EXPLORING THE RELATIONSHIP BETWEEN FRESHWATER WETLAND RESTORATION AND FLOOD MITIGATION

Kristen Hychka[1], Lisa Wainger[1], Elizabeth Murray[2], and Taylor Hollady[1]

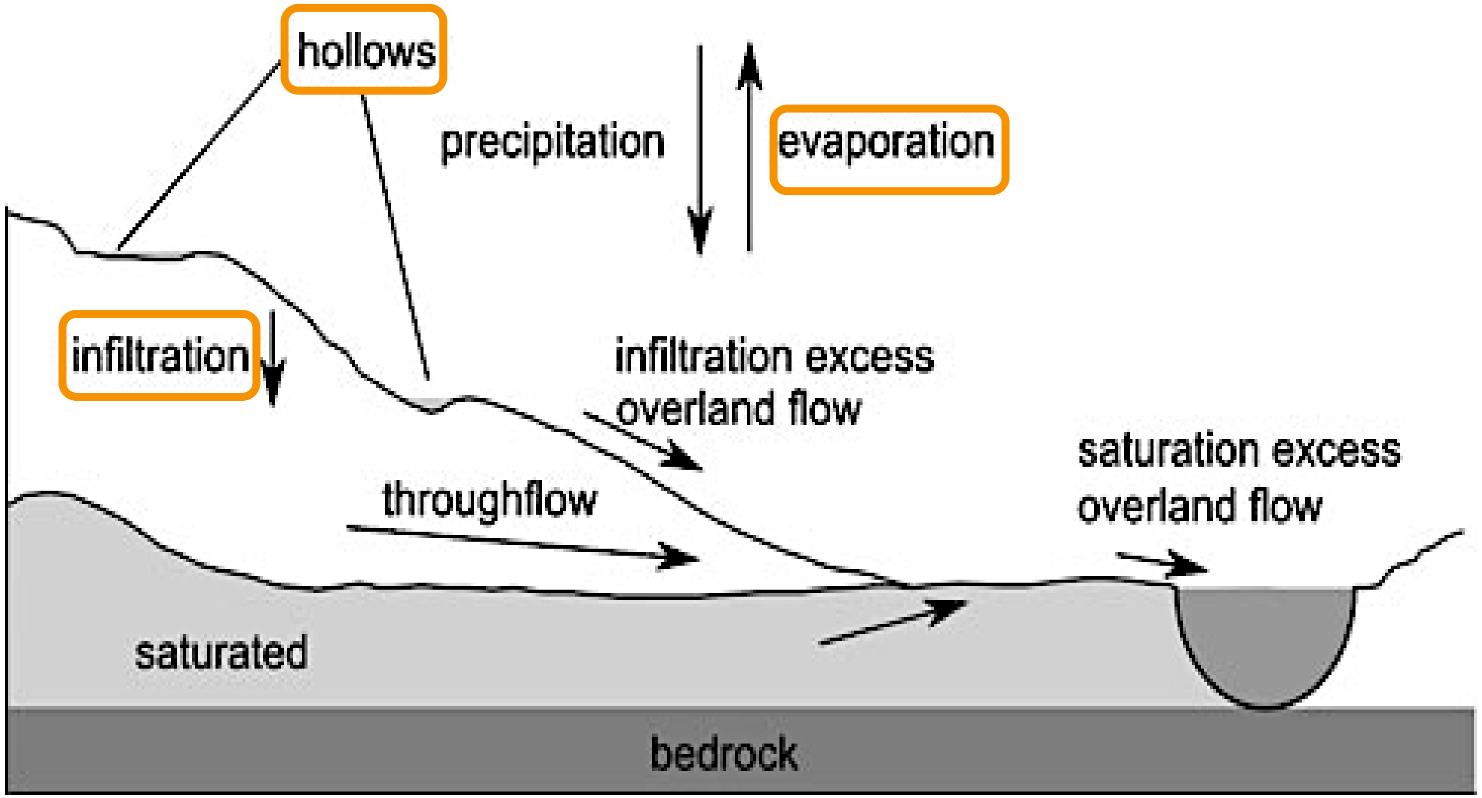
[1]University of Maryland Center for Environmental Science, Solomons, MD, USA
[2]U.S. Army Corps of Engineers, Engineer Research and Development Center, San Francisco, CA, USA

ACES 12/4/2018

How Wetlands Influence Flooding

Wetlands can influence the peak flows, timing, volume and duration of floods through:

- Runoff pathways
- Surface roughness
- Desynchronizing flows



Acreman and Holden 2011

Questions

- **Can we create a simple, defensible method for estimating flood risk reduction benefits of a wetland restoration project?**

- Has there been enough analysis to empirically determine when and where restored freshwater wetlands reduce flood risk?
- How can the benefits of wetland restoration be accounted for and, ideally, maximized in an ecosystem services framework in the face of difficulty in quantifying the effects of restoration on flooding?
- What information can be applied now to flood reduction and/or how to mitigate flooding?
- What data do we need to push us towards a multivariate conceptualization of the impacts of freshwater wetlands on flood risk?

Approach

Perform literature review of empirical relationships between wetland restoration and flood risk reduction

Develop an empirical statistical relationship between variables based on literature review and data availability review
a) Response Hydrologic Variables
b) Predictor Variables (GIS, Remote Sensing)

Synthesize information on site-specific storm water engineering methods that can be contextualized to the landscape level to address benefits

Evaluate potential for meta-analysis to generate a statistical model

Evaluate potential for fitting statistical relationship in restoration- and data-rich watersheds

Develop guidance materials on restoration and flood water retention benefits

How Wetlands Influence Flooding

- Not uniform
  - Maybe be positive, negative, or neutral
- Function of
  - Type of wetland
  - Landscape location
  - Hydrologic conditions
  - Management
  - Overriding watershed characteristics

Brinson 1993, Bullock and Acreman, Acreman and Holden 2011, Kadykalo and Findlay 2016

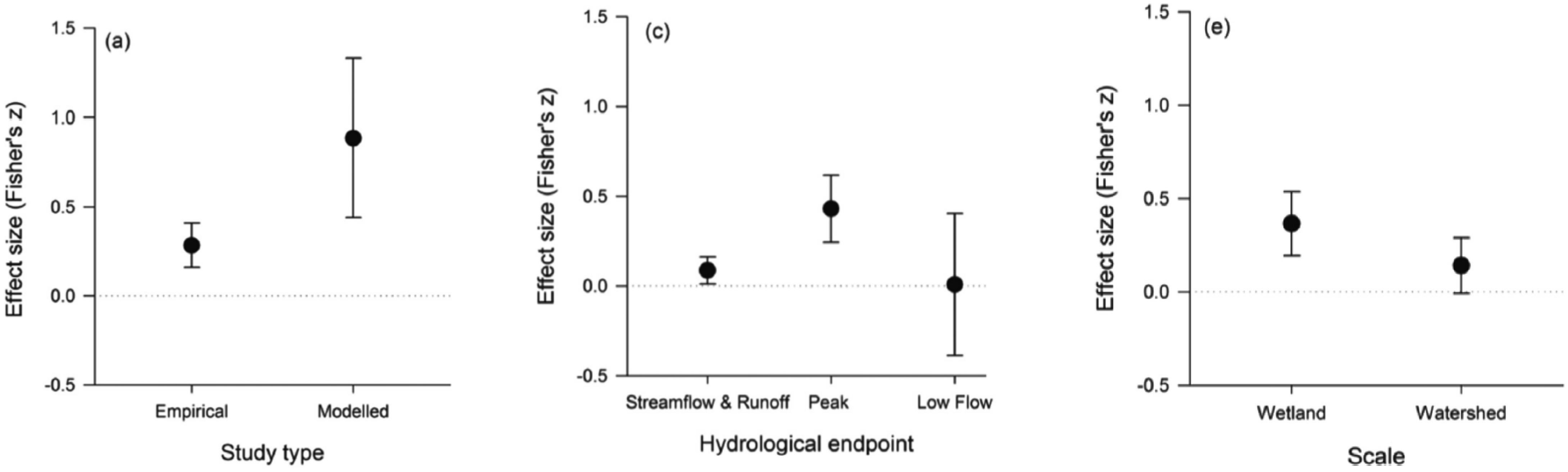
Variable relationships identified in the literature

	High Flood Water Retention	Mechanism	Low Flood Water Retention	Mechanism
Wetland Characteristics				
Vegetation	Higher vegetation cover	Higher ET Increase surface roughness	Little vegetation cover or vegetation	Lower ET Decrease surface roughness
Water Source	Surface water fed systems	Depressional and soil water storage available	Groundwater fed systems	Depressional and soil water storage less likely available
Morphology	Depressional	Depressional and soil water storage available	Slopes	Depressional and soil water storage less likely available
Landscape Position	Mainstem floodplain wetlands	Closer and more connected to the stream		
	Headwater wetlands	Desynchronize flood flows	Headwaters in extensive peatlands	Soil water storage not available

	High Flood Water Retention	Mechanism	Low Flood Water Retention	Mechanism
Watershed Characteristics				
Extent of wetlands	Increasing extent of wetlands	Depressional and soil water storage available	Increasing extent of wetlands--particularly peatlands	Soil water storage not available
Physiographic Characteristics	Mean slope decreases	Depressional and soil water storage available	Mean slope increases	Soil water storage not available
	Size of the watershed decreases	Less surface for runoff	Size of watershed increases	More surface for runoff
Land Use	Effective storm water implementation	Depressional water storage available	Impervious surface increases	Depressional and soil water storage not available
	More vegetation	Higher ET	Developed land increases	Lower ET Depressional and soil water storage not available [Higher evaporation]
Dams			Flood mitigation, such as dams	Can supersede wetland effects
Climate	Low antecedent moisture conditions	Depressional and soil water storage available	High antecedent moisture conditions	Depressional and soil water storage not available
	Lower storm intensity	Depressional and soil water storage not available	Higher storm intensity	Depressional and soil water storage not available

Flood Response Variable	Definition	Type of Hydrologic Variable	Type of Response	Relation to Flooding
Time to Peak	Time from initial rise in the hydrograph to the peak height or volume in an event.	Peak	-	As the time to peak decreases, so does the time of concentration.
Peakflow to Average, Peak, or Total Precipitation	Ratio of the peak flow to the average, peak, or total precipitation for a given interval.	Peak	+	As the ratio of peak flow to precipitation goes up, peaks are higher while controling for variability in precipitation.
Months exceeding average	Count of months exceeding the average flow for a fixed interval (12-year)	Streamflow and Runoff	+	Measure of overall amount of stream flow; generally as stream flow goes up so does flooding.

- **Recent, rigorous meta-analysis of wetland influence on flow regulation services had already evaluated such an approach (Kadykalo and Findlay, 2016)**
  - found a generalized statistically significant influence of wetlands on hydrologic variables associated with flood risk
  - on average, wetlands contributed to flood abatement by reducing the frequency and magnitude of flood flows.
  - small sample size in the literature (28 studies and 59 effects), limited their ability to control for moderating variables or confounding factors in their statistical tests



Kadykalo and Findlay, 2016

Potential for Meta-analysis

- Generally replicate but expand citations for Kadykalo & Findlay analysis to do the multivariate analysis
  - Non-conceptual/modeled, non-low flow studies, non-temperate, or peatland studies
- Could not substantially increase the number of studies for analysis
  - Offline articles
    - 19 articles met our criteria
    - <1/3 of articles at this stage met their statistical requirements for analysis
  - New articles
    - They ran their literature review in 2014
    - Did not appear to produce many more results

Approach

Perform literature review of empirical relationships between wetland restoration and flood risk reduction

Develop an empirical statistical relationship between variables based on literature review and data availability review
a) Response Hydrologic Variables
b) Predictor Variables (GIS, Remote Sensing)

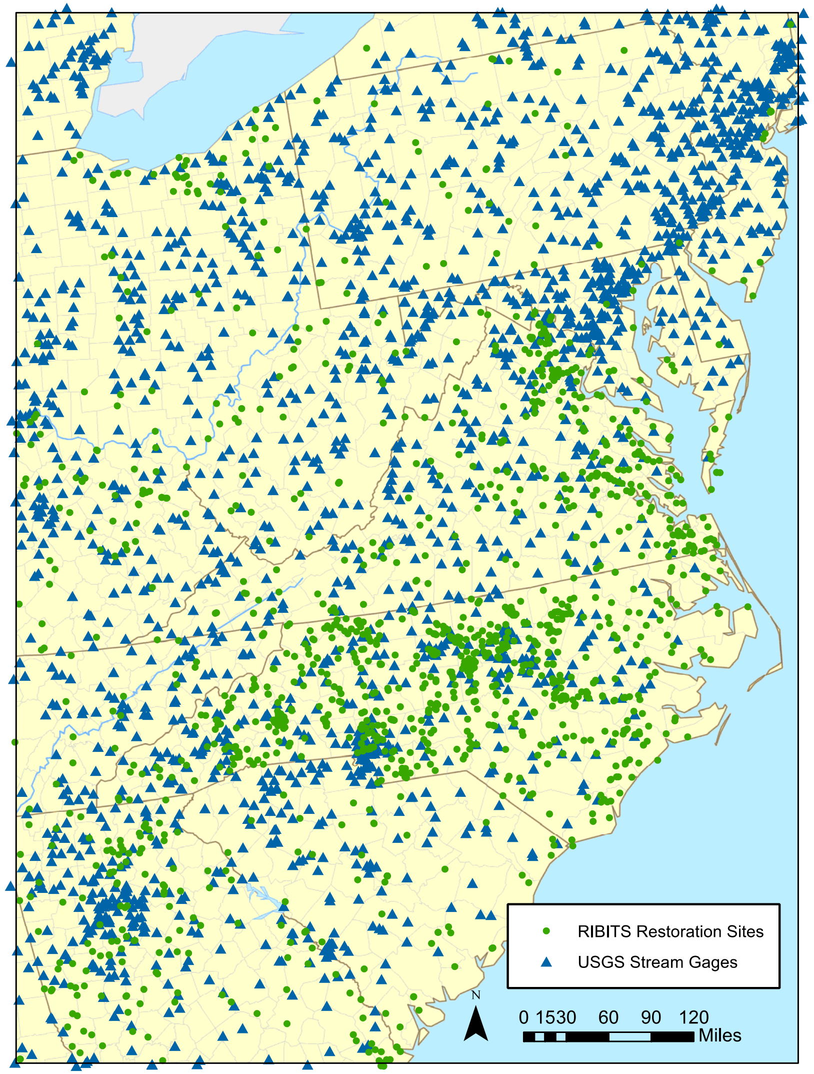
Synthesize information on site-specific storm water engineering methods that can be contextualized to the landscape level to address benefits

Evaluate potential for meta-analysis to generate a statistical model

Evaluate potential for fitting statistical relationship in restoration- and data-rich watersheds

Develop guidance materials on restoration and flood water retention benefits

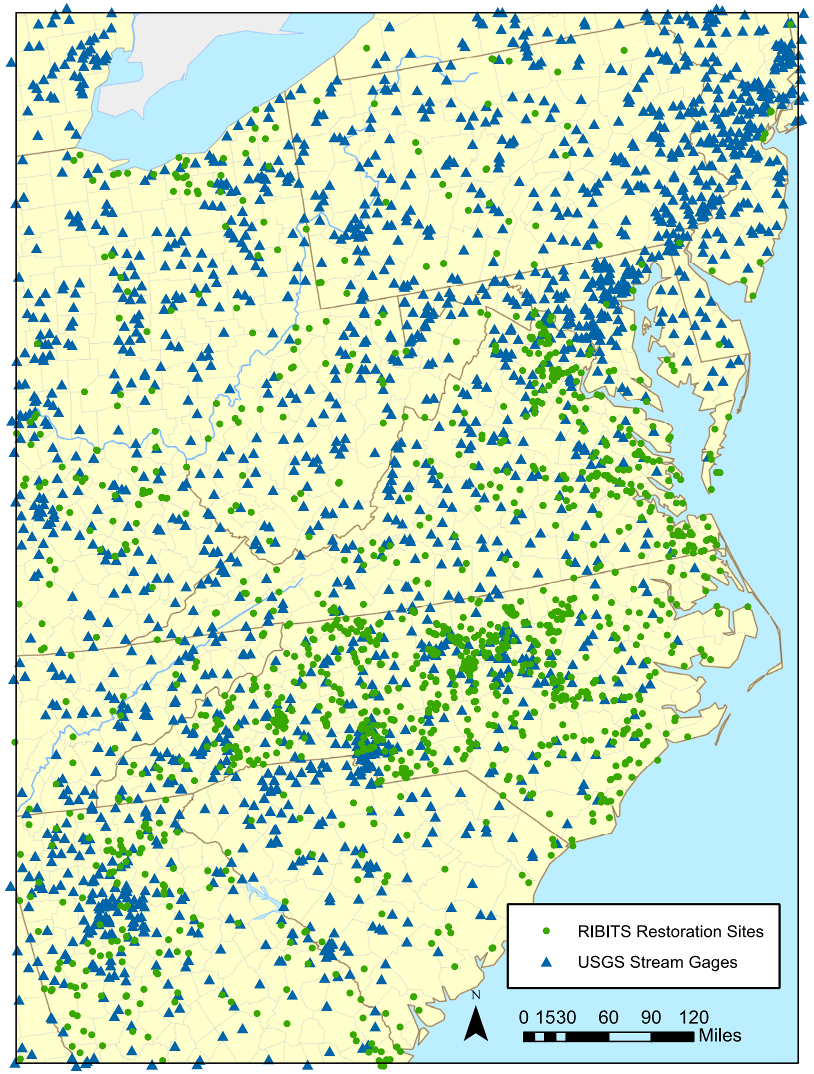
Literature Review and Data Availability Review to Develop a Statistical Relationship between variables



RIBITS database (Regulatory In-Lieu Fee and Bank Information Tracking System)

- Developed by the US Army Corps Engineer Research and Development Center (ERDC)
- Houses information from over 3,282 regulatory mitigation projects nationally and of those projects, 1,750 include wetland restoration
  - All sites include information about the location of the site (centroid coordinates)
  - Some sites have
    - the extent of the wetland restoration (polygon),
    - the extent of the area served by the wetland,
    - wetland type, and
    - coarse location of the impacts for

Literature Review and Data Availability Review to Develop a Statistical Relationship between variables



Limitations

- Database has lack of:
  - Extent and wetland type data for all restoration projects
  - Restoration type
  - Timing of project
- Lack of spatial and temporal alignment with stream gages for hydrologic analysis

Synthesize information on site-specific storm water engineering methods

Generate guidance of how to evaluate which tools to use under which conditions

- Which wetland processes are included?
- Can they differentiate between wetland types?
- How well can they account for spatial and temporal variability?
- Can they capture climate variability (antecedent moisture conditions)?

Generate suggestions

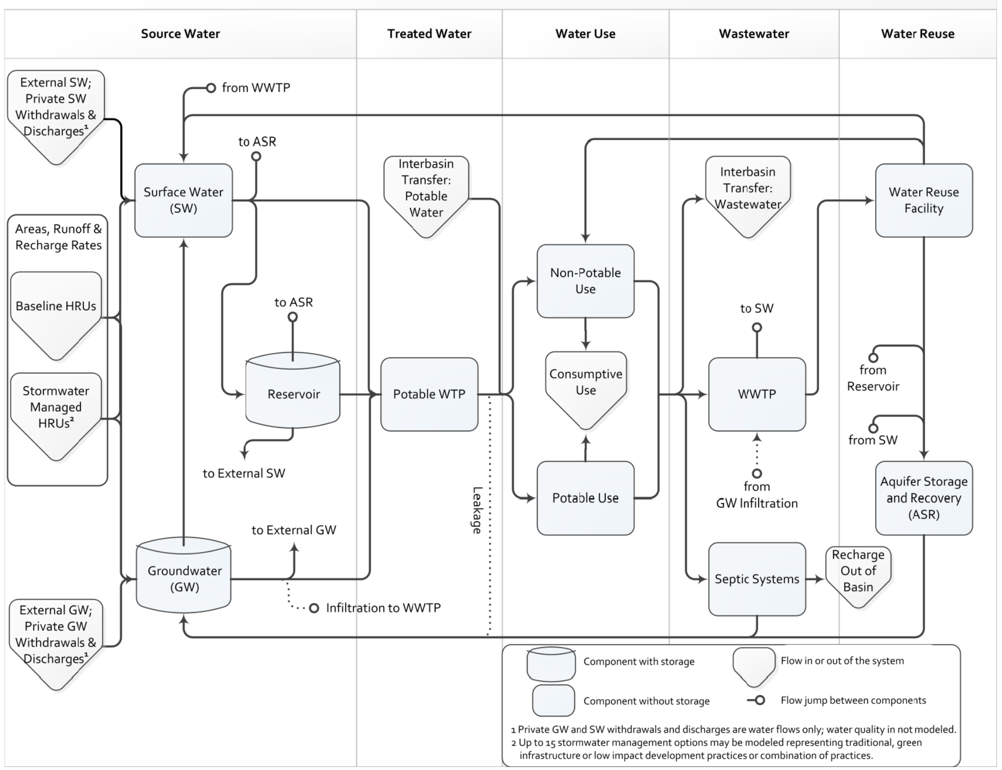
- Decision tree to demonstrate why we'd chose one or more models?
- What research still needs to be done?
- What would make these models easier to implement? (GIS layers)

Synthesize information on site-specific storm water engineering methods

US EPA GI Modelling Toolkit

WMOST (Watershed Management Optimization Tool)

- **Runoff** and required storage volume is calculated by SCS curve number method used in SWAT (Texas A&M University 2011)
- (R – 0.2*S)2 / (R + 0.8*S) * Managed Area
  - R = rainfall depth in inches (design storm depth)
  - S is the retention parameter is defined as:
    - S = 1000/CN – 10
- **Storage volume provided** per square foot of BMP:
  - Sum of (Depth x Porosity) across all components
    - Porosity is assumed to be 0.4 for all wetlands
    - Fixed soil depth (0.67 ft)



Detenbeck et al. 2018

CONCLUSIONS

- Influence of wetlands on flooding varies greatly with wetland and watershed characteristics
- Currently, metanalysis of empirical studies do not allow for robust, multivariate methods of predicting flood retention potential from individual wetlands
- Negative results of empirical analysis on restored wetlands point to:
  - Need for more consistent characterization of wetland restoration
  - Need for surface water monitoring of wetland restoration
    - Not just depth to saturation
    - Upstream/downstream; Before/after
- Given lack of generalizable, statistical relationships between wetland extent and flood responses,
  - Can engineering or stormwater approaches be used defensibly with sufficient literature-based guidance on when and where they can be applied?

THANK YOU

Kristen Hychka[1], Lisa Wainger[1], Elizabeth Murray[2], and Taylor Hollady[1]

[1]University of Maryland Center for Environmental Science, Solomons, MD, USA
[2]U.S. Army Corps of Engineers, Engineer Research and Development Center, San Francisco, CA, USA

khychka@umces.edu