Regional measurement and modeling of the input and loss of sediment and nutrients from streambanks and floodplains: The Chesapeake watershed

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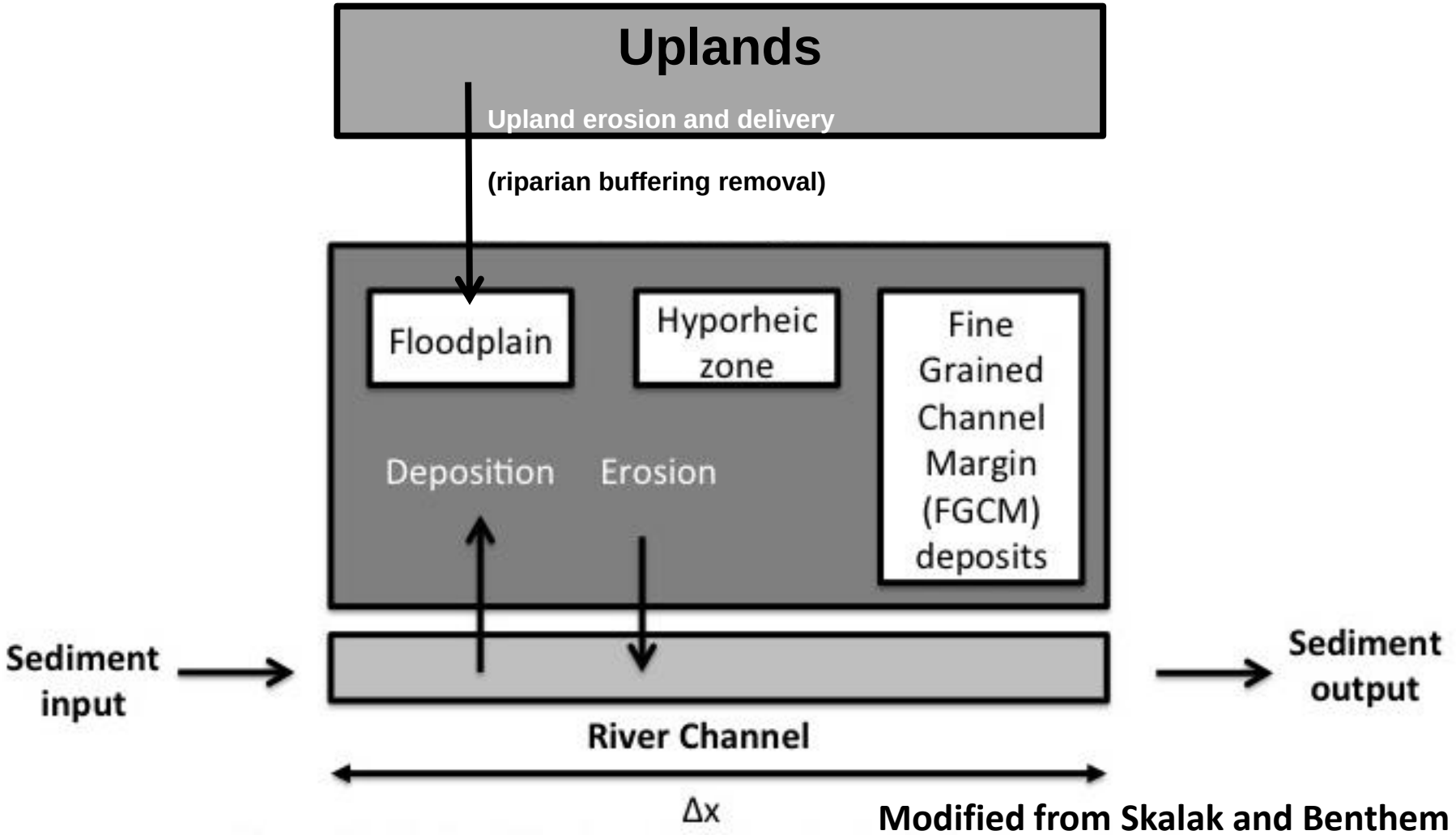
U.S. Department of the Interior
U.S. Geological Survey

Understanding and scaling transport processes thru watersheds

Alluvial sediment exchange



USGS

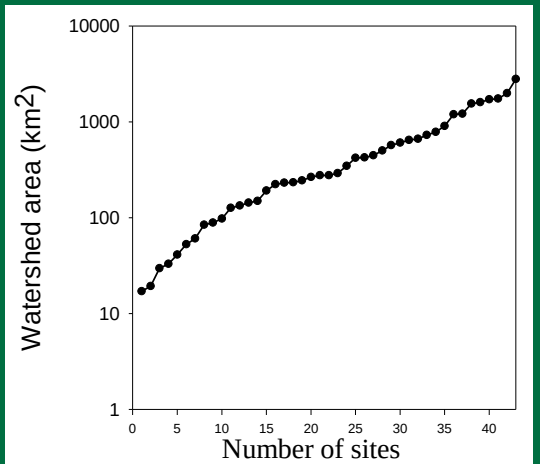
79% of P load and 28% of N load to Chesapeake Bay is particulate
(Noe and Hupp 2009, from Langland et al. 2006)

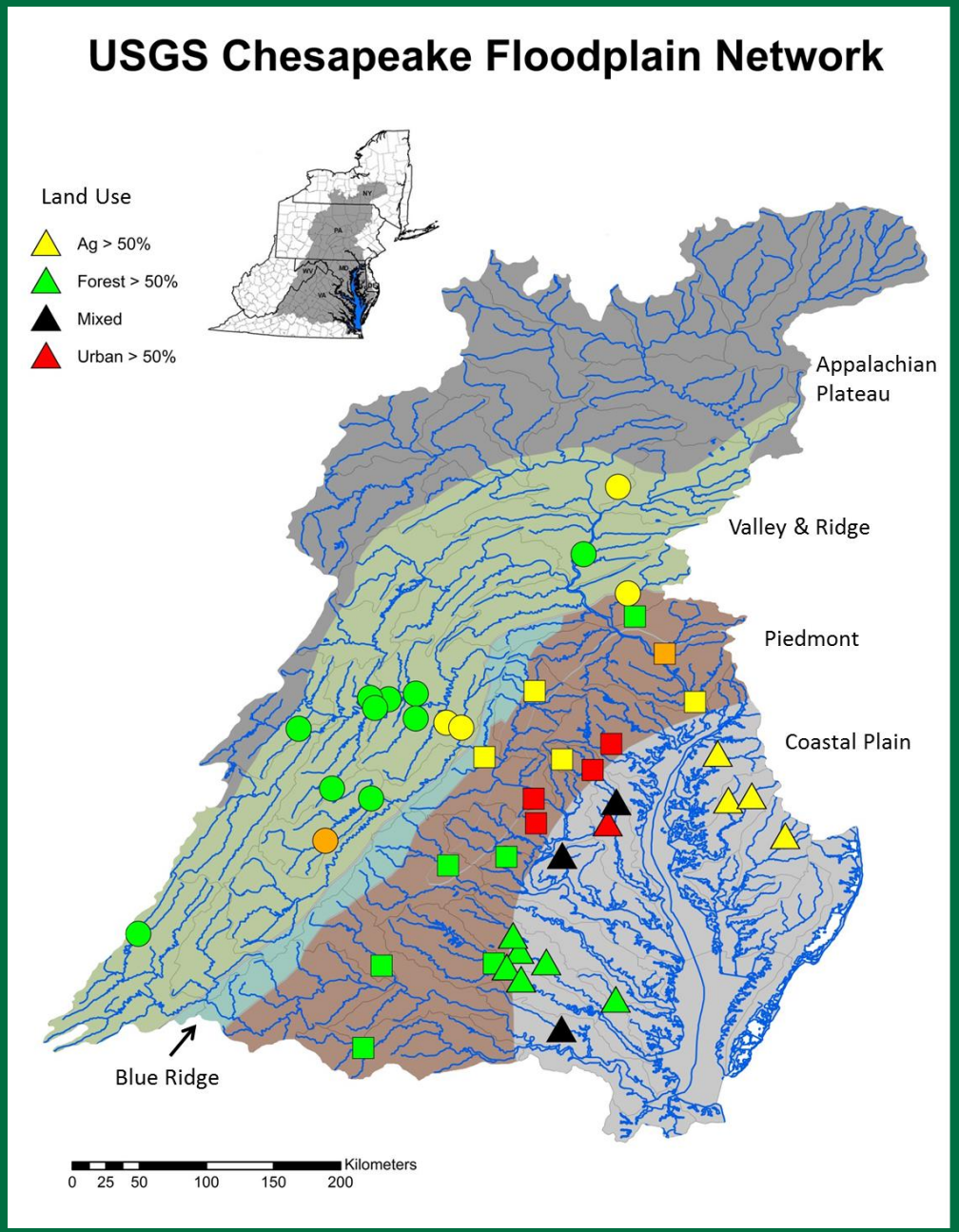
The USGS Chesapeake Floodplain Network: 43 sites

Goal:
Measure, predict, and scale the sediment/N/P fluxes of bank erosion and floodplain deposition for entire Chesapeake watershed

Long-term: dendrogeomorphology
Short-term: pins

Site selection:
- Chesapeake NTN load gages
- 'unmanaged' floodplain land use
- Unchannelized
- Landowner permission





Dendrogeomorphic method

Flux calculations:

$g\ m^{-1}\ yr^{-1}$

Floodplain: vertical change rate * bulk density * total floodplain width
($m\ yr^{-1}$) ($g\ cm^{-3}$) (m)

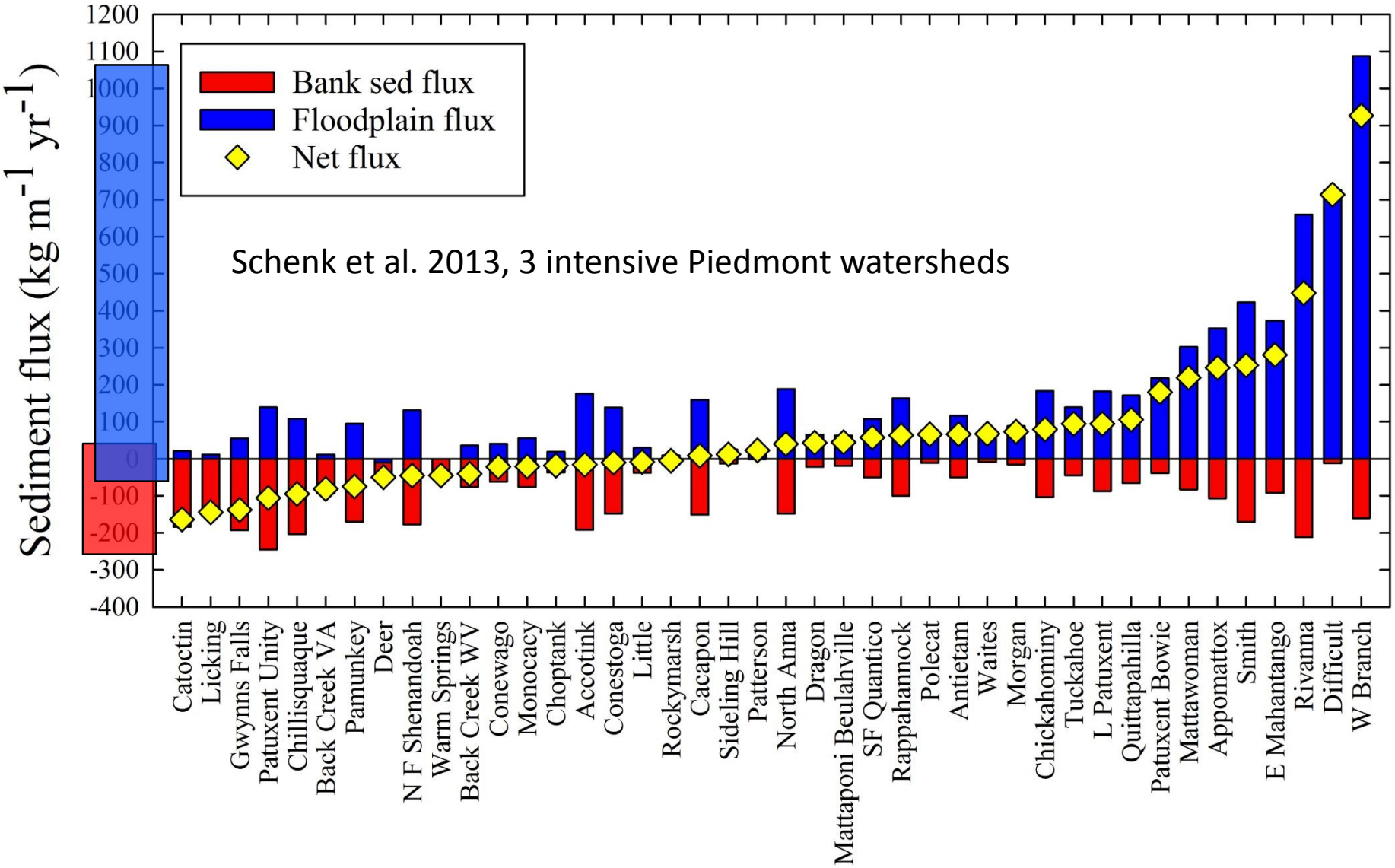
Bank: lateral change rate * bulk density * bank height * 2 * correction

Net balance: Floodplain flux – Bank flux

USGS Chesapeake Floodplain Network:

Dendrogeomorphic results all 3 PP

Mean ages of trees:
floodplain = 48 yr
bank = 17 yr root exposed



USGS Chesapeake Floodplain Network:

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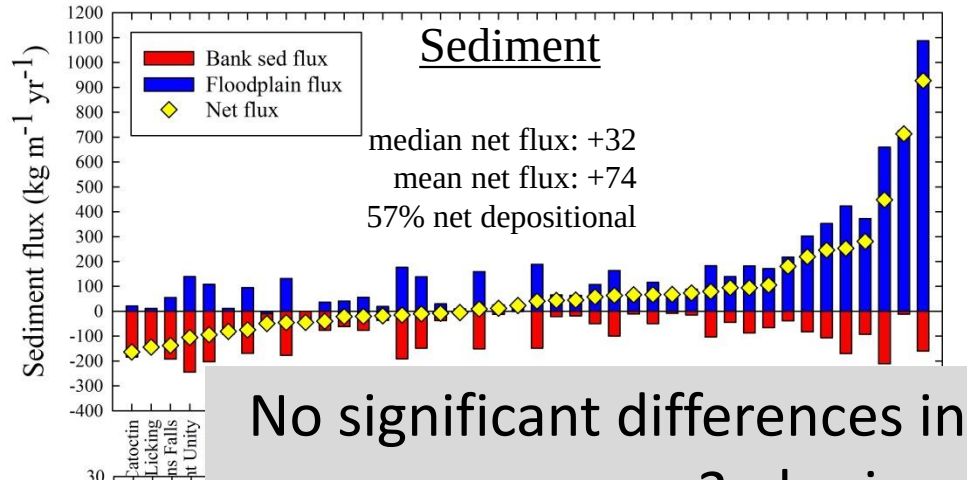
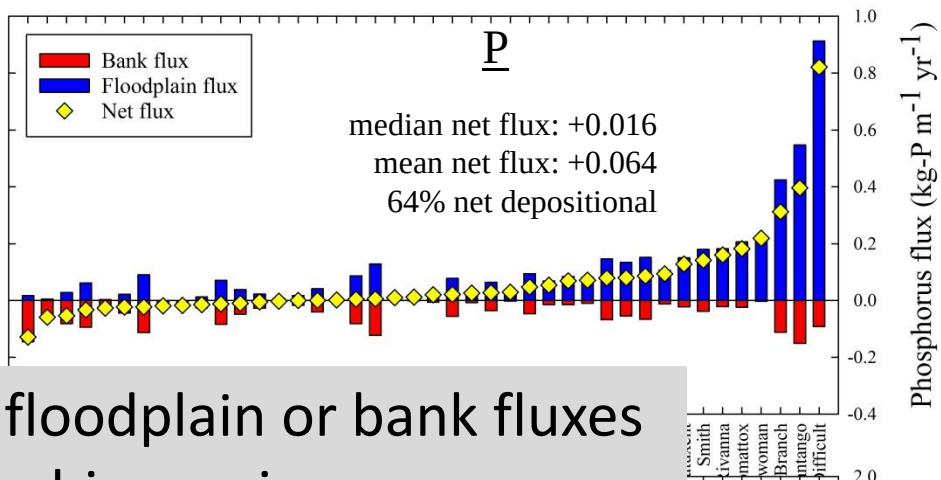
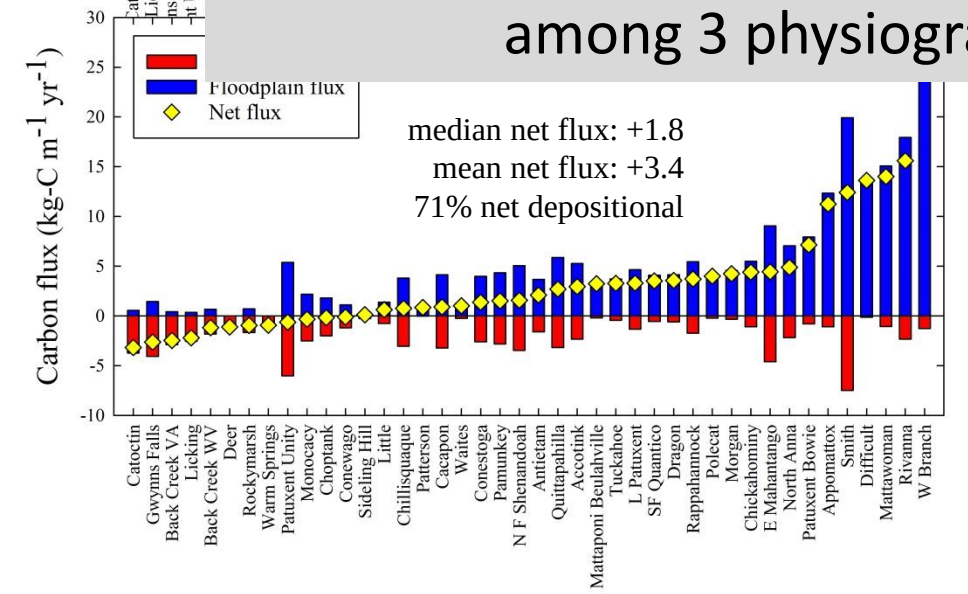
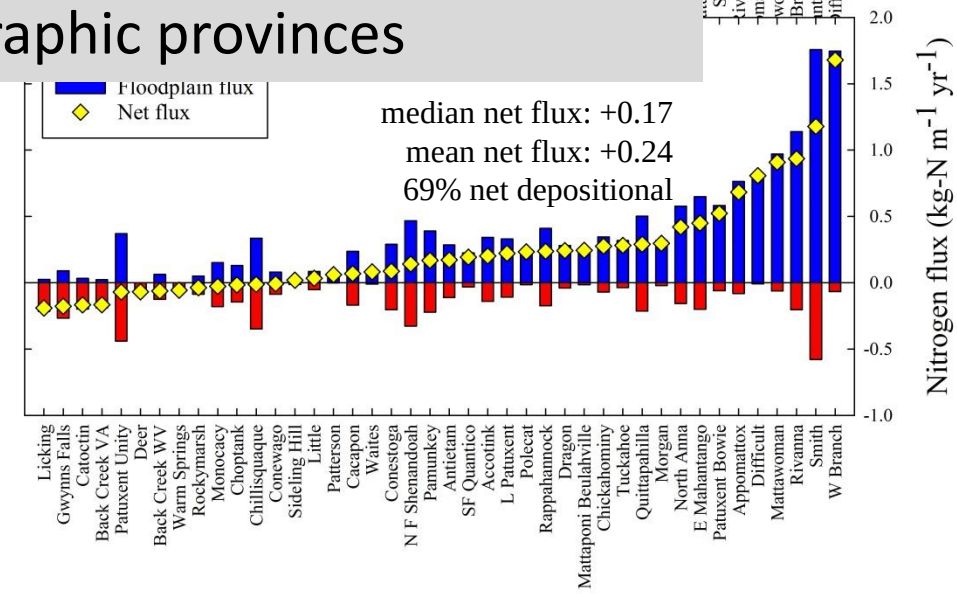




No significant differences in floodplain or bank fluxes among 3 physiographic provinces

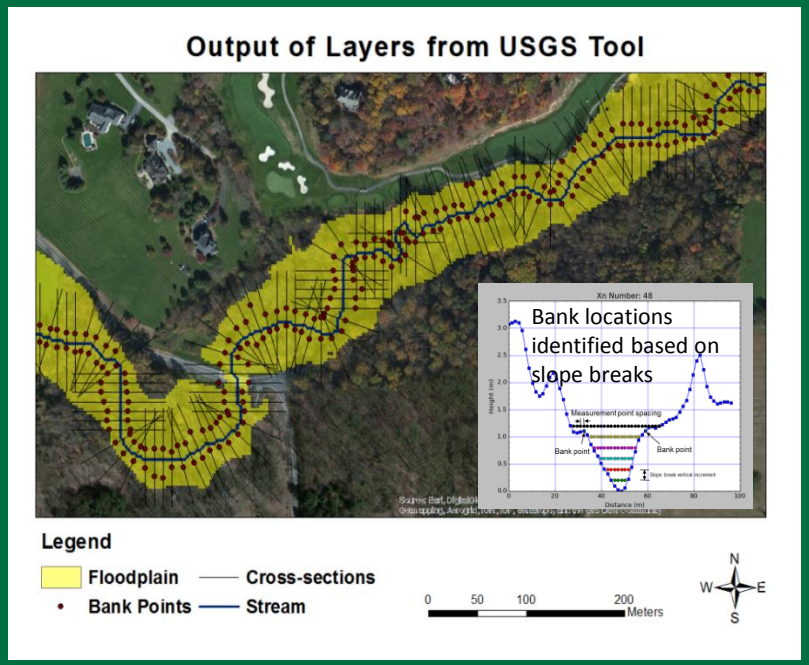




USGS Stream Channel and Floodplain Metric Toolbox v1.3

Channel Cross-section Metrics
- Bank height
- Bank angle
- Channel width
- Channel length
- Bankfull area
- Floodplain width
- Floodplain elevation range
- Floodplain elevation StdDev
- Ratios of bank, floodplain, and channel

Stream Reach Metrics
- Length
- Profile slope
- Order
- Drainage area



GIS watershed attributes

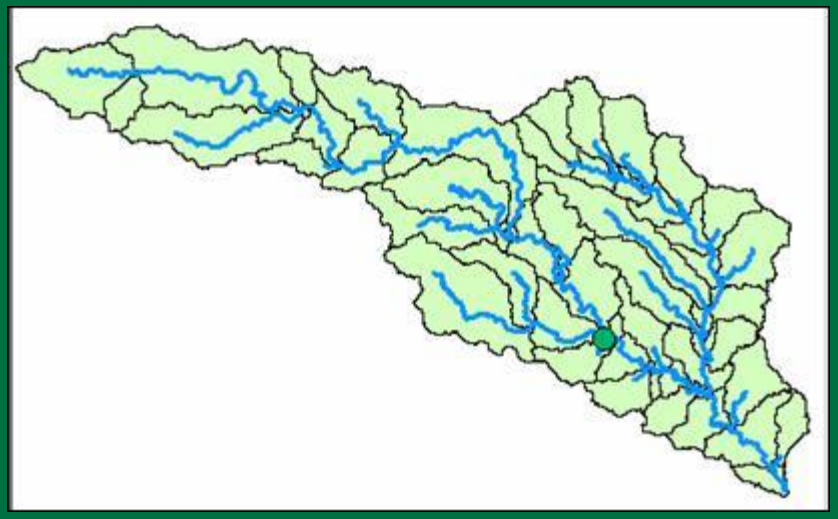
Land Use
- Developed 1974 land use
- Developed 2012 land use
- Production 1974 land use
- Production 2012 land use
- Change developed land use 2012-1974
- Change production land use 2012-1974
- Crop Phase6
- Pasture Phase6
- Forest Phase6
- Roads impervious cover Phase6
- Housing density 2010

Hydrology
- Dam drainage density
- Precipitation
- Evapotranspiration
- Base flow index

Soils
- K factor
- LS factor
- Ksat
- Horton flow index

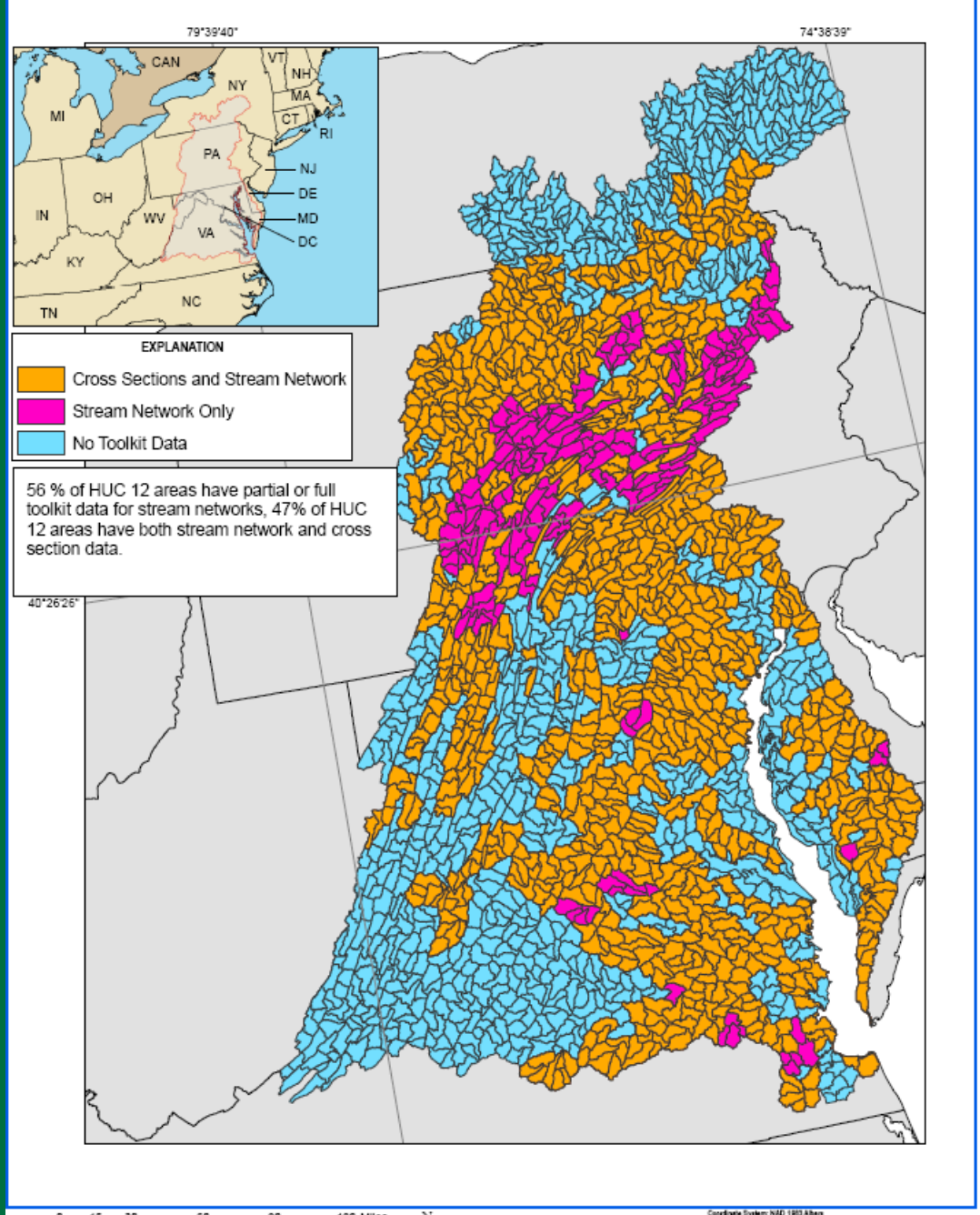
Topography
- Watershed area
- Topographic wetness index

Upland erosion
- Net upland erosion
- Sediment delivered to stream



USGS GIS Geomorphic Toolkit: status 8/29/16

Fluvial geomorphic measures have been extracted for 47% of HUC12s



Fluxes are predictable!

Backward stepping multiple regressions (*P*-to-remove=0.10):

Bank sediment flux

Watershed only:

R^2=0.45

Model terms	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	633.628	206.336		3.071	0.004		
Pasture	-325.143	81.555	-0.561	-3.987	0.000	0.756	1.324
Precipitation	-0.40022	0.168	-0.33	-2.375	0.023	0.774	1.292
Base Flow Index	-343.458	129.582	-0.337	-2.651	0.012	0.925	1.081
Horton overland flow	-20735.9	5701.391	-0.453	-3.637	0.001	0.962	1.039

Watershed + Reach:

R^2=0.86

Model terms	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	3379.971	577.916		5.849	0.000		
Crop	-887.657	277.161	-1.862	-3.203	0.006	0.026	38.687
Pasture	-1519.86	328.683	-2.783	-4.624	0.000	0.024	41.471
Forest	-1080.2	281.797	-3.508	-3.833	0.001	0.01	95.865
Dam drainage density	68.01	27.894	0.384	2.438	0.027	0.352	2.837
Base Flow Index	-359.503	144.835	-0.352	-2.482	0.025	0.435	2.298
Soil k-saturation	-0.00012	0	-1.054	-3.825	0.001	0.115	8.693
Evapotranspiration	-1.857	0.398	-0.939	-4.664	0.000	0.216	4.64
Topographic wetness index	-89.906	37.418	-0.508	-2.403	0.029	0.196	5.113
2012-1974 developed	383.112	205.616	0.446	1.863	0.081	0.152	6.567
Developed 2012	-1879.82	434.696	-5.94	-4.324	0.001	0.005	216.044
Housing density 2010	0.065127	0.025	1.413	2.606	0.019	0.03	33.686
Sediment delivery to stream	-227.398	69.774	-0.541	-3.259	0.005	0.317	3.155
Slope	5494.143	2679.86	0.256	2.05	0.057	0.562	1.779
Bank height	-52.512	21.693	-0.651	-2.421	0.028	0.121	8.268
Channel width	2.38	0.924	0.649	2.575	0.020	0.137	7.284
Floodplain width	-0.813	0.164	-0.982	-4.969	0.000	0.224	4.471
Bank:floodplain	9456.012	1943.308	2.537	4.866	0.000	0.032	31.121
Channel:floodplain	-551.818	107.326	-2.761	-5.142	0.000	0.03	33.027
Bank:channel	-3174.86	1030.068	-1.048	-3.082	0.007	0.076	13.231

USGS

Fluxes are predictable!

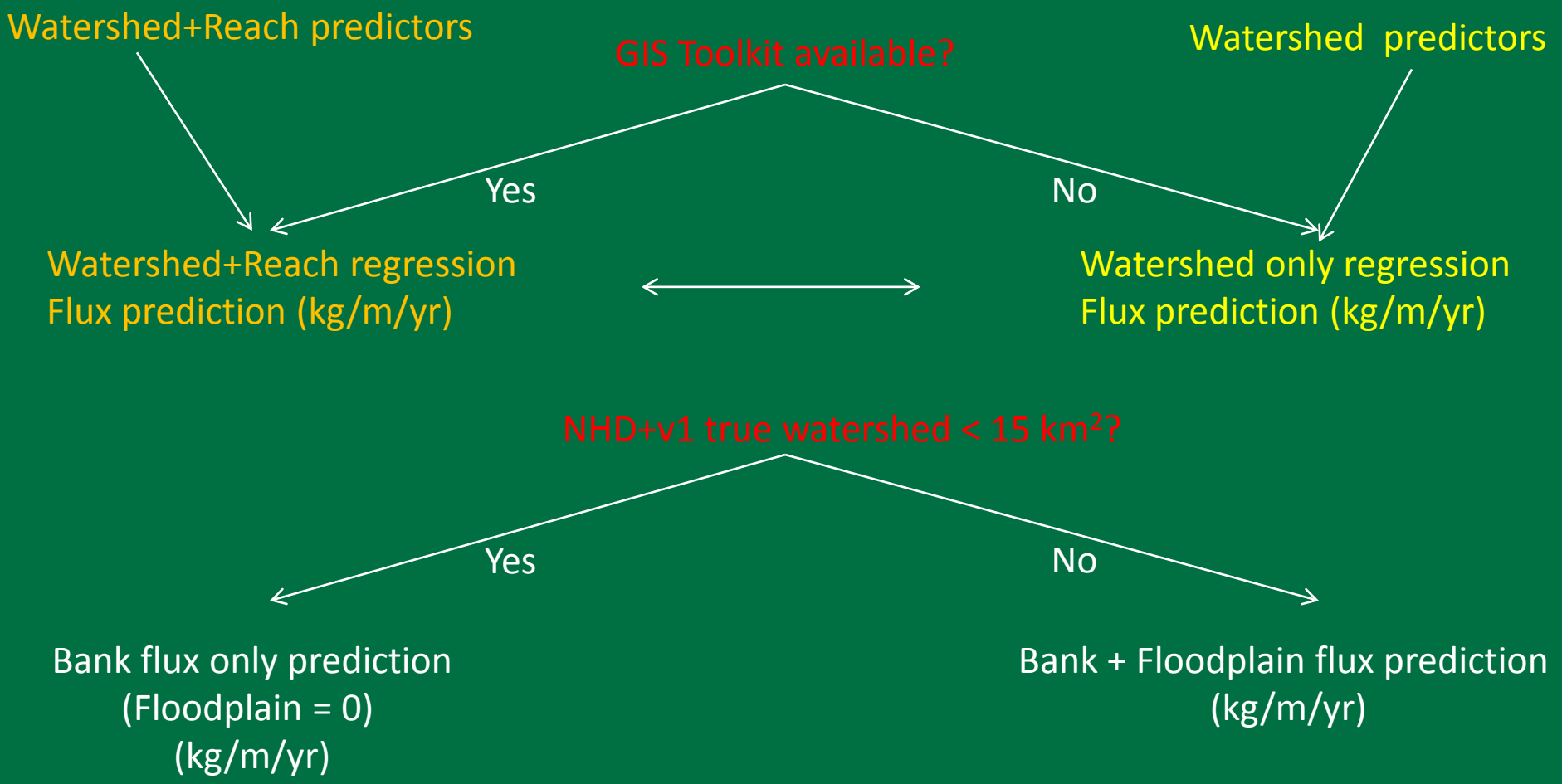
Backward stepping multiple regressions (*P*-to-remove=0.10):

Flux	R^2 Watershed only	# predictors Watershed only	R^2 Watershed + Reach	# predictors Watershed + Reach
Bank Sediment	0.45	4	0.86	19
Bank Sediment < 63 um	0.45	4	0.85	17
Bank P	0.52	6	0.88	18
Bank N	0.38	2	0.93	20
Bank C	0.49	5	0.92	17

Flux	R^2 Watershed only	# predictors Watershed only	R^2 Watershed + Reach	# predictors Watershed + Reach
Floodplain Sediment	0.41	5	0.78	17
Floodplain Sediment < 63 um	0.43	6	0.57	10
Floodplain P	0.35	5	0.48	7
Floodplain N	0.34	5	0.64	13
Floodplain C	0.40	5	0.71	16

P<0.0096

Workflow



Every NHD+v1 reach:

Bank Flux (kg/m/yr) x Stream length (m) = Load (kg/yr)

Floodplain Flux (kg/m/yr) x Stream length (m) = Load (kg/yr)

USGS

Fluxes to be extrapolated to 80,000 NHD+ v1 digital stream reaches

Goal:

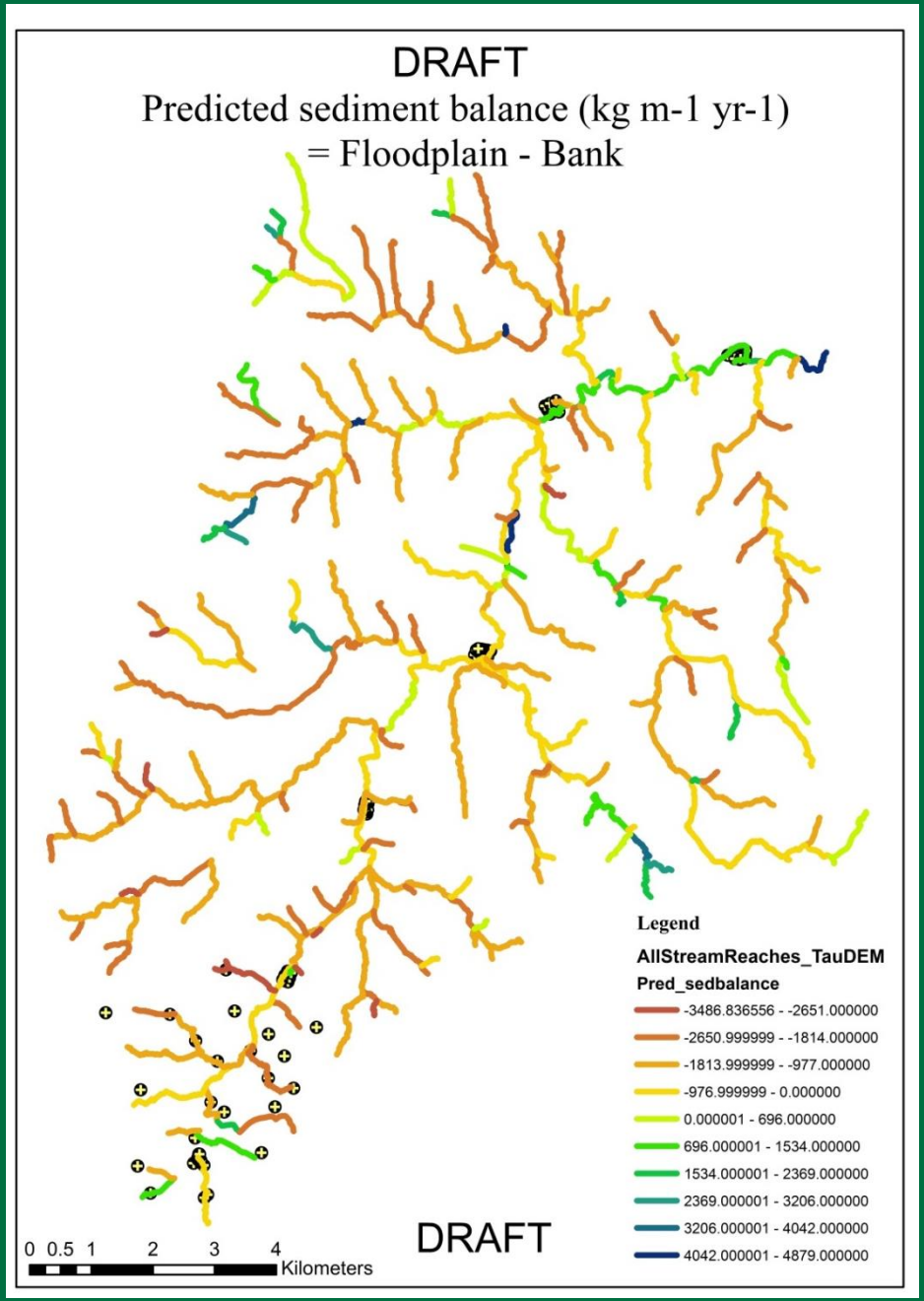
Sediment, P, N, and C loads to CBP imminently

<u>Online viewer to visualize and download for each reach</u>:

Channel characteristics

Bank flux (sediment, P, N, C)

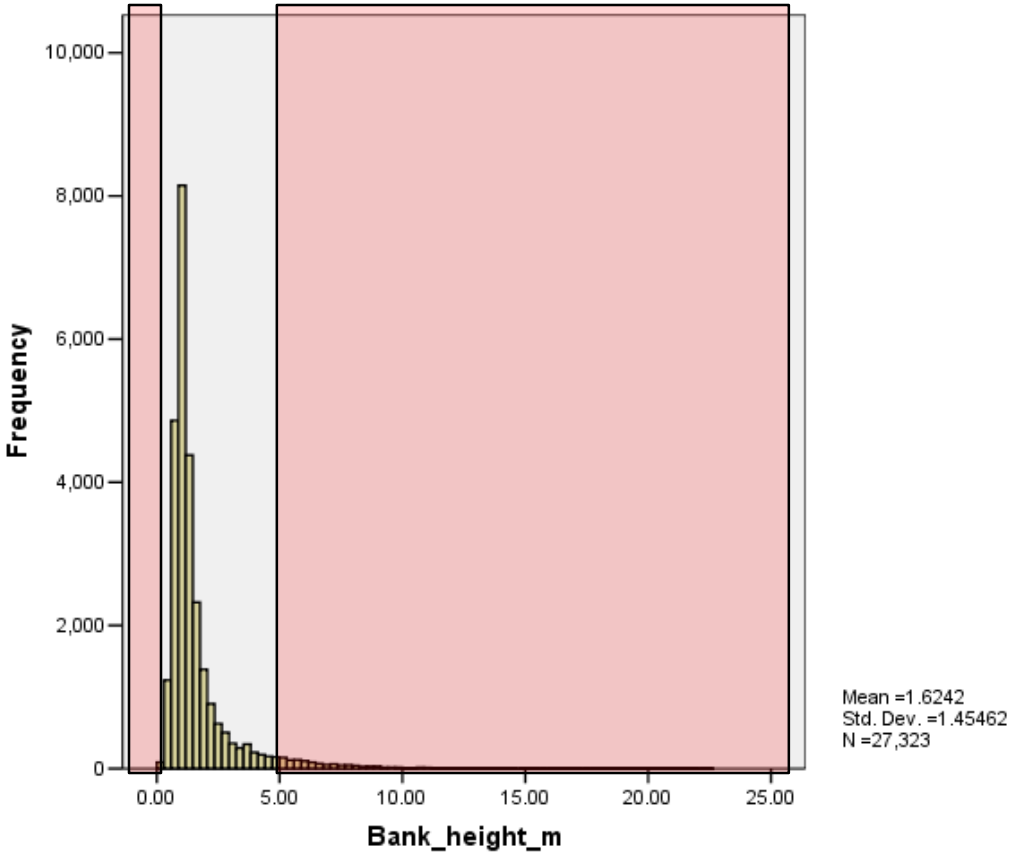
Floodplain flux (sediment, P, N, C)

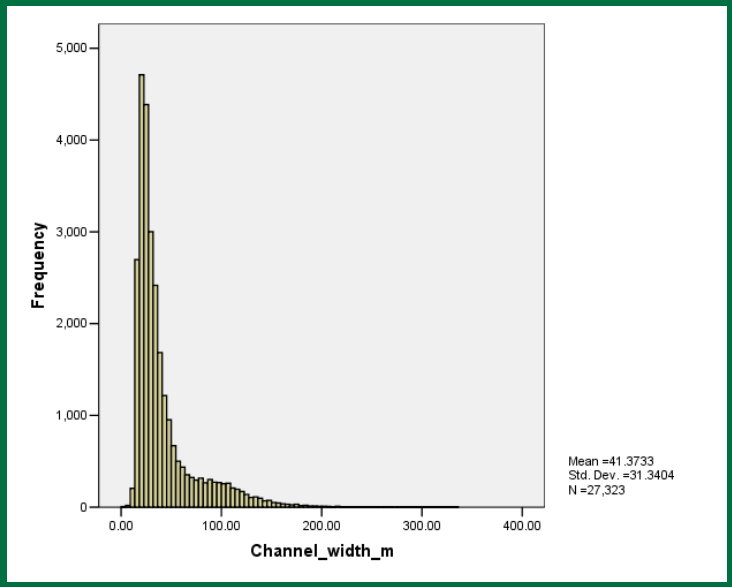


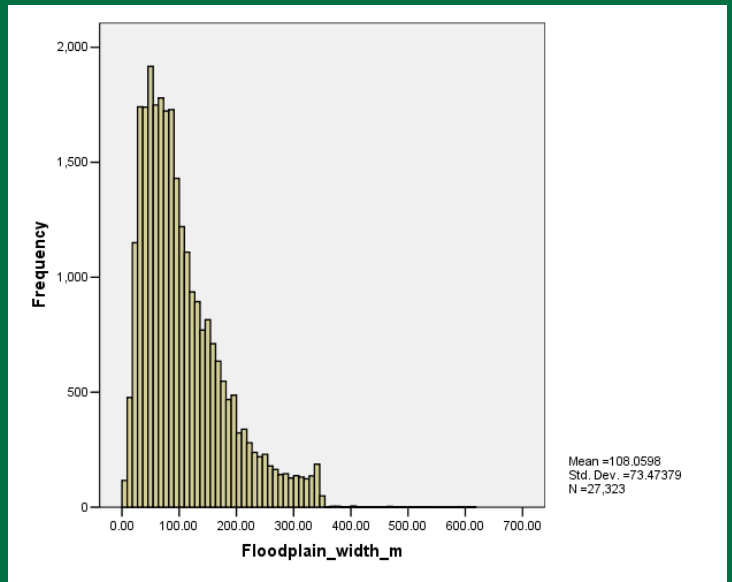
GIS geomorphology:

Distribution of Chesapeake alluvial geometry

average 1.8 km long NHD+ v1 reach







USGS

Sediment Fluxes and Budgets of Simulated Rivers

Edge-Of-Field Erosion
RUSLE2

Sediment Delivery Ratio:
Borselli et al., 2008
Cavalli et al., 2013 & 2014

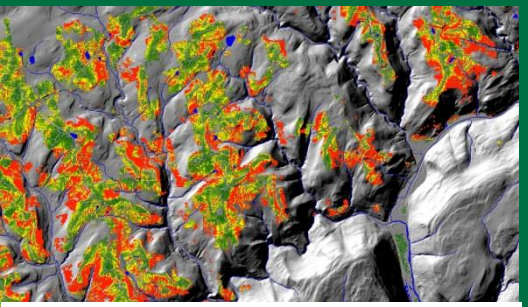
Bank Erosion and Floodplain Deposition:
Extrapolated CFN

Soil Loss

Sediment Transport

Floodplain deposition

Bank erosion



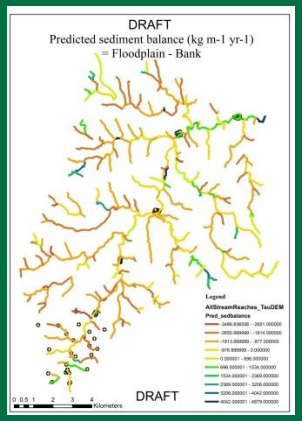
RUSLE2_Pasture
0-4 tons/acre/month(April)

$$D_{dn} = \sum_i \frac{d_i}{W_i S_i}$$

Path length

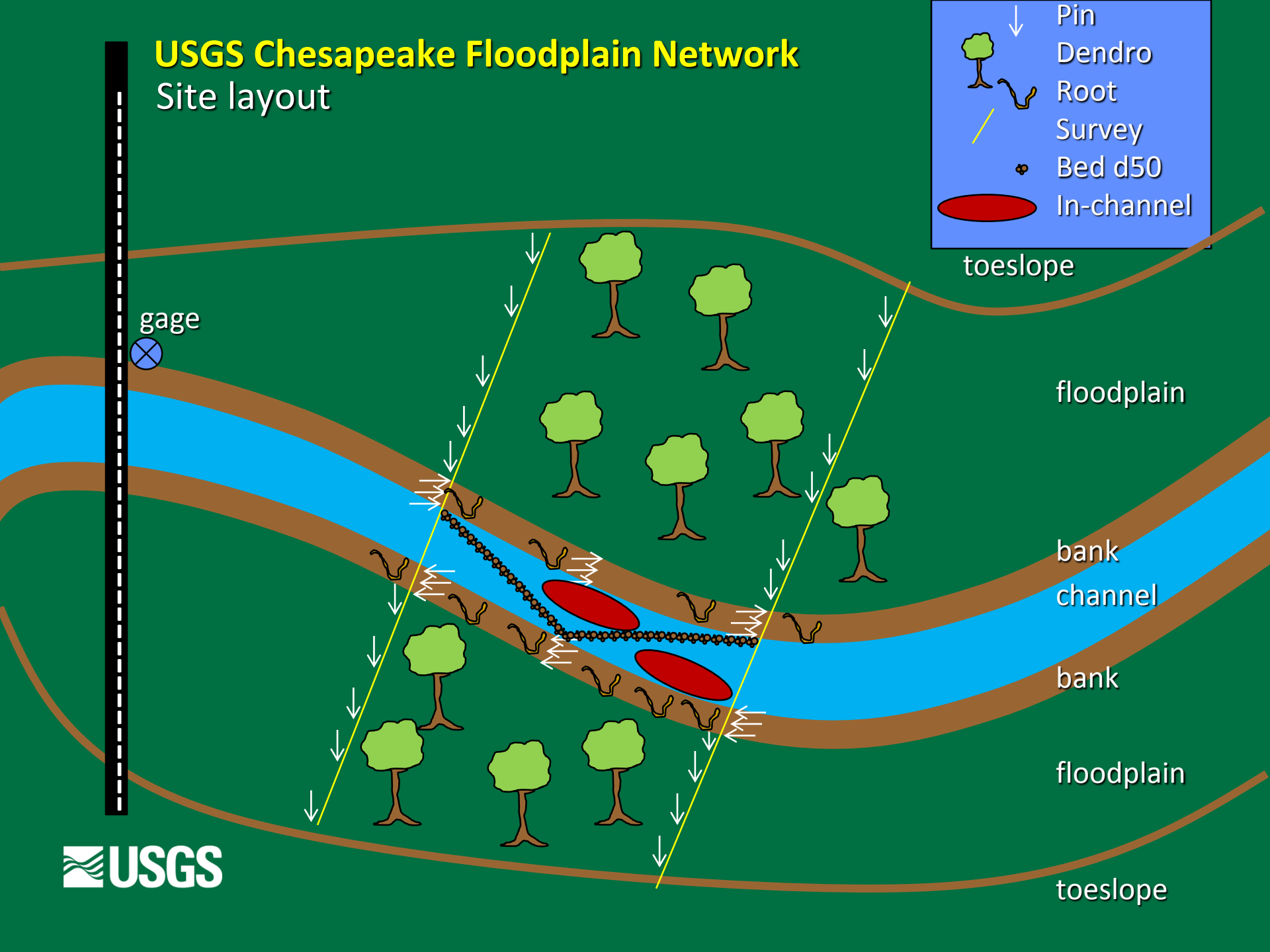
Relative surface roughness

Slope gradient

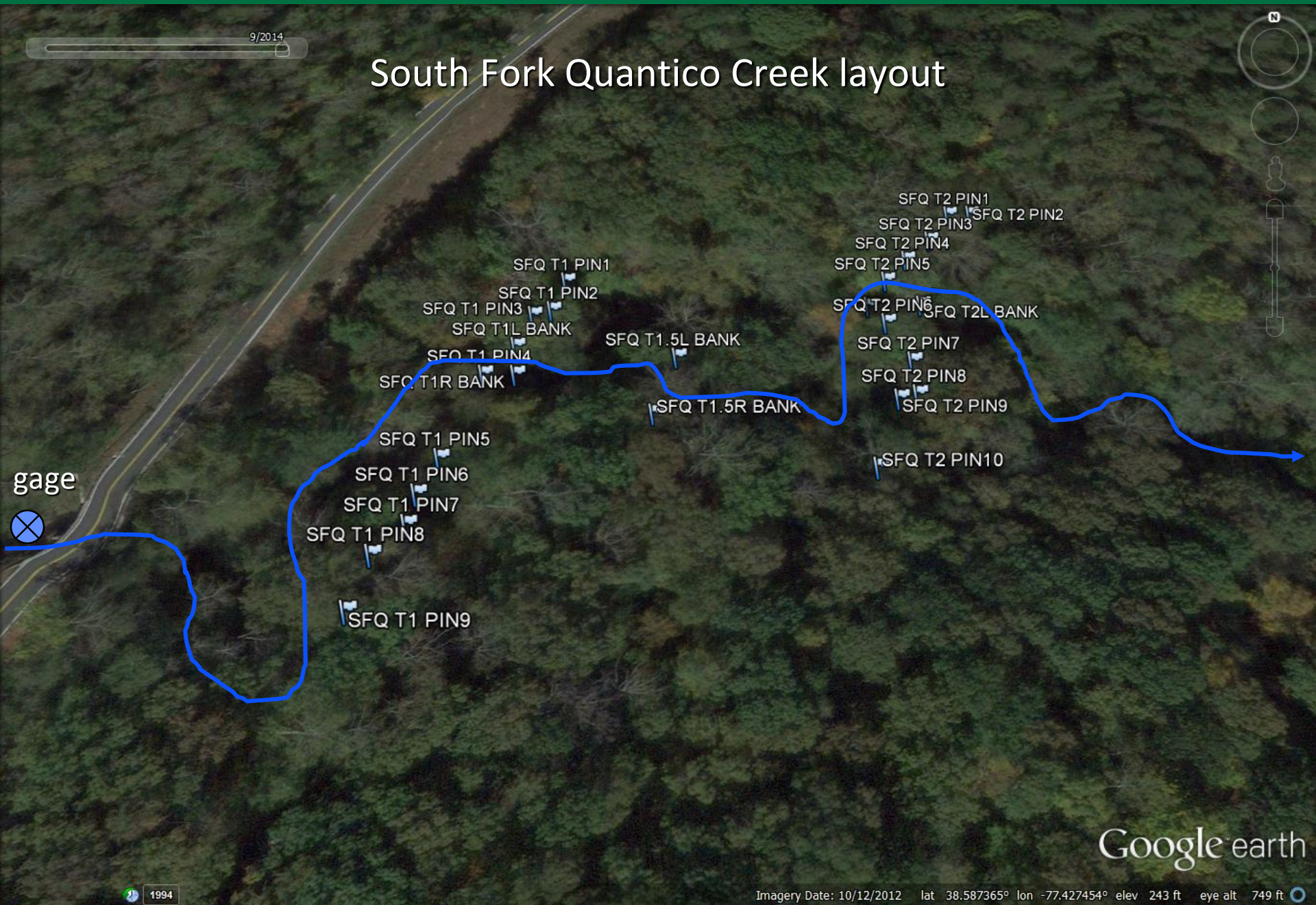


USGS

Adapted from:
http://www.ars.usda.gov/Research/docs.htm?docid=6016

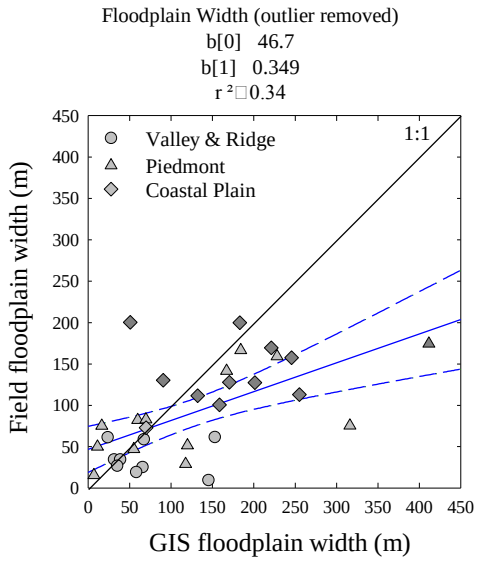

USGS Chesapeake Floodplain Network
Site layout
Pin
Dendro
Root
Survey
Bed d50
In-channel
toeslope
gage
floodplain
bank
channel
bank
floodplain
toeslope
USGS

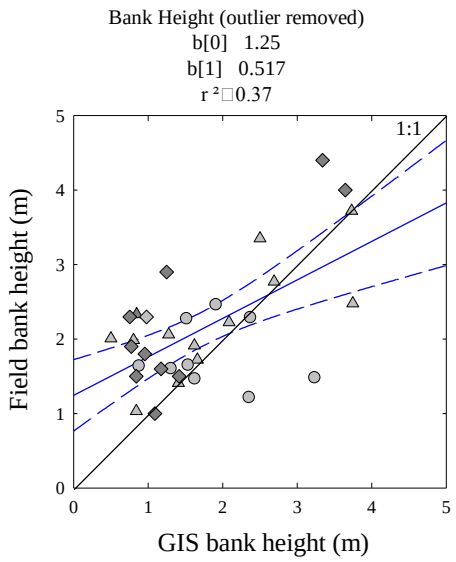
USGS Chesapeake Floodplain Network: example site

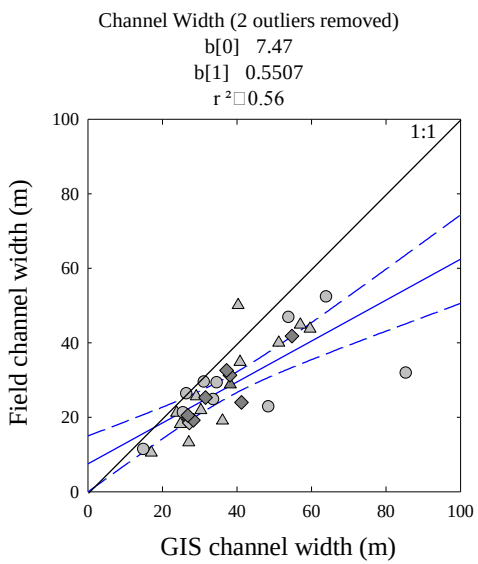


Measured vs. GIS geomorphology: evaluating Toolkit performance

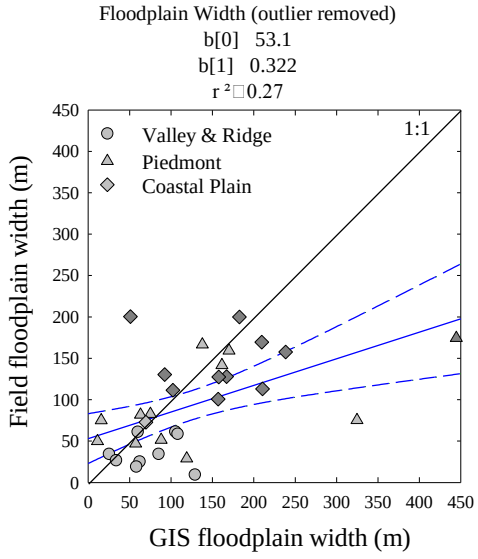
Cross section -scale

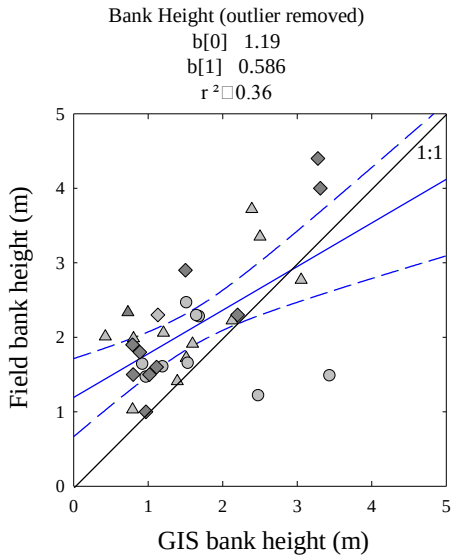


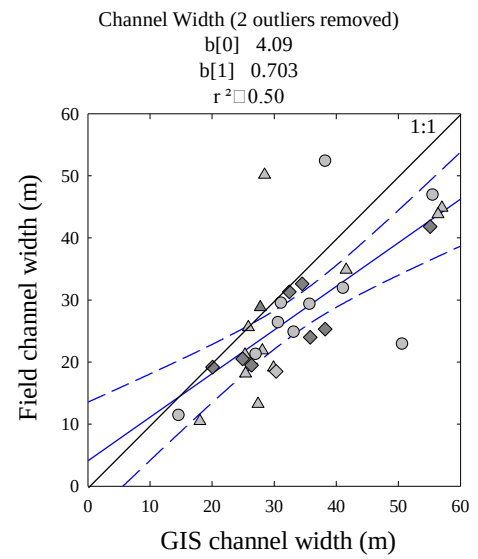




Reach-scale



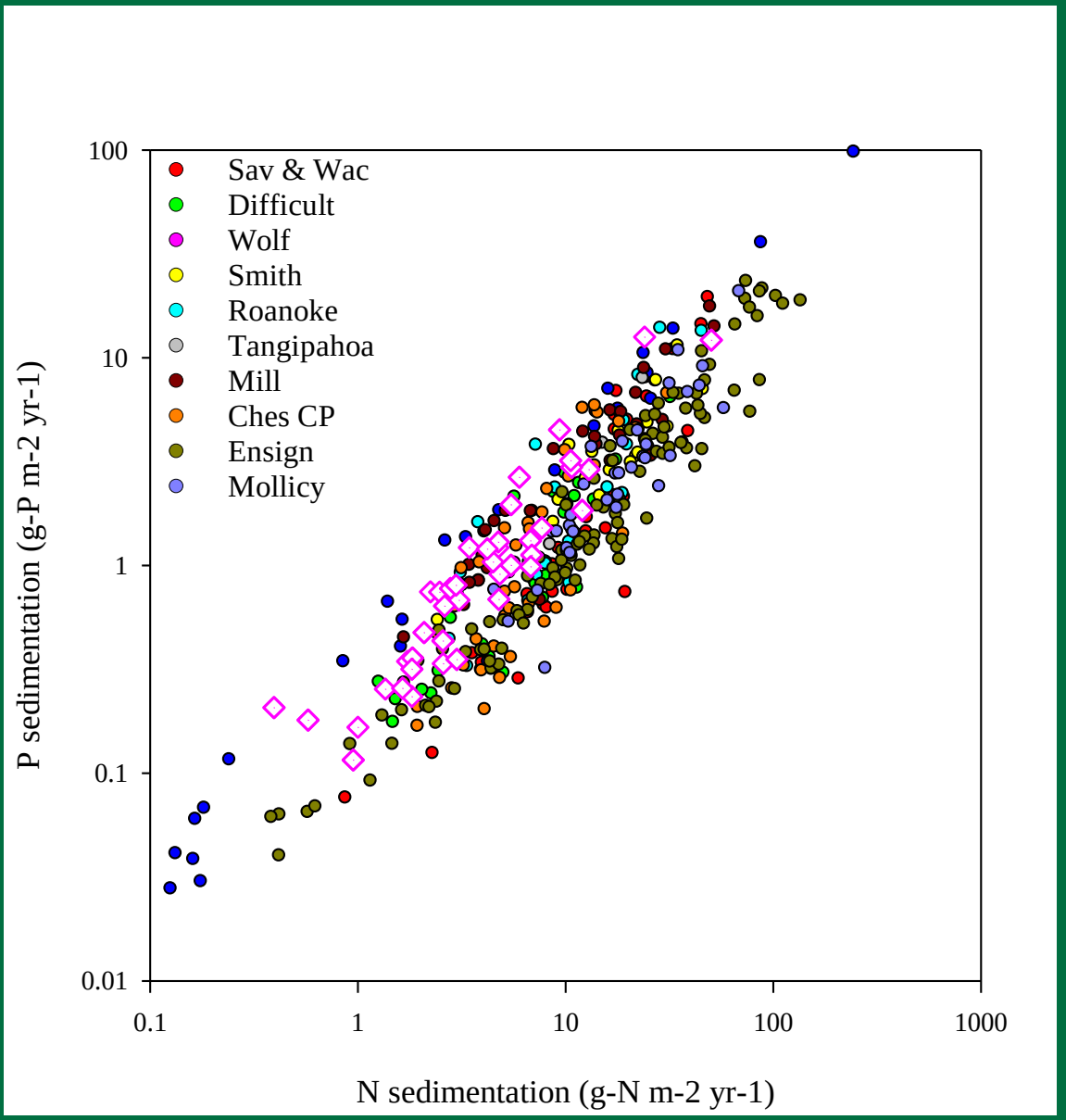




USGS

USGS Chesapeake Floodplain Network vs. other studies

Floodplain flux rates are typical



USGS

Floodplain inundation history:
Relating floodplain x-section topography to river gage

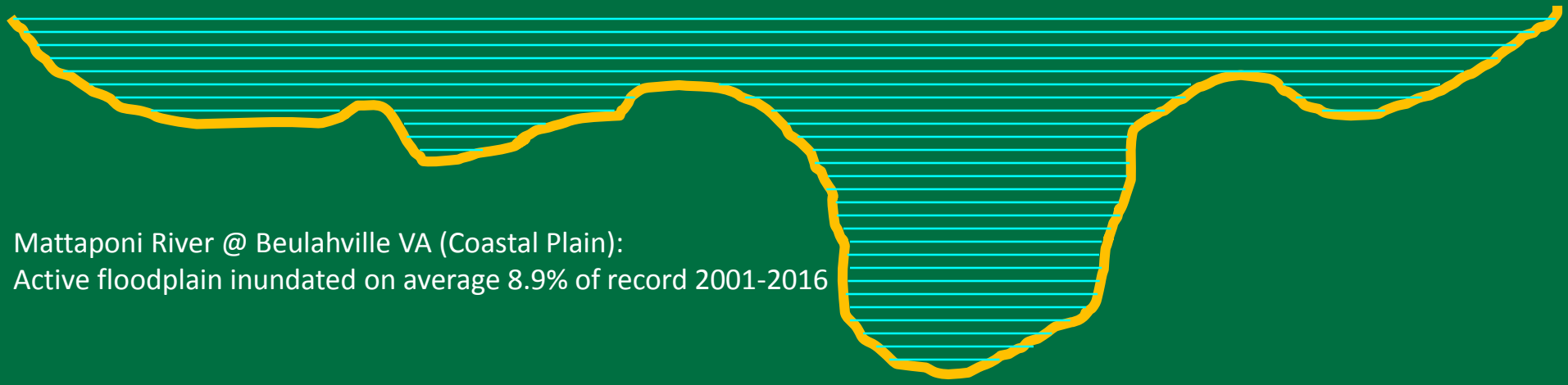
15 min gage height/discharge record (period of record)

+

2 floodplain elevation x-sections tied into gage

=

Long-term duration, frequency, and magnitude of overbank inundation of floodplain



Mattaponi River @ Beulahville VA (Coastal Plain):
Active floodplain inundated on average 8.9% of record 2001-2016

USGS