How to model sediment and nutrient fluxes of floodplains and streambanks across the Chesapeake watershed

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The USGS Chesapeake Floodplain Network: 42 full sites

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

Site selection:
- Chesapeake NTN load gages
- ‘unmanaged’ floodplain land use (forest/scrub/herbaceous; not ag/pasture/developed)
- Unchannelized
- Landowner permission
- Range of watershed size and land-use

USGS Chesapeake Floodplain Network

1. Measure
2. Predict
3. Scale
USGS GIS Toolkit
Reach Geomorphology: LiDAR availability

~ 80% of Chesapeake watershed has available LiDAR

Coastal Plain analyzed by Spring 2016

Appalachian Plateau low quality

Remaining SW VA/WV planned September 2016
Mean ages of trees:
floodplain = 48 yr
bank = 17 yr root exposed
Approaches for predicting the whole Chesapeake watershed

Valley & Ridge, Piedmont, and Coastal Plain

- **OPTION #1** Average: all 3 PP
- **OPTION #2** Average: each PP
- **OPTION #3** Regression: Watershed+Reach predictors
- **OPTION #4** Regression: Watershed only predictors (where GIS Toolkit unavailable)

Appalachian Plateau and Blue Ridge

- **OPTION #1** Average: PP of CFN
- **OPTION #3** Regression: Watershed+Reach predictors
- **OPTION #4** Regression: Watershed only predictors (where GIS Toolkit unavailable)
### USGS Chesapeake Floodplain Network:

**Dendrogeomorphic fluxes of all 3 PP**

<table>
<thead>
<tr>
<th>Flux (kg/m/yr)</th>
<th>Mean</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net Balance:</strong></td>
<td>74.3</td>
<td>9.1 to 139.6</td>
<td>&lt;0.027</td>
</tr>
<tr>
<td><strong>Floodplain:</strong></td>
<td>167.6</td>
<td>100.1 to 235.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Bank:</strong></td>
<td>-93.3</td>
<td>-114.8 to -71.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Net Balance:</strong></td>
<td>0.240</td>
<td>0.118 to 0.361</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Floodplain:</strong></td>
<td>0.377</td>
<td>0.250 to 0.505</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Bank:</strong></td>
<td>-0.138</td>
<td>-0.176 to -0.010</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Net Balance:</strong></td>
<td>0.064</td>
<td>0.015 to 0.112</td>
<td>&lt;0.011</td>
</tr>
<tr>
<td><strong>Floodplain:</strong></td>
<td>0.110</td>
<td>0.057 to 0.162</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Bank:</strong></td>
<td>-0.046</td>
<td>-0.059 to -0.033</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
### USGS Chesapeake Floodplain Network:
Comparing fluxes of all 3 PP

Kruskal-Wallis tests comparing Valley & Ridge, Piedmont, and Coastal Plain

<table>
<thead>
<tr>
<th></th>
<th>Sediment</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Net Balance</td>
<td>$P$</td>
<td>Net Balance</td>
</tr>
<tr>
<td>Sediment</td>
<td>Floodplain</td>
<td>0.262</td>
<td>Sediment</td>
</tr>
<tr>
<td></td>
<td>Bank</td>
<td>0.190</td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Floodplain</td>
<td>0.115</td>
<td>Mineral sediment</td>
</tr>
<tr>
<td></td>
<td>Bank</td>
<td>0.138</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Floodplain</td>
<td>0.055</td>
<td>Carbonate sediment</td>
</tr>
<tr>
<td></td>
<td>Bank</td>
<td>0.249</td>
<td></td>
</tr>
</tbody>
</table>

Root age since exposure also differed ($P=0.008$):
- Valley & Ridge: 26 yr
- Piedmont: 12 yr
- Coastal Plain: 12 yr

Coastal Plain > Piedmont = Valley & Ridge
### USGS Chesapeake Floodplain Network:
Comparing fluxes of all 3 PP

<table>
<thead>
<tr>
<th>Location</th>
<th>Flux (kg/m/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valley &amp; Ridge</td>
<td>1.27</td>
</tr>
<tr>
<td>Piedmont</td>
<td>3.19</td>
</tr>
<tr>
<td>Coastal Plain</td>
<td>6.34</td>
</tr>
<tr>
<td>Carbon</td>
<td></td>
</tr>
<tr>
<td>Valley &amp; Ridge</td>
<td>.129</td>
</tr>
<tr>
<td>Piedmont</td>
<td>.192</td>
</tr>
<tr>
<td>Coastal Plain</td>
<td>.438</td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
</tr>
<tr>
<td>Valley &amp; Ridge</td>
<td>.0275</td>
</tr>
<tr>
<td>Piedmont</td>
<td>.0458</td>
</tr>
<tr>
<td>Coastal Plain</td>
<td>.1306</td>
</tr>
<tr>
<td>Phosphorus</td>
<td></td>
</tr>
</tbody>
</table>

**Net balance:**

- Coastal Plain > Piedmont = Valley & Ridge
Regressions: Predictors of flux

Geomorphology, hydrology, land use, sediment, nutrients, ...

Wall-to-wall

- Watershed characteristics
- Topography
- Geology
- Climate
- Hydrology
- Land use
- Soils
- Nutrient application
- River load
- Geomorphology

+ Reach geomorphology

- Floodplain
- Bank
- Channel

Patchy availability

USGS
Catchment + reach predictors of flux

**Gages2**
- Area
- Elevation median
- Dimensionless elevation - relief ratio
- Slope
- Precipitation
- Base Flow Index
- Horton overland flow %
- Topographic wetness index
- Subsurface flow contact time index
- Soil permeability
- Soil R-factor rainfall/runoff
- Soil K-factor erodibility upper horizon
- Dam density 2009
- Dam storage 2009

**NAWQA**
- % Developed 1974
- % Developed 2012
- % Production 1974
- % Production 2012
- ΔDeveloped 2012-1974

**Loads**
- SPARROW sed load
- SPARROW P load
- SPARROW N load
- SPARROW sed yield
- SPARROW P yield
- SPARROW N yield

**Reach Geomorphology (USGS GIS Toolkit)**
- Floodplain width
- Channel width
- Bank height
- Bank angle (mean, max, min)
- Bankfull
- Slope
- Various ratios and products

**USGS NTN**
- Q50
- Q90
- Q99
- Q50 yield
- Q90 yield
- Q99 yield
- Q50 ‘watershed power’
- Q90 ‘watershed power’
- Q99 ‘watershed power’

**Physiographic Province**
- Valley & Ridge = 1
- Piedmont = 1
- Coastal Plain = 1

**Physiographic Province**
- Valley & Ridge = 1
- Piedmont = 1
- Coastal Plain = 1
### Fluxes are predictable: Watershed + Reach GIS-derived predictors

Stepwise multiple regressions ($P$-to-enter=0.10):

#### Sediment: net balance
- $n=31$, $R^2=0.61$, $P<0.001$
  - $FP\_width:Bnk\_height$: $\beta=+$
  - $FP\_width:Ch\_width$: $\beta=-$
  - K factor erodibility uppersoil: $\beta=+$
  - Soil permeability avg: $\beta=+$
  - Elevation-Relief Ratio: $\beta=-$

#### Nitrogen: net balance
- $n=31$, $R^2=0.70$, $P<0.001$
  - $\Delta$Developed 2012-1974: $\beta=+$
  - Horton Overland Flow %: $\beta=-$
  - K factor erodibility uppersoil: $\beta=+$
  - $Sed\_load\_SPARROW$: $\beta=+$
  - Soil permeability avg: $\beta=+$
  - Base Flow Index avg: $\beta=-$
  - $FP\_width:Bnk\_height$: $\beta=+$

#### Phosphorus: net balance
- $n=31$, $R^2=0.70$, $P<0.001$
  - $\Delta$Developed 2012-1974: $\beta=+$
  - Horton Overland Flow %: $\beta=-$
  - K factor erodibility uppersoil: $\beta=+$
  - $Sed\_load\_SPARROW$: $\beta=+$
  - PP: Piedmont: $\beta=-$
  - Q50: $\beta=-$

#### Sediment: floodplain flux
- $n=33$, $R^2=0.70$, $P<0.001$
  - $\Delta$Developed 2012-1974: $\beta=+$
  - Horton Overland Flow %: $\beta=-$
  - $Bank\_avg\_angle$: $\beta=-$
  - $Bank\_ht$: $\beta=-$
  - $FP\_range\_elev$: $\beta=+$
  - PP: Coastal Plain: $\beta=+$
  - Power_watershed_Q50: $\beta=+$

#### Nitrogen: floodplain flux
- $n=33$, $R^2=0.68$, $P<0.001$
  - $\Delta$Developed 2012-1974: $\beta=+$
  - K factor erodibility uppersoil: $\beta=+$
  - Soil permeability avg: $\beta=+$
  - $Bank\_avg\_angle$: $\beta=-$
  - Horton Overland Flow %: $\beta=-$
  - PPT_avg: $\beta=+$

#### Phosphorus: floodplain flux
- $n=33$, $R^2=0.93$, $P<0.001$
  - $\Delta$Developed 2012-1974: $\beta=+$
  - P_yield_SPARROW: $\beta=+$
  - N_appl_rate: $\beta=-$
  - NLCD_Ag_2011: $\beta=+$
  - Horton Overland Flow %: $\beta=-$
  - $Bank\_max\_angle$: $\beta=-$
  - Q50_yield: $\beta=+$
  - Dam_density: $\beta=+$
  - Bnk_height:FP_width: $\beta=+$
  - Dam_storage: $\beta=+$
  - P_appl_rate: $\beta=-$
  - NLCD_Urb_2011: $\beta=+$
  - K factor erodibility uppersoil: $\beta=+$

#### Sediment: bank flux
- $n=31$, $R^2=0.37$, $P=0.005$
  - $Bank\_max\_angle$: $\beta=+$
  - PPT_avg: $\beta=-$
  - Over_ratio: $\beta=+$

#### Nitrogen: bank flux
- $n=31$, $R^2=0.27$, $P=0.004$
  - Land-use Production 1974: $\beta=-$
  - NLCD_Ag_2011: $\beta=+$
  - Elevation-Relief Ratio: $\beta=+$
  - PP: Valley & Ridge: $\beta=+$
  - Dam_density: $\beta=+$

#### Phosphorus: bank flux
- $n=31$, $R^2=0.55$, $P=0.002$
  - Land-use Production 1974: $\beta=-$
  - NLCD_Ag_2011: $\beta=+$
  - Elevation-Relief Ratio: $\beta=+$
  - PP: Valley & Ridge: $\beta=+$
  - Dam_density: $\beta=+$
Fluxes are predictable: **Watershed GIS-derived predictors**
Stepwise multiple regressions ($P$-to-enter=0.10):

<table>
<thead>
<tr>
<th>Fluxes: net balance</th>
<th>Fluxes: floodplain flux</th>
<th>Fluxes: bank flux</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sediment</strong></td>
<td><strong>Nitrogen</strong></td>
<td><strong>Phosphorus</strong></td>
</tr>
<tr>
<td>net balance</td>
<td>net balance</td>
<td>net balance</td>
</tr>
<tr>
<td>$n=31$, $R^2=0.55$, $P&lt;0.001$</td>
<td>$n=31$, $R^2=0.70$, $P&lt;0.001$</td>
<td>$n=31$, $R^2=0.70$, $P&lt;0.001$</td>
</tr>
<tr>
<td>$\Delta$Developed 2012-1974 $\beta=+$</td>
<td>$\Delta$Developed 2012-1974 $\beta=+$</td>
<td>$\Delta$Developed 2012-1974 $\beta=+$</td>
</tr>
<tr>
<td>Horton Overland Flow % $\beta=+$</td>
<td>Horton Overland Flow % $\beta=+$</td>
<td>Horton Overland Flow % $\beta=+$</td>
</tr>
<tr>
<td>Sed_load_SPARROW $\beta=+$</td>
<td>K factor erodibility uppersoil $\beta=+$</td>
<td>Sed_load_SPARROW $\beta=+$</td>
</tr>
<tr>
<td>K factor erodibility uppersoil $\beta=+$</td>
<td>Soil permeability avg $\beta=+$</td>
<td>Phosphorus: bank flux</td>
</tr>
<tr>
<td></td>
<td>Base Flow Index avg $\beta=+$</td>
<td>$n=31$, $R^2=0.55$, $P=0.002$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land-use Production 1974 $\beta=+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NLCD_Ag_2011 $\beta=+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elevation-Relief Ratio $\beta=+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PP: Valley &amp; Ridge $\beta=+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dam_density $\beta=+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dam storage $\beta=+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Subsurface Flow Contact T $\beta=+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q50 $\beta=+$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Q90 $\beta=+$</td>
</tr>
</tbody>
</table>

**Sediment:**
- Fluxes: net balance
  - $n=31$, $R^2=0.55$, $P<0.001$
  - $\Delta$Developed 2012-1974 $\beta=+$
  - Horton Overland Flow % $\beta=+$
  - Sed_load_SPARROW $\beta=+$
  - K factor erodibility uppersoil $\beta=+$

**Nitrogen:**
- Fluxes: net balance
  - $n=31$, $R^2=0.70$, $P<0.001$
  - $\Delta$Developed 2012-1974 $\beta=+$
  - Horton Overland Flow % $\beta=+$
  - K factor erodibility uppersoil $\beta=+$
  - Sed_load_SPARROW $\beta=+$
  - Soil permeability avg $\beta=+$
  - Base Flow Index avg $\beta=+$

- Fluxes: floodplain flux
  - $n=33$, $R^2=0.41$, $P<0.001$
  - $\Delta$Developed 2012-1974 $\beta=+$
  - PP: Coastal Plain $\beta=+$

- Fluxes: bank flux
  - $n=31$, $R^2=0.12$, $P=0.062$
  - Horton Overland Flow % $\beta=+$

**Phosphorus:**
- Fluxes: net balance
  - $n=31$, $R^2=0.70$, $P<0.001$
  - $\Delta$Developed 2012-1974 $\beta=+$
  - Horton Overland Flow % $\beta=+$
  - K factor erodibility uppersoil $\beta=+$
  - Sed_load_SPARROW $\beta=+$
  - PP: Piedmont $\beta=–$
  - Q50 $\beta=–$

- Fluxes: floodplain flux
  - $n=33$, $R^2=0.87$, $P<0.001$
  - $\Delta$Developed 2012-1974 $\beta=+$
  - P_yield_SPARROW $\beta=+$
  - N_appl_rate $\beta=–$
  - NLCD_Ag_2011 $\beta=+$
  - Horton Overland Flow % $\beta=–$
  - Q50 $\beta=+$
  - Land-use Production 2012 $\beta=–$
  - Dam storage $\beta=+$
  - Subsurface Flow Contact T $\beta=–$
  - Q90 $\beta=–$

- Fluxes: bank flux
  - $n=31$, $R^2=0.55$, $P=0.002$
  - Land-use Production 1974 $\beta=–$
  - NLCD_Ag_2011 $\beta=+$
  - Elevation-Relief Ratio $\beta=+$
  - PP: Valley & Ridge $\beta=+$
  - Dam_density $\beta=+$
### Fluxes are predictable: Watershed + Reach GIS-derived predictors

**Stepwise multiple regressions** ($P$-to-enter=$0.10$, $R^2$ change > $0.05$):

#### Sediment: net balance

- **$n=31$, $R^2=0.61$, $P<0.001$**
  - $FP\_width:Bnk\_height \quad \beta = +$
  - $FP\_width:Ch\_width \quad \beta = -$
  - $K$ factor erodibility uppersoil $\beta = +$
  - $Soil$ permeability avg $\beta = +$
  - $Elevation$-Relief Ratio $\beta = -$

#### Nitrogen: net balance

- **$n=31$, $R^2=0.70$, $P<0.001$**
  - $\Delta$Developed 2012-1974 $\beta = +$
  - $Horton$ Overland Flow % $\beta = -$
  - $K$ factor erodibility uppersoil $\beta = +$
  - $Sed\_load\_SPARROW \beta = +$
  - $Soil$ permeability avg $\beta = +$
  - $Base$ Flow Index avg $\beta = -$

#### Phosphorus: net balance

- **$n=31$, $R^2=0.70$, $P<0.001$**
  - $\Delta$Developed 2012-1974 $\beta = +$
  - $Horton$ Overland Flow % $\beta = -$
  - $K$ factor erodibility uppersoil $\beta = +$
  - $Sed\_load\_SPARROW \beta = +$
  - $PP: Piedmont $\beta = -$
  - $Q50 \beta = -$

#### Sediment: floodplain flux

- **$n=33$, $R^2=0.61$, $P<0.001$**
  - $\Delta$Developed 2012-1974 $\beta = +$
  - $Horton$ Overland Flow % $\beta = -$
  - $Bank\_avg\_angle \beta = -$
  - $Bank\_ht \beta = -$
  - $FP\_range\_elev \beta = +$

#### Nitrogen: floodplain flux

- **$n=33$, $R^2=0.55$, $P<0.001$**
  - $\Delta$Developed 2012-1974 $\beta = +$
  - $K$ factor erodibility uppersoil $\beta = +$
  - $Soil$ permeability avg $\beta = +$
  - $Bank\_avg\_angle \beta = -$

#### Phosphorus: floodplain flux

- **$n=33$, $R^2=0.79$, $P<0.001$**
  - $\Delta$Developed 2012-1974 $\beta = +$
  - $P\_yield\_SPARROW \beta = +$
  - $N\_appl\_rate \beta = -$
  - $NLCD\_Ag\_2011 \beta = +$
  - $Horton$ Overland Flow % $\beta = -$
  - $Bank\_max\_angle \beta = -$

#### Sediment: bank flux

- **$n=31$, $R^2=0.37$, $P=0.005$**
  - $Bank\_max\_angle \beta = +$
  - $PPT\_avg \beta = -$
  - $Over\_ratio \beta = +$

#### Nitrogen: bank flux

- **$n=31$, $R^2=0.27$, $P=0.004$**
  - $Land\_use \; Production \; 1974 \beta = -$
  - $NLCD\_Ag\_2011 \beta = +$
  - $Elevation$-Relief Ratio $\beta = +$
  - $PP: Valley \& Ridge $\beta = +$
  - $Dam\_density \beta = +$
**Fluxes are predictable: Watershed GIS-derived predictors**

Stepwise multiple regressions ($P$-to-enter=0.10, $R^2$ change > 0.05):

### Sediment: net balance
- $n=31, \ R^2=0.55, \ P<0.001$
- $\Delta$Developed 2012-1974 $\beta=+$
- Horton Overland Flow % $\beta=-$
- Sed_load_SPARROW $\beta=+$
- K factor erodibility uppersoil $\beta=+$

### Nitrogen: net balance
- $n=31, \ R^2=0.66, \ P<0.001$
- $\Delta$Developed 2012-1974 $\beta=+$
- Horton Overland Flow % $\beta=-$
- K factor erodibility uppersoil $\beta=+$
- Sed_load_SPARROW $\beta=+$
- Soil permeability avg $\beta=+$

### Phosphorus: net balance
- $n=31, \ R^2=0.66, \ P<0.001$
- $\Delta$Developed 2012-1974 $\beta=+$
- Horton Overland Flow % $\beta=-$
- K factor erodibility uppersoil $\beta=+$
- Sed_load_SPARROW $\beta=+$
- PP: Piedmont $\beta=-$

### Sediment: floodplain flux
- $n=33, \ R^2=0.46, \ P<0.001$
- $\Delta$Developed 2012-1974 $\beta=+$
- Horton Overland Flow % $\beta=-$
- K factor erodibility uppersoil $\beta=+$

### Nitrogen: floodplain flux
- $n=33, \ R^2=0.41, \ P<0.001$
- $\Delta$Developed 2012-1974 $\beta=+$
- PP: Coastal Plain $\beta=+$

### Phosphorus: floodplain flux
- $n=33, \ R^2=0.69, \ P<0.001$
- $\Delta$Developed 2012-1974 $\beta=+$
- P_yield_SPARROW $\beta=+$
- N_appl_rate $\beta=-$
- NLCD_Ag_2011 $\beta=+$
- Horton Overland Flow % $\beta=-$

### Sediment: bank flux
- $n=31, \ R^2=0.12, \ P=0.062$
- Horton Overland Flow % $\beta=-$

### Nitrogen: bank flux
- $n=31, \ R^2=0.27, \ P=0.004$
- Land-use Production 1974 $\beta=-$

### Phosphorus: bank flux
- $n=31, \ R^2=0.55, \ P=0.002$
- Land-use Production 1974 $\beta=-$
- NLCD_Ag_2011 $\beta=+$
- Elevation-Relief Ratio $\beta=+$
- PP: Valley & Ridge $\beta=+$
- Dam_density $\beta=+$
Approaches for predicting the whole Chesapeake watershed

Valley & Ridge, Piedmont, and Coastal Plain

- **OPTION #1**: Average: all 3 PP (for sediment, and all floodplain and bank fluxes)
- **OPTION #2**: Average: each PP (for N and P net balance fluxes)
- **OPTION #3**: Regression: Watershed+Reach predictors
- **OPTION #4**: Regression: Watershed only predictors (where GIS Toolkit unavailable)

Appalachian Plateau and Blue Ridge

- **OPTION #1**: Average: Valley & Ridge and Piedmont
- **OPTION #3**: Regression: Watershed+Reach predictors
- **OPTION #4**: Regression: Watershed only predictors (where GIS Toolkit unavailable)

Other issues:

- Intensive land-use on floodplain (e.g. urban, row crop)
- Channelized/leveed rivers
- Headwaters
Predicting fluxes: Difficult Run pilot

Regression
Mainstem X-section
net sediment balance predicted
\( R^2 = 0.57, \ P = 0.007 \) by:
- Channel width
- Floodplain elevation range

DRAFT
Predicted sediment balance (kg m\(^{-1}\) yr\(^{-1}\))
\[ \text{Floodplain} - \text{Bank} \]
Dendrogeomorphic method

Flux calculations: $g \text{ m}^{-1} \text{ yr}^{-1}$

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

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

Net balance: Floodplain flux – Bank flux
USGS Chesapeake Floodplain Network

Goal:

*Measure and predict the sediment/N/P balance of streams and rivers (sink or source of floodplain and banks) in entire Chesapeake watershed*
Chesapeake Geomorphic GIS toolkit:
Channel x-section analysis

Bank locations based on slope breaks

Fluvial Geomorphic Characteristics:
- Bank height
- Bank angle
- Channel width
- Channel profile slope
- Floodplain width
- Floodplain elevation range
- Floodplain elevation StDev
- Valley width
- Drainage area
Measured vs. GIS geomorphology: evaluating Toolkit performance

Cross section -scale

Reach-scale
Understanding and scaling transport processes thru watersheds

Alluvial sediment exchange

Upland erosion

Riparian buffering

Figure 1. Spatial structure (in plan view) of a 1-dimensional “valley-averaged” suspended sediment routing model.

Modified from Benthem and Skalak

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

Flowpath connectivity

Claggett

Upland erosion

Bank

Floodplain

Noe, Hupp, Claggett

Stream load

Any and every reach: alluvial geometry, upland flux, bank flux, floodplain flux
We can measure and model if streams and rivers are sinks for sediment and associated particulate N and P over long time scales.

The Chesapeake watershed is mostly in ‘equilibrium’ for sediment fluvial exchange; but some floodplains are strongly depositional.

Fluxes of sediment and nutrients were similar in Valley & Ridge and Piedmont physiographic provinces (and sediment in Coastal Plain), indicating limited control of regional geology over alluvial sediment exchange.

Measured rates of floodplain depositional flux of N and P were typical of the Mid-Atlantic and Southeastern U.S.

Regional floodplain, bank, and net fluxes of sediment and nutrients were predictable using a combination of reach geomorphology and watershed characteristics (all of which could be estimated in GIS).

Floodplains are hotspots in the landscape for sediment and nutrient sinks and sources, influencing river loads to the Chesapeake Bay.

Chesapeake GIS toolkit and database should be valuable tool for additional research on transport processes and stream condition and health.
We can measure and predict the important role of floodplain/bank sediment exchange in Chesapeake watersheds.
### ANOVA

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**Coefficients**

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### V&R + Piedmont fluxes are predictable (and available in GIS)

#### Stepwise multiple regressions:

<table>
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<tr>
<th>Set of predictors</th>
<th>Statistics</th>
<th>Fluxes</th>
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<td>1. Channel width ÷ Floodplain width</td>
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<tr>
<td></td>
<td>2. Channel width ÷ Floodplain width</td>
<td>2. Bank height</td>
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</table>
Can vary:
- Linear fit length, spacing, width, point spacing
- Width limited to catchment boundary
Chesapeake Geomorphic GIS toolkit:

Fluvial Geomorphic Characteristics:
- Bank height
- Bank angle
- Channel width
- Channel profile slope
- Floodplain width
- Floodplain elevation range
- Floodplain elevation StDev
- Valley width
- Drainage area
Chesapeake Geomorphic GIS toolkit:
Field vs. GIS validation

Patuxent River near Unity MD
Big picture of approach for sediment modeling

Flowpath connectivity

Claggett  Upland erosion

Noe, Hupp, Claggett  Bank

Floodplain

Stream load

Any and every reach: alluvial geometry, upland flux, bank flux, floodplain flux
What’s next:

1. Validate GIS geomorphology (VR & PIED) using field geomorphology.
2. Calculation of Coastal Plain long-term fluxes.
4. GIS geomorphology database ready (VR & PIED)
5. GIS geomorphology database complete (~90%; CP and Shenandoah added).
6. Regress VR & PIED & CP fluxes using GIS geomorphology + watershed characteristics.
7. Extrapolate bank and floodplain sediment fluxes to all of VR & PIED & CP
   1. Summed by NHD+ catchment
   2. Maps by reach of fluxes
8. Add SW VA and WV LiDAR gap (100% of watershed complete)
9. Measure contemporary fluxes 3-yr post installation and repeat.

Completed:

Nov 2015
Dec 2015
Dec 2015
Jan 2016
Apr 2016
Apr 2016
May 2016
Jan 2017
2019
Sediment Delivery to Simulated Rivers

Drainage Network

Flow path connectivity

RUSLE2 EoF

NHD+

FlowPath connectivity

NOE

NHD+

Bank Erosion

EoF erosion

Bank Erosion

Synthetic Streams

Floodplain Deposition

Phase 6 Modeled NHD Catchment Processes

P6 Simulated River
Floodplain flux rates are typical

- Sav & Wac
- Difficult
- Wolf
- Smith
- Roanoke
- Tangipahoa
- Mill
- Ches CP
- Ensign
- Mollicy
USGS Chesapeake Floodplain Network: example site

South Fork Quantico Creek layout

gage
USGS Chesapeake Floodplain Network

Measurements:

**Sediment budget terms** (45 sites)
Contemporary (pin) floodplain and bank flux
Long-term (dendro) floodplain and bank flux
In-channel sediment storage volumes

**Geomorphic measurements** (45 sites)
X-section survey (channel, banks, floodplain)
Longitudinal survey (tie to gage, reach slope)
Channel bed particle size

**Biogeochemistry** (45 sites)
Soil/sediment TN, TP, TOC, LOI, particle size
Soil/sediment biogeochemical processes

**Age Distributions** (6 sites)
In-channel (bomb radiocarbon, Be-7, Pb-210)
Floodplain (Be-7, Pb-210, OSL, radiocarbon)
Scaling to the whole Chesapeake watershed: measuring and predicting bank and floodplain rates

Steps

- CFN measurement
- CFN prediction model
- Claggett et al. Chesapeake channel-floodplain geomorphic GIS

Products

- Chesapeake floodplain/bank rates
  1) long-term
  2) contemporary
- Chesapeake watershed hotspot maps
- Chesapeake watershed extrapolated budget
Dynamic exchange of sediment + nutrients = hotspot

Gross floodplain trapping factor (Schenk et al. 2013):

<table>
<thead>
<tr>
<th></th>
<th>Avg.</th>
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<tbody>
<tr>
<td>Sed</td>
<td>72</td>
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<tr>
<td>P</td>
<td>40</td>
</tr>
<tr>
<td>N</td>
<td>12</td>
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</table>

Kg m\(^{-2}\) yr\(^{-1}\) of floodplain SPARROW yield estimates

Average hectare of floodplain traps 72X the sediment load generated by hectare of watershed

Indicator of importance to watershed loads
The importance of floodplains to WQ in the Chesapeake watershed

Measurement of functions

Log bank height:floodplain width

-2.0 -1.8 -1.6 -1.4 -1.2 -1.0 -0.8

Log (+200) site sediment balance (kg m$^{-1}$ yr$^{-1}$)

1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2

Difficult Run
Little Conestoga Creek
Linganore Creek

$r = -0.783$
$p < 0.001$

Predictability of functions

Schenk et al. 2013, ESP&L
Gellis et al. 2015, SIR

Only 3 Piedmont watersheds!

→ Not expected to be general, but shows promise of approach:

Easy geomorphic metrics may be predictive