Chesapeake Bay Program

Science. Restoration. Partnership.

Indicators of Physical Stream Health

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NATIONAL STREAM RESTORATION CONFERENCE

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Purpose

This project is conducting interviews with experts, reviewing data, creating a framework, providing a data inventory matrix, and making recommendations that may help develop multi-metric stream health indicators for hydraulics and geomorphology. The development of these additional indicators will address the significant science and management need to better understand and communicate how streams respond to management actions.

Technical Advisory Group

Stream Health Work Group

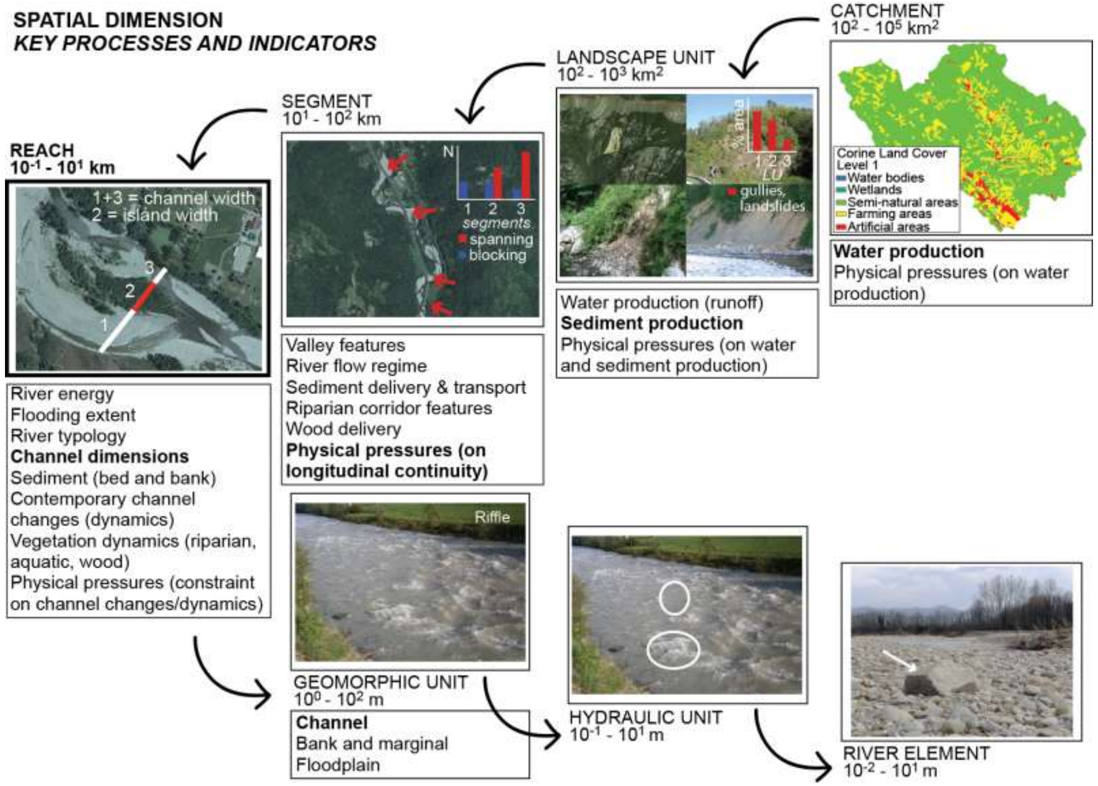
Chesapeake Bay Program

Interviews

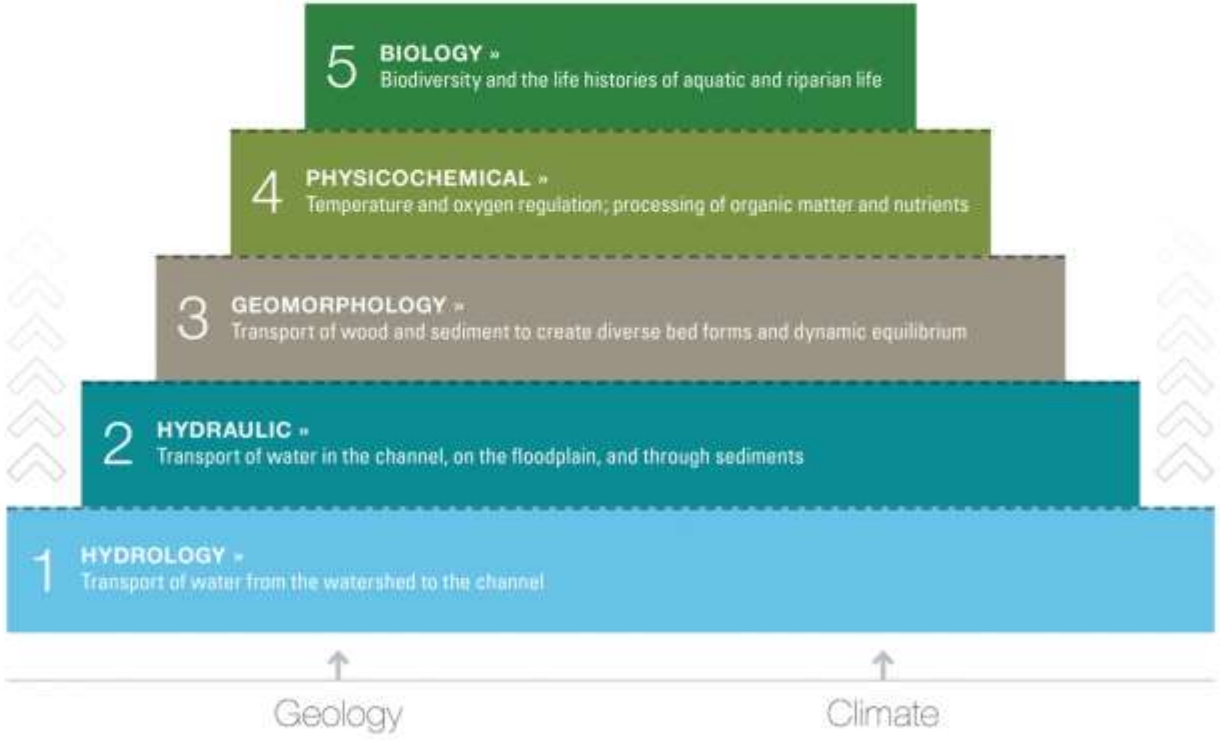
- Interstate Commission on the Potomac River Basin (ICPRB)
- UMBC (Matt Baker)
- Maryland Environmental Service (MES)
- Maryland Water Monitoring Conference (MWMC) Stream Monitoring Subcommittee
- USGS/Chesapeake Bay Program (CBP)
- USEPA Water Resources Registry (Emily Gentry)
- Virginia Tech (Tess Thompson)
- Fairfax County (Chris Ruck)
- Biohabitats (Joe Berg)
- Maryland Department of Natural Resources/Forest Service (Anne Hairston-Strang)
- FACET Team (Labeeb Ahmed, Peter Claggett, Krissy Hopkins and Greg Noe)
- Maryland Department of Natural Resources/Center for Economic and Social Science of Chesapeake and Coastal Service (Elliott Campbell)
- USGS MD-DE-DC Water Science Center (Matt Cashman)

Holistic Approach

REFORM Spatial Dimensions



Stream Functions Pyramid



Proposed Multi-Metric Hydromorphology Indicator Framework

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Catchment (Basin) and Landscape Unit/Pyramid Level 1–Hydrology

- The landscape unit scale provides the broad context for understanding conditions affecting a stream

River Segment/Pyramid Level 2–Hydraulic

- The river segment scale characterizes the relationship of the stream to its valley, how valley conditions affect stream energy, and the width of floodplain area that may be available

Reach/Pyramid Levels 2—Hydraulic and 3—Geomorphology

- The reach scale is characterized by differences in stream dimension, pattern and profile, the degree to which flow is confined within a channel, and the prevalence of riparian vegetation cover

Geomorphic and Hydraulic Unit/Pyramid Levels 2—Hydraulic and 3—Geomorphology

- Geomorphic units are areas containing a landform created by erosion and/or deposition of sediment, essentially the creation of a stream system network through stream energy

Relevant Data Tools

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- European Commission REFORM Project
- Watershed Resources Registry – Stream Stability Index
- Function-based Rapid Stream Assessment Protocol Revision
- Maryland Department of Transportation/State Highway (SHA) – US 301 Waldorf Area Transportation Project, Environmental Stewardship Methodologies and Results
- USEPA Dynamic Stream Systems
- Multi-jurisdictional Rapid Habitat Assessment Database
- Stream and Floodplain Geometry Mapping and Geomorphic Change Modeling
- Flow Alteration Metrics
- Maryland Healthy Watersheds Assessment – Hydrology and Geomorphology GIS Metrics
- Maryland Stream Restoration Planning Tool

Candidate Desktop Indicators

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Catchment (Basin) and Landscape Unit/Pyramid Level 1–Hydrology

- Runoff – Flow regime
- Sediment Production – Potential watershed sediment load
- Geology – Used to assess runoff and sediment production
- Climate – Can influence flow regime
- LULC – Used to assess runoff and sediment production

River Segment/Pyramid Level 2–Hydraulic

- Valley confinement – Available floodplain to reduce scouring flows
- Sediment Transport – Ability to process sediment load

Candidate Desktop Indicators

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Reach/Pyramid Levels 2—Hydraulics and 3—Geomorphology

- Planform – Valley type and stream pattern/sinuosity
- Stream energy – Can produce excessive degradation or aggradation
- Floodplain connectivity – Storm flow floodplain access, storage, and attenuation
- Channel Dimension – Width-depth ratio in natural migration
- Buffer Width – Width of riparian vegetation

Geomorphic and Hydraulic Unit/Pyramid Levels 2—Hydraulics and 3—Geomorphology

- Lateral stability – Streambank features such as riparian buffer, erosion of outer banks, and excessive bar formation
- Bed stability – Indicative of supporting stream functions

Refined List of Hydromorphology Indicators of Stability

- Valley type/confinement
- Floodplain connectivity
- Riparian vegetation
- Bedform diversity/stability
- Lateral stability

Data Sources

- Multi-jurisdictional Rapid Habitat Data
- High-resolution Land Use/Land Cover (LULC)
- USGS Floodplain and Channel Evaluation Tool (FACET)
- Hyper-Resolution Terrain-based Hydrography Mapping
- Gridded Soil Survey Geographic Database (gSSURGO)

Example Uses of GIS Data

Compare to field collected stream data from 8 stream restoration projects

1. Compare physical measurements from FACET to field data
2. Compare stability predictions of desktop GIS layers with field data

8 Stream Restoration Projects

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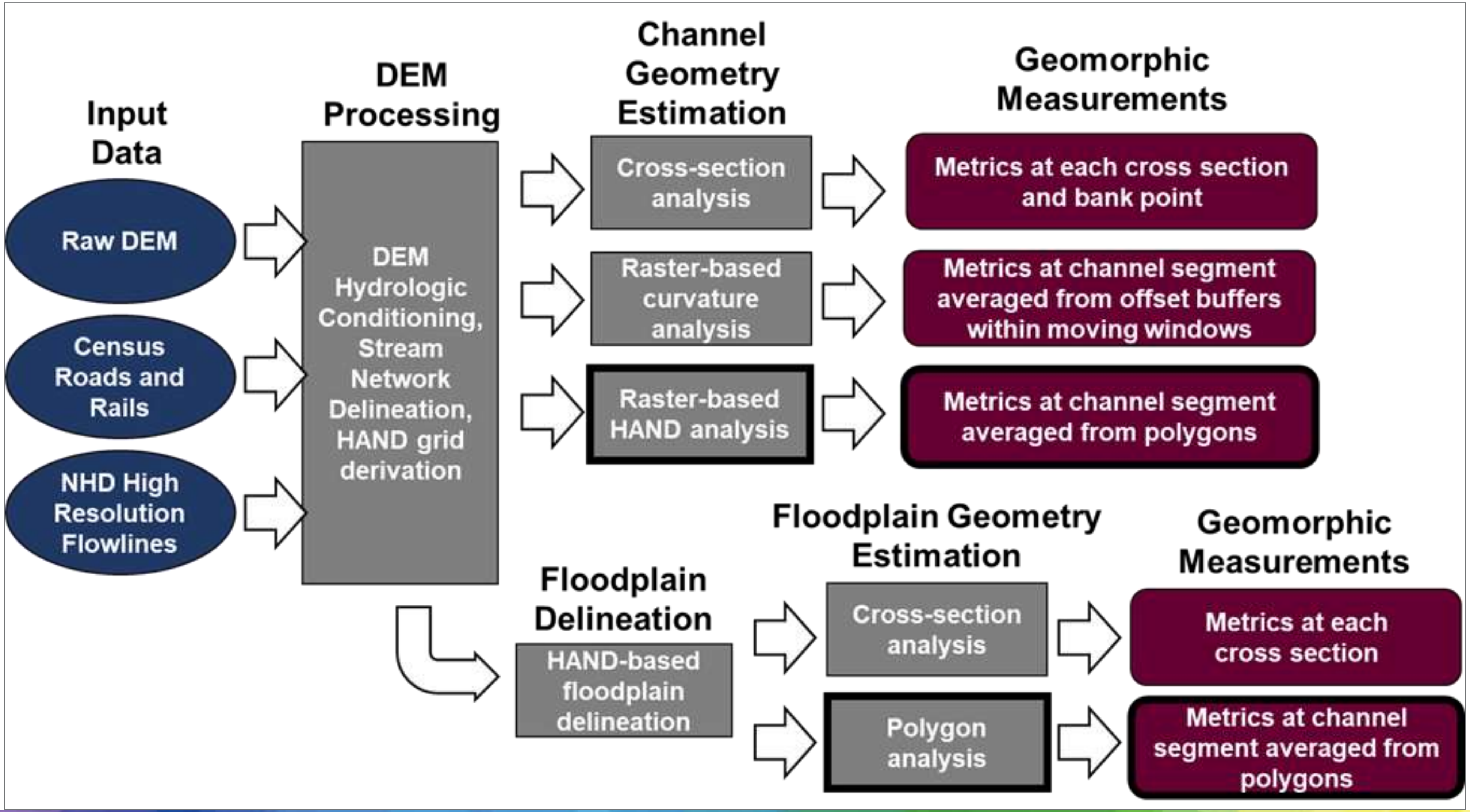
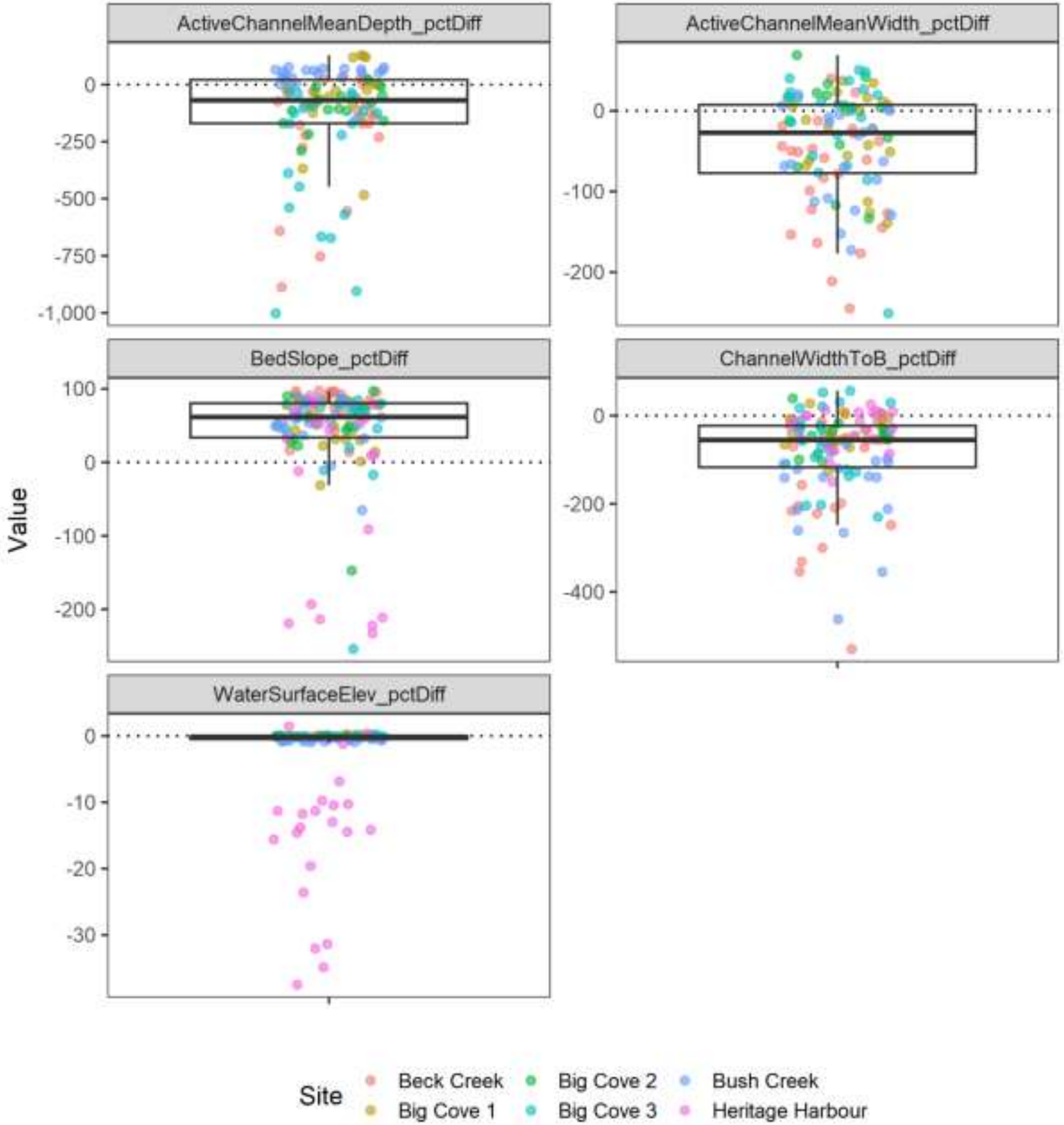
1. Broad Creek Valley West, MD
   - DA – 0.15 mi2, Coastal Plain Region, 38.970047,-76580141
2. UT Flat Creek, MD
   - DA – 0.27 mi2, Coastal Plain Region, 38.952208,-76.625244
3. Heritage Harbour, MD
   - DA – 0.39 mi2, Coastal Plain Region, 38.970773,-76.596366
4. Beck Creek, PA
   - DA – 2.42 mi2, Piedmont Region, 40.286740, -76.458800
5. Big Cove Site 1, PA
   - DA – 6.4 mi2, Ridge and Valley Region, 39.909328,-78.013957
6. Bush Creek, MD
   - DA – 7.66 mi2, Piedmont Region, 39.371655,-77.252766
7. Big Cove Site 2, PA
   - DA – 10.3 mi2, Ridge and Valley Region, 39.891018,-78.022149
8. Big Cove Site 3, PA
   - DA – 15.9 mi2, Ridge and Valley Region, 39.880632,-78.027757

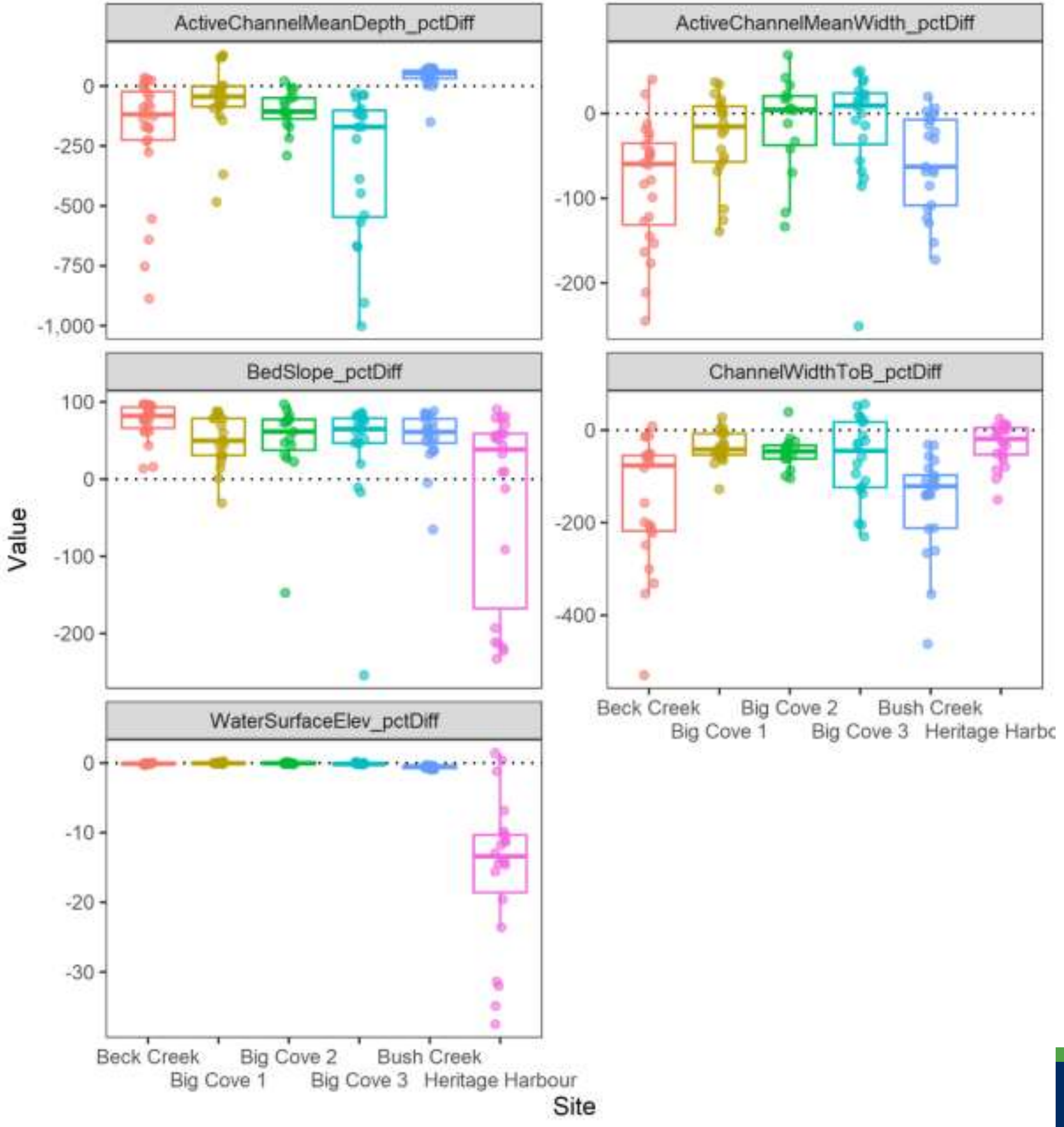
Comparing FACET to Field Measurements



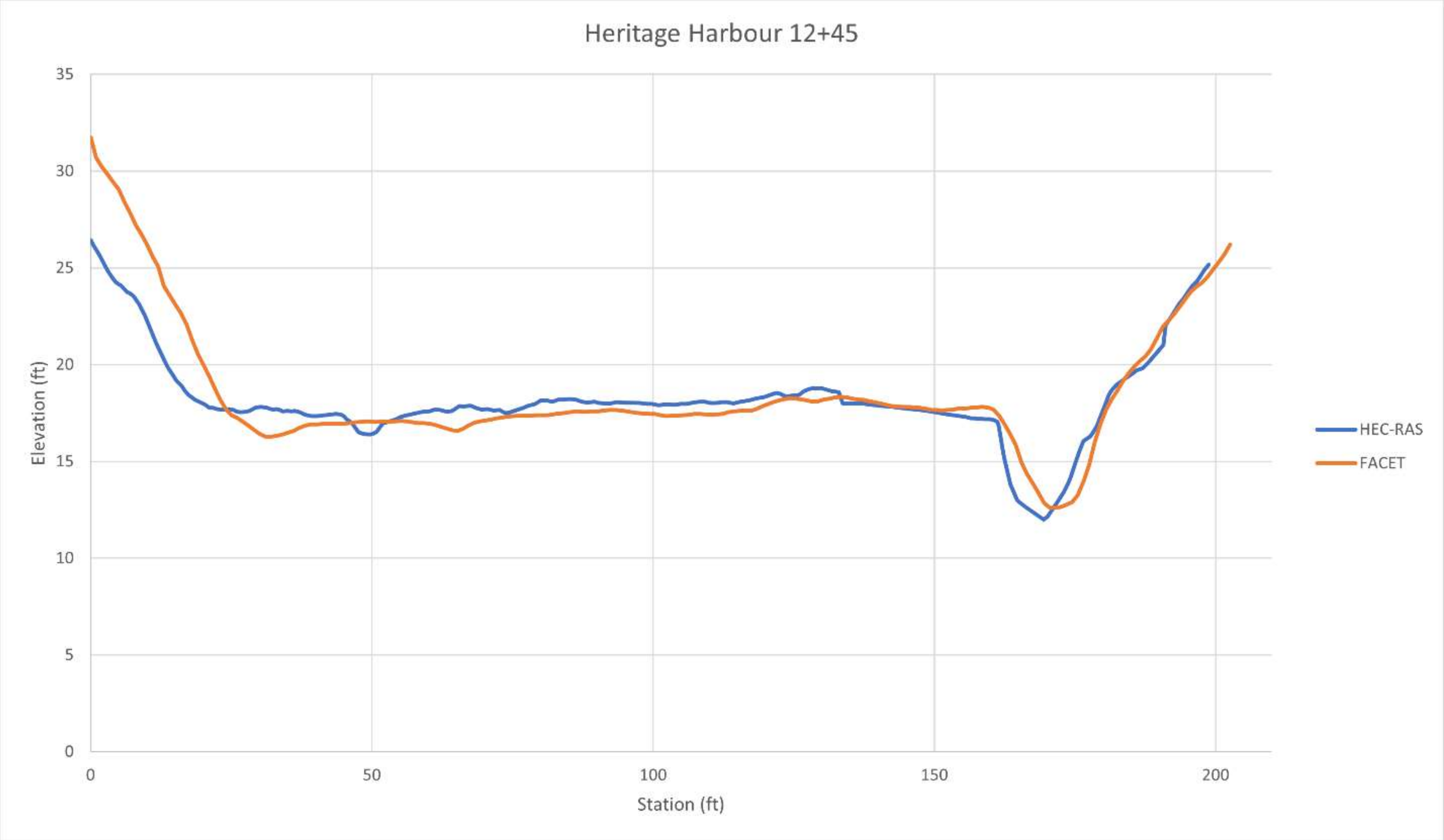
Comparing FACET to Field Measurements



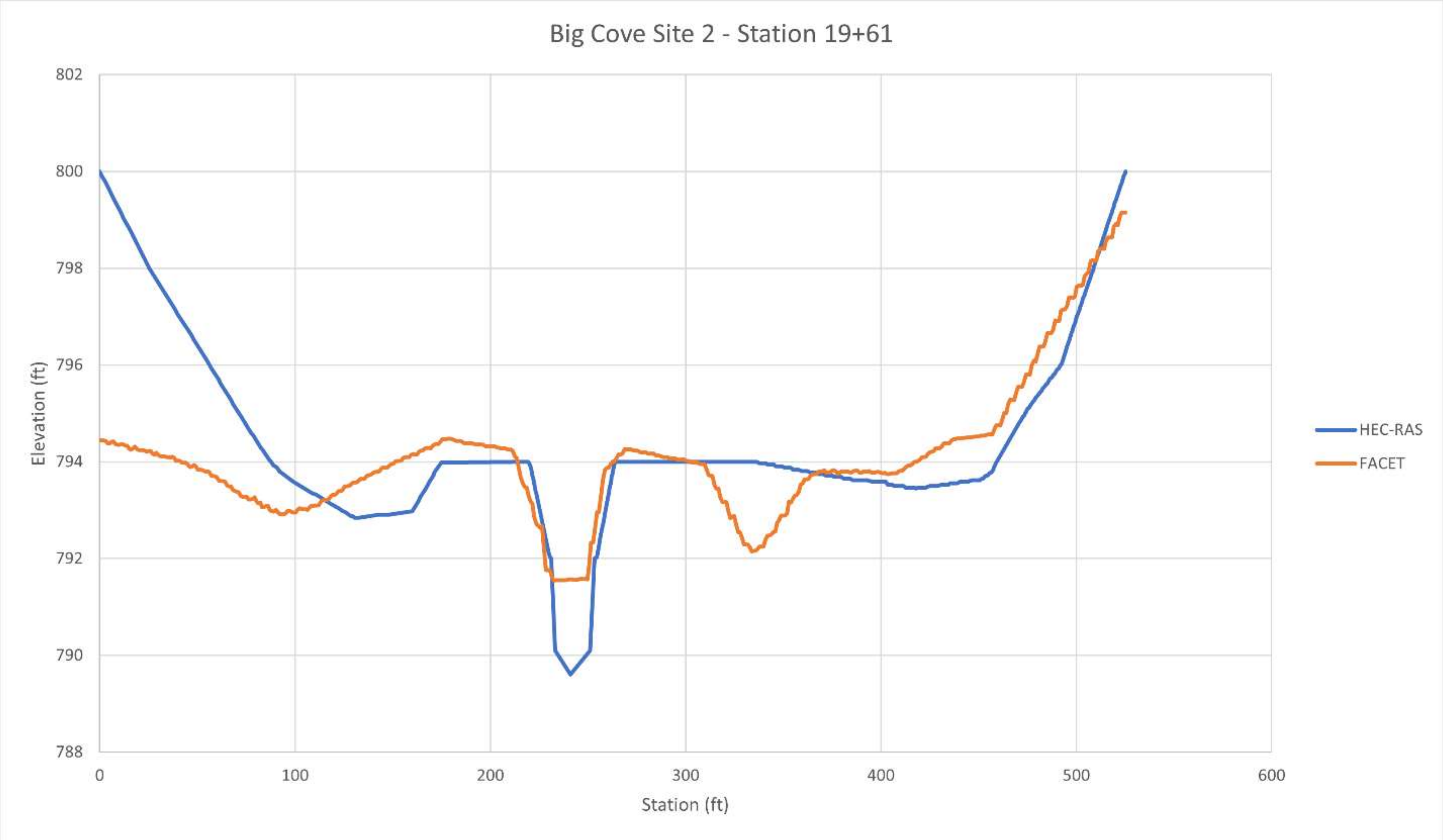
Comparing FACET to Field Measurements



Comparing FACET to Field Cross Sections



Comparing FACET to Field Cross Sections



Using GIS Layers to Predict Stability

Metrics from Maryland SHA 2009 to predict stream stability

- Slope
- Erodible soils
- Impervious surface
- Riparian vegetation

Using GIS Layers to Predict Stability

Thresholds used to rate stream stability

- Slope:
  - Piedmont – greater than 2% is unstable
  - Coastal Plain – greater than 1% is unstable
- Soil K Factor:
  - <0.25 = low erosion susceptibility
  - 0.25-0.4 = moderate erosion susceptibility
  - >0.4 = high erosion susceptibility
- Impervious Cover: Greater than 15% is unstable
- Forest: Value less than 50% of the assessed buffer area is unstable

Using GIS Layers to Predict Stability

Site	Drainage Area (mi^2)	Slope (degrees)	Slope (%)	Slope Rating[1]	Soil K Factor	Soil K Factor Description[2]	Soil K Factor Rating	Impervious Cover (IC)	Percent IC (%)	IC Rating[3]	Forest Buffer (m^2)	Forest Buffer (%)	Forest Buffer Rating[4]	Overall Stability Rating
Beck Creek (piedmont)	2.42	1.61	2.82	Unstable	0.41	High erosion susceptibility	Unstable	2188	2	Stable	7,875	5	Unstable	Unstable
UT Flat Creek (western coastal plain)	0.27	3.45	6.04	Unstable	0.33	Moderate erosion susceptibility	Unstable	0	1	Stable	25,236	90	Stable	Unstable
Heritage Harbour (western coastal plain)	0.39	0.07	0.134	Stable	0.43	High erosion susceptibility	Unstable	0	33	Unstable	0	0	Unstable	Unstable
Big Cove Site 3 (use carbonate curve)	15.9	2.01	3.52	Unstable	0.35	Moderate erosion susceptibility	Unstable	713	3	Stable	34,36	10	Unstable	Unstable
Big Cove Site 1 (use carbonate curve)	6.4	1.49	2.61	Unstable	0.31	Moderate erosion susceptibility	Unstable	788	3	Stable	11,061	20	Unstable	Unstable
Bush Creek (piedmont)	7.66	0.78	1.37	Stable	0.32	Moderate erosion susceptibility	Unstable	0	15	Stable	15,404	92	Stable	Stable
Big Cove Site 2 (use carbonate curve)	10.3	0.75	1.319	Stable	0.31	Moderate erosion susceptibility	Unstable	219	3	Stable	2	1	Unstable	Unstable
Broad Creek Valley West (western coastal plain)	0.15	0.00	0.013	Stable	0.43	High erosion susceptibility	Unstable	0	11	Stable	0	0	Unstable	Unstable

Using GIS Layers to Predict Stability

Metrics from EPR Ongoing Study at Big Cove (near McConnellsburg PA) and Spring Creek (near Hershey PA) with 66 more sites available for further testing

- Sinuosity
- Forest
- Agriculture
- Development
- Roads
- Soils

Each metric is scored 1-2-3 for low-medium-high instability and then the scores are summed and broken into thirds for assignment of the overall stability rating

Recommendations

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- Principles of Indicator Development
- Desktop Hydromorphology Assessment Tool
- Matrix of Candidate Metrics, Measurement Methods, Thresholds (TBD), and Data Sources

General Principles of Indicator Development

- Represent conditions from least-disturbed to most-disturbed, so that the indicator can show responsiveness across the gradient
- Precise within comparable least-disturbed sites
- Strong, independent response to diverse stressors
- Should have distinguishable values between the least-disturbed and most-disturbed stressor conditions in both calibration and validation data
- To extent possible, the indicator values should be readily interpretable

Principles of Hydromorphology Indicator Development

- Quantify degree of health or include thresholds (likely as deviations from expected values) that are indicative of healthy vs. unhealthy stream hydromorphology
- Regression relationships (regional curves) that estimate bankfull discharge and related channel dimensions based on drainage area (using empirical stream gage data) may be able to serve as the expectation for potential hydromorphology indicators such a floodplain connectivity
- Change over time may serve to determine if a stream has recently become degraded, is continuing to be degraded, or is nearing health again
- Ratings and thresholds should be in context of physiographic region and stream size, such as scaling streams on watershed size, stream order, valley types, stream type, etc.
- Both absolute and relative values should be investigated in terms of practicality, accuracy, and precision

Developing a Desktop Hydromorphology Assessment Tool

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1. Reevaluate recommended potential metrics/indicators
   - Investigate potential for new indicators
2. Reevaluate potential new data sources and/or assessment methodologies
   - Investigate potential for new indicators
3. Select measurement methods to quantify metrics/indicators
   - Ideally, potential measurement methods would be scientifically based and proven to be effective.
4. Select data sources to conduct measurements
   - Selection of measurement methods and data sources will likely be an iterative process
5. Develop metric thresholds that can quantitatively describe the range of stability for each indicator/metric
   - Determining expected (natural) state of the metrics or multi-metric indicator
   - Absolute and relative values for metric thresholds should be investigated
   - Iterative process with measurement methods and data sources
   - Measurement method must be able to quantify the metric
   - Data source must be able to apply measure method

Developing a Desktop Hydromorphology Assessment Tool

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6. Determine whether thresholds need vary with physiographic region, watershed size, stream order, landscape position, valley type, stream type, or other factors
   - Statistical analyses can help tease out the thresholds from a continuum of these factors, if they exist.
7. Refine the Metrics for Hydromorphology Indicator table
8. Develop desktop assessment tool based on selected metrics, measurement methods, data sources, and thresholds
9. Test accuracy of desktop analysis results to empirical data and/or models
   - Ensures the desktop tool accurately predicts stream health
   - Different thresholds for a given metric requires testing needs for each set of thresholds
   - Empirical data require test desktop predictions
10. Iteratively, revise desktop hydromorphology assessment tool based on testing results until tool accurately predicts stream health
11. Validate revised desktop hydromorphology assessment tool with new data
12. Finalize desktop hydromorphology assessment tool

Refined List of Proposed Multi-Metric Hydromorphology Indicators

- Valley type/confinement
- Floodplain connectivity
- Riparian vegetation
- Bedform diversity/stability
- Lateral stability

Matrix of Recommended Metrics/Data for Hydromorphology Indicator Development

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Spatial Dimension	Metric	Measurement Method	Metric Thresholds			Data Source	Comments
			Stable	Partially Unstable	Unstable		
Large Catchment and Landscape Unit (Pyramid Level 1)	Impervious Cover (IC)	Percent IC				Existing GIS IC data layer	
	Runoff	Flashiness				Existing GIS land use / land cover (LULC) and IC data layers; Flow Alteration Metrics (Maloney et al. 2021)	
	Sediment Production	Sediment Load				Existing GIS LULC, IC, soils, and riparian vegetation data layers and flow regime analysis results; Gridded Soil Survey Geographic Database (gSSURGO) and Parameter-elevation Regressions on Independent Slopes Model (USGS under development)	
River Segment (Pyramid Level 2)	Valley Type/ Confinement*	Anthropogenic Confinement				Floodplain and Channel Evaluation Tool (FACET) and valley type based on landscape position; Hyper-Resolution Terrain-based Hydrography Mapping (CIC and UMBC under development)	
	Sediment Transport	Degrading or Aggrading				FACET and floodplain connectivity and channel dimension analysis results; Multi-jurisdictional Rapid Habitat Assessment Database (USGS under development); Gridded Soil Survey Geographic Database (gSSURGO) and Parameter-elevation Regressions on Independent Slopes Model (USGS under development)	

Matrix of Recommended Metrics/Data for Hydromorphology Indicator Development (continued)

Spatial Dimension	Metric	Measurement Method	Metric Thresholds			Data Source	Comments
			Stable	Partially Unstable	Unstable		
Reach (Pyramid Levels 2 & 3)	Floodplain Connectivity*	Bank Height Ratio (BHR)				FACET and bankfull channel dimensions regional curves	
		Entrenchment Ratio (ER)				Hyper-Resolution Terrain-based Hydrography Mapping (CIC and UMBC under development); Stream and Floodplain Geometry Mapping (USGS in revision)	
	Stream Energy	Stream Power				FACET and stream power equation; Stream and Floodplain Geometry Mapping (USGS in revision)	
	Channel Dimension	Width/Depth (W/D) Ratio				FACET and bankfull channel dimensions regional curves	
	Riparian Vegetation*	Width				Existing GIS data layer(s)	
	Planform	Sinuosity/ Meander Pattern based on Valley Type				FACET and potential stream planform based on valley type; Multi-jurisdictional Rapid Habitat Assessment Database (USGS under development); Hyper-Resolution Terrain-based Hydrography Mapping (UMBC under development); Stream and Floodplain Geometry Mapping (USGS in revision)	
		Meander Width Ratio *(C and E Stream Types)*				FACET and potential stream planform based on valley type; Hyper-Resolution Terrain-based Hydrography Mapping (CIC and UMBC under development)	

Matrix of Recommended Metrics/Data for Hydromorphology Indicator Development (continued)

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Spatial Dimension	Metric	Measurement Method	Metric Thresholds			Data Source	Comments
			Stable	Partially Unstable	Unstable		
Geomorphic and Hydraulic Unit (Pyramid Levels 2 & 3)	Bedform Stability*	Channel Slope				Existing GIS data layer(s)	
		Erodible Soils				Existing GIS data layer(s)	
		Percent IC				Existing GIS data layer(s)	
	Lateral Stability*	Bank Erosion Rate				Multi-jurisdictional Rapid Habitat Assessment Database (USGS under development); Gridded Soil Survey Geographic Database (gSSURGO) and Parameter-elevation Regressions on Independent Slopes Model (USGS under development); Stream and Floodplain Geometry Mapping (USGS in revision)	
		Riparian Width				Existing GIS data layer(s)	
	Bedform and Habitat Features*	Bed Habitat *(embeddedness, riffle frequency velocity/depth combination)*				USGS identified 12 rapid habitat metrics and 2 PCA-derived summary metrics (representing bed and bank/riparian elements) with potential for describing habitat quality. Because these rapid habitat data are field assessments at specific sites, Bay-wide coverage would require modeling unsampled streams, as is done for the Chessie BIBI	
		Bank/Riparian Habitat *(riparian condition score, bank stability, bank vegetation, sediment deposition)*				USGS identified 12 rapid habitat metrics and 2 PCA-derived summary metrics (representing bed and bank/riparian elements) with potential for describing habitat quality. Because these rapid habitat data are field assessments at specific sites, Bay-wide coverage would require modeling unsampled streams, as is done for the Chessie BIBI	

Potential Next Steps

- Large body of useful work in hydromorphology has been documented
- Next step might be to combine the efforts of current investigators into a central team, including:
  - USGS staff working with FACET and rapid habitat assessment data
  - Individuals working on hyper-resolution mapping at Chesapeake Conservancy CIC and UMBC
- Our recommended approach is similar to restoration planning effort by Maryland DNR that developed quintile-based hydromorphology indicators by comparing FACET results to regional curves