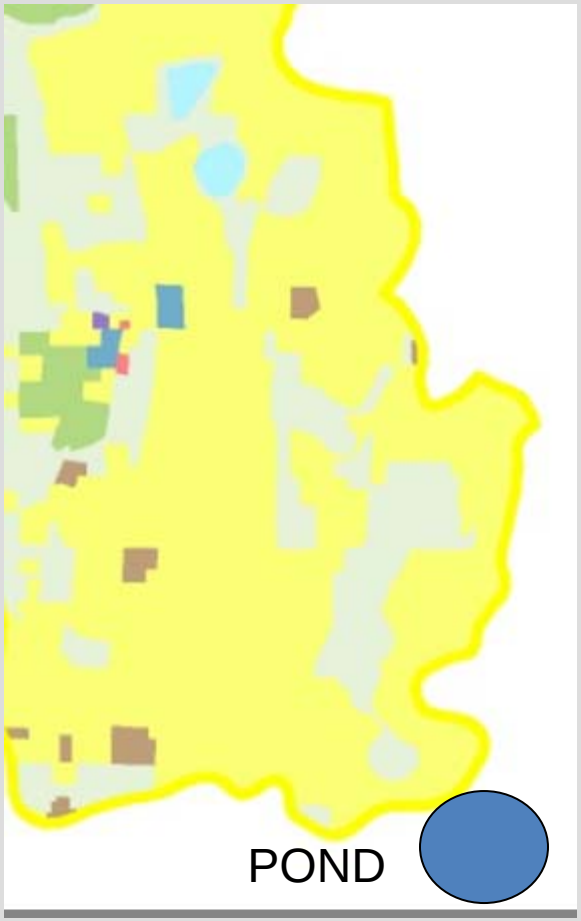
Pollutant removals

Portion of residential development drains to wet pond

10 acres

60% P removal

Area (ac)	UAL (lb P/ac-yr)	Load to Pond (lb/yr)	60 % Removal (lb/yr)
10	0.8	8	4.8



Pollutant removals

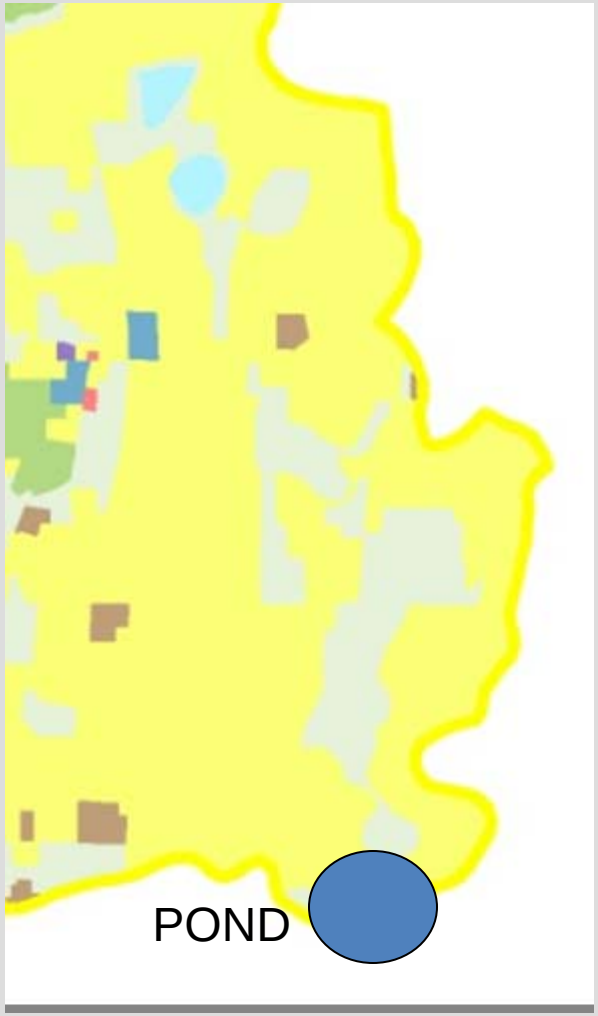
Initial pollutant loading = 20 lb P/yr

Land cover change pollutant loading = 23 lb P/yr

Wet pond removal = 4.8 lb P/yr

Total loading after land cover change and wet pond = 18 lb P/yr

Total load reduction = 2 lb P/yr



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- Pollutant removals - septics
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Streambank erosion

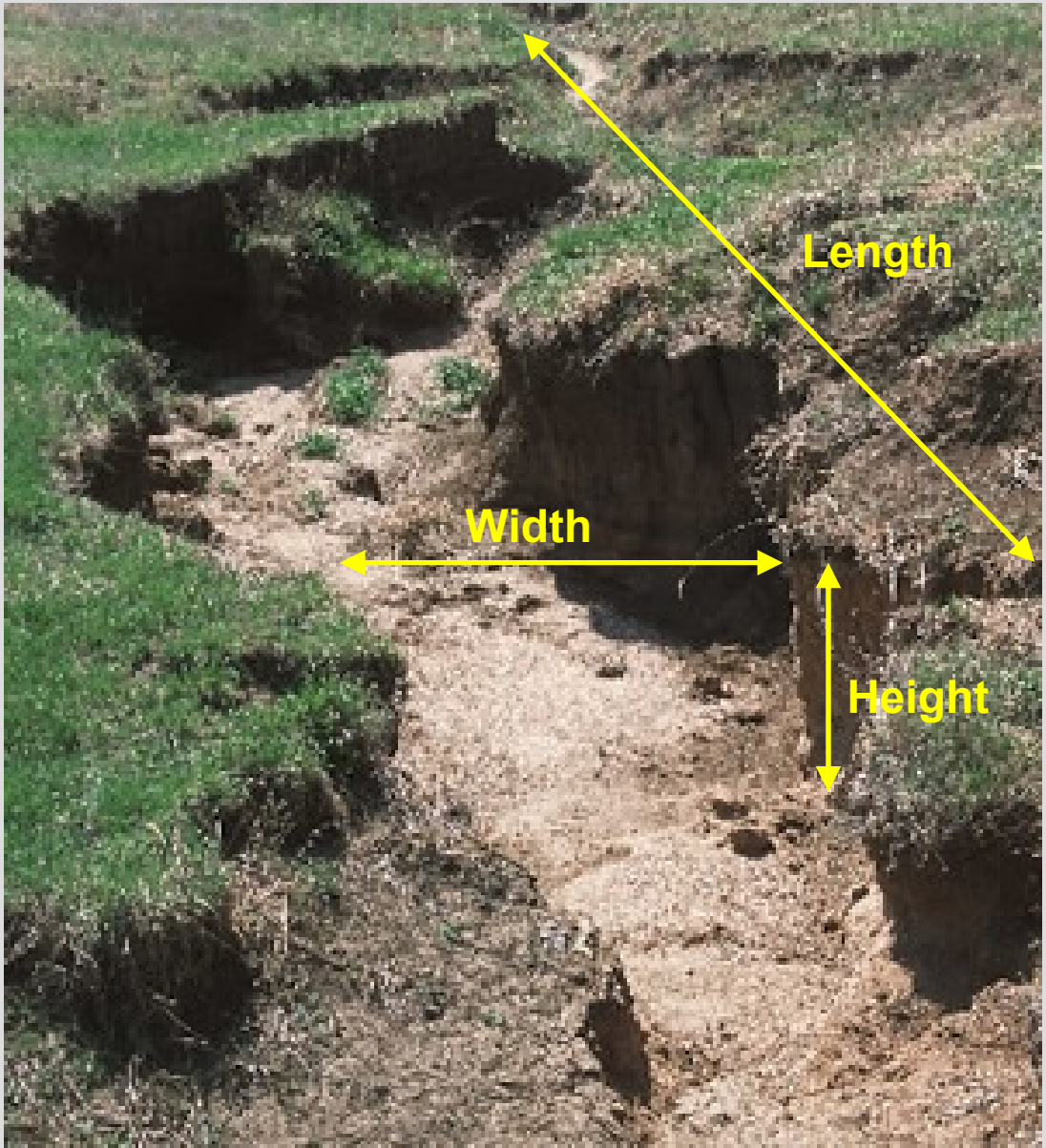
Streambank erosion

Streambank erosion

Row	Description	Notes	Example Values
A	Height (ft)	Height of erosion	*12*
B	Width (ft/year)	Lateral recession rate	*1.2*
C	Length (ft)	Length of erosion	*279*
D	Annual Volume Lost (cf/year)	A x B x C	*4,018*
E	Annual mass lost (tons/year)	D x soil density (assumes silt soil at 85 lb/cf)	*171*
H	Phosphorus loss (lbs/year)	Assume 1 lb P per ton of soil	*171*

Lateral Recession Rate (ft/yr)	Category	Description
0.5 +	Very severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.

Gully erosion



Gully erosion

Gully erosion

Row	Description	Notes	Example Values
A	Height (ft)	Height of erosion	*12*
B	Width (ft)	Width of erosion	*20*
C	Length (ft)	Length of erosion	*279*
D	Volume (cf)	A x B x C	*66,960*
E	Total mass lost (tons)	D x soil density (assumes silt soil at 85 lb/cf)	*2,846*
F	Time (years)	Estimated time erosion has been occurring	*17*
G	Soil loss (tons/year)	E / F	*167*
H	Phosphorus loss (lbs/year)	Assume 1 lb P per ton of soil	*167*

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Septics

- **Per capita load from ISTS**

Location	Conforming vs. non-conforming	P that reaches surface water (lb/capita-yr)
Shoreline	Conforming	0.39
Shoreline	Non-conforming, failing	0.84
Shoreline	Non-conforming, ITPHS	0.84
Upland	Conforming	0.19
Upland	Non -conforming, failing	0.58
Upland	Non -conforming, ITPHS	0.84

Septics

- **Example:**

Scenario	Loading rate (lb/capita-yr)	Load from 4 Shoreline Households (lb P/yr)
ITPHS	0.84	9
Full compliance	0.39	4

Assume 2.7 people / household

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Examples

- **Work in groups to solve problems**
  - **Use any method provided today**

- **Reconvene to review examples**

Examples

Example 1.

A landowner installs a 50-foot filter strip at the edge of an 80-acre cornfield along a county drainage ditch. Using field observations, the technician determined that the contributing area is only 30 acres.

a) Estimate the average annual phosphorus and sediment load to the ditch from this field prior to filter strip installation.

Using UALs, TP = 30ac x 0.4(lb/ac-yr) = **12 lb/yr**

TSS = 30ac x 2.0 (T/ac-yr) = **60 T/yr**

Using EMCs, TP = 28inches x [0.05 + (0.009 x 30)] x 0.32 mg/L x 30 ac x 0.2 = **17 lb/yr**

TSS = 28inches x [0.05 + (0.009 x 30)] x 1362 mg/L x 30 ac x 0.2 = **37 T/yr**

Examples

b) Assuming sheet flow across the filter strip, calculate the sediment and phosphorus reduction from the filter strip?

Land conversion = 50ft x 2,640ft = 3 acres converted from cropland to grassland

Using UALs,
TP = 3ac x 0.4 (lb/ac-yr) = 1.2 lb/yr, grassland = 3ac x 0.08 (lb/ac-yr) = 0.2lb/yr.
Reduction = 1.2 - 0.2 = **1 lb/yr**

TSS = 3ac x 2 (T/ac-yr) = 6T/yr, grassland = 3 a x 0.1 (T/ac-yr) = 0.3 T/yr
Reduction = 6 – 0.3 = **6 T/yr**

Contributing drainage area reduction = 30ac – 3ac = 27ac
Assume filter strip has 25% reduction for TP and 50% reduction for TSS

TP Reduction from filtering = 27ac x 0.4 (lb/ac-yr) x 0.25 = **2.7 lb/yr**
TSS Reduction from filtering = 27ac x 2 (T/ac-yr) x 0.5 = **27 T/yr**

Total phosphorus reduction, 1 + 3 = **4 lb/yr**
Total TSS reduction, 6 + 27 = **33 T/yr**

c) How would the phosphorus and sediment reductions change if the fields were tiled and the tile lines ran under the filter strip?

There would be no removal due to filtering.

Examples

Example 2.

The Stormy Lake TMDL study identified that the annual watershed phosphorus loadings to the lake need to be reduced by 321 pounds (or 65%). The Stormy Lake SWCD has an opportunity to work with Stormy County to install a rain garden (an infiltration system) that treats the stormwater from a 1/2-acre parking lot just upstream from the lake.

a) What is the current estimated phosphorus loading from the parking lot?
   Using UALs, 0.5ac x (1.1lb/ac-yr) = **0.6 lb/yr**
b) What is the predicted phosphorus load reduction from the rain garden?
   Load reduction = 0.6lb/yr x 0.75 = **0.5 lb/yr**
c) What percentage of the overall load reduction needed for the TMDL will the rain garden provide?
   (0.5 lb/yr) / (321 lb/yr) = **0.15%**

Examples

Example 3.

Impasse Creek is impaired for turbidity and the study found severe bank erosion as a major source of sediment. One of the parcels in the area contributing to the impairment has a slumping streambank that is 150 feet in length. The original bank height was 6 feet. The landowner chose to armor the toe of the streambank, pull the slope of the bank back to a 2:1 ratio and re-vegetate the streambank with native shrubs and grass. Calculate the reduction in sediment and nutrients from the streambank stabilization.

TSS reduction = 6ft x 0.4ft/yr x 150ft x 85lb/cf x 1 T/2000lb = **15 T/yr**

TP reduction = **15 lb/yr**

Examples

Example 4.

A water and sediment control basin is being installed on a gully that is 20 feet from the county drainage ditch. The original gully was formed over the last 3 years and is 3 feet wide at the top, 3 feet deep, 2 feet wide and 55 linear feet long. Calculate the sediment and nutrient reductions for this practice.

TSS reduction = 3ft x ([3ft+2ft]/2) x 55ft x 85lb/cf x 1 T/2000lb = 17.5 T
17.5T / 3yr = **6T/yr**
TP reduction = **6lb/yr**

TSS reduction = 6T/yr x 0.5 = 3T/yr
TP reduction = 6T/yr x 0.4 = 2lb/yr

Examples

Example 5.

The Phineaus Lake Watershed District in southwest Minnesota is targeting 153 acres of cropland to be replaced with native grasses.

a) Calculate the sediment and phosphorus reductions for this project.

Using UALs,

TP = 153ac x 0.4 (lb/ac-yr) = 61 lb/yr, grassland = 153ac x 0.08 (lb/ac-yr) = 12lb/yr.
Reduction = 61 - 12 = **49 lb/yr**

TSS = 153ac x 2 (T/ac-yr) = 306T/yr, grassland = 153 a x 0.1 (T/ac-yr) = 15 T/yr
Reduction = 306 - 15 = **291 T/yr**

Using EMCs,

For cropland, TP = 26inches x [0.05 + (0.009 x 30)] x 0.32 mg/L x 153 ac x 0.2 = 81 lb/yr
For grassland, TP = 26inches x [0.05 + (0.009 x 4)] x 0.04 mg/L x 153 ac x 0.2 = 3 lb/yr
Reduction = 81 – 3 = **78lb/yr**

For cropland, TSS = 26inches x [0.05 + (0.009 x 30)] x 1362 mg/L x 153 ac x 0.2 = 173 T/yr
For grassland, TSS = 26inches x [0.05 + (0.009 x 4)] x 11 mg/L x 153 ac x 0.2 = 0.4 T/yr
Reduction = 173 – 0.4 = **173T/yr**

Examples

b) How would the numbers change (increase or decrease) if this project were in the Anoka Sand Plain?

If using UALs, no change.

If using EMCs, Rainfall would increase, Runoff Factor would decrease.

Using EMCs, TP = 29inches x [0.05 + (0.009 x 10)] x 0.32 mg/L x 153 ac x 0.2 = 40 lb/yr
For grassland, TP = 29inches x [0.05 + (0.009 x 4)] x 0.04 mg/L x 153 ac x 0.2 = 3 lb/yr
Reduction = 40 – 3 = **37lb/yr**

TSS = 29inches x [0.05 + (0.009 x 10)] x 1362 mg/L x 153 ac x 0.2 = 85 T/yr
For grassland, TSS = 29inches x [0.05 + (0.009 x 4)] x 11 mg/L x 153 ac x 0.2 = 0.4 T/yr
Reduction = 85 – 0.4 = **85T/yr**

Examples

Example 6.

Green Lake is impaired for phosphorus. Reacher County conducted a septic inventory around the lake and identified 5 imminent health threat systems along the lakeshore.

a) Calculate the phosphorus load to the lake from one IPTHS system.

0.84 (lb/person-yr) x 2.7 people/household = **2.3lb/yr**

b) Calculate the reduction in phosphorus from fixing the 5 identified septic systems.

0.45 (lb/person-yr) x 2.7 people/household x 5 = **6lb/yr**

Thank You