Hydrogeomorphic (HGM) Functions in Appalachian Headwater and Perennial Streams

United States Army Corps of Engineers, ERDC
Functions in Streams

1) Hydrology
2) Biogeochemical cycling
3) Habitat
Function 1
Hydrology

- Definition: the ability of a stream to dissipate energy associated with flow velocity and transport water downstream
Rationale

- Water transport and energy dissipation are fundamental functions of streams
- Affects the amount of sediment, organic matter and nutrients transported downstream
Effects of Hydrology

- Hydrologic alterations increase runoff and bank erosion, increasing sediment in channel.
- Stream energy affects movement of materials downstream.
- Excess sediment reduces habitat:
  - Macroinvertebrates
  - Amphibians
  - Fish
Influences to Hydrology

- **Natural conditions:**
  - Climate
  - Geomorphic characteristics
  - Soil

- **Anthropogenic alterations to watershed and riparian areas**
  - Logging
  - Urban development
  - Agriculture
  - Grazing
  - Filling
  - Road building
  - Removal of large woody debris
Variables for Hydrology Function – Headwater Streams:

- Channel Substrate Embeddedness ($V_{EMBED}$)
- Channel Substrate Size ($V_{SUBSTRATE}$)
- Channel Bank Erosion ($V_{BERO}$)
- Large Woody Debris ($V_{LWD}$)  
  - Affects flow and dissipation of stream energy
- Watershed Land-use ($V_{WLUSE}$) 
  - Affect timing and delivery of water to the channel
Hydrology Functional Capacity Index – Headwater Streams

\[
FCI = \left\{ V_{WLUSE} + \left[ \frac{V_{LWD} + \min(V_{SUBSTRATE}, V_{EMBED}, V_{BERO})}{2} \right] \right\} \div 2
\]

- Water inputs from surrounding watershed
- Large woody debris in the riparian/buffer zone
- Channel indicators of hydrology
Variables for Hydrology Function – Perennial Streams:

- **Streambank Stability** ($V_{BANKSTAB}$)
  - If banks are not excessively eroded, channel flow, sediment transport and stream energy are likely appropriate

- **Channel Substrate Size** ($V_{SUBSTRATE}$)
  - Indicator of degradation in channel

- **Channel Substrate Embeddedness** ($V_{EMBED}$)
Hydrology Functional Capacity Index – Perennial Streams

\[ FCI = \frac{V_{BANKSTAB} + \min (V_{EMBED}, V_{SUBSTRATE})}{2} \]

- Bank conditions
- Hydrologic impacts to channel substrate
Function 2
Biogeochemistry

- Definition: ability of stream to retain and transform inorganic materials into organic forms and oxidize back into elemental forms through respiration and decomposition

- Includes activities of
  - Producers
  - Consumers
  - Decomposers
Rationale

- Supply of organic carbon maintains plant community
  - Primary productivity
  - Species composition
- Plant community provides food and structure for animal community
- Decomposers break down these organic materials, which reenter the nutrient cycle
Biogeochemistry: Processes

- 4 components of carbon cycle
  - Soil
  - Plants
  - Consumers (animals, fungi, bacteria)
  - Detritus

- Primary production sets the stage for all other processes
Influences to Biogeochemical Cycling

- Changes in vegetative cover
  - Amount of detritus
  - Temperature
  - Nutrients in soil

- Hydrologic alterations
  - Plant community
  - Nutrient delivery to channel

- Other alterations
  - Deposition of fill
  - Excavation
  - Fire
Variables for Biogeochemical Cycling Function – Headwater Streams:

- Channel Substrate Embeddedness ($V_{EMBED}$)
- Large Woody Debris ($V_{LWD}$)
- Riparian/Buffer Zone Tree Diameter ($V_{TDBH}$)
- Riparian/Buffer Zone Soil Detritus ($V_{DETRITUS}$)
- Watershed Land-use ($V_{WLUSE}$)
- Riparian/Buffer Zone Sapling/Shrub Density ($V_{SSD}$)
- Riparian/Buffer Zone Herbaceous Cover ($V_{HERB}$)

*Only for streams with <20% canopy cover*
Biogeochmoechemical Cycling Functional Capacity Index – Headwater Streams

Streams with ≥20% canopy cover:

\[ FCI = \left\{ V_{EMBED} \times \left[ \frac{V_{LWD} + V_{DETRITUS} + V_{TDBH}}{3} + V_{WLUSE} \right] + \frac{V_{LWD} + V_{DETRITUS} + V_{SSD} + V_{HERB}}{4} \right\}^{1/2} \]

Nutrient retention in channel

Nutrient inputs and long-term retention

Inputs from watershed

Streams with <20% canopy cover:
Variables for Biogeochemical Cycling Function – Perennial Streams:

- Channel Substrate Embeddedness \( (V_{EMBED}) \)
- Channel Substrate Size \( (V_{SUBSTRATE}) \)
- Channel Canopy Cover \( (V_{CCANOPY}) \)
- Riparian/Buffer Zone Tree Density \( (V_{TDEN}) \)
Biogeochemical Cycling Functional Capacity Index – Perennial Streams

$$FCI = \left\{ \frac{\min (V_{EMBED}, V_{SUBSTRATE}) + \min (V_{CCANOPY}, V_{TDEN})}{2} \right\}$$

Nutrient retention in channel

Nutrient inputs and retention
Function 3: Habitat

Definition:

- The capacity of a stream ecosystem to provide critical life requisites to selected components of the vertebrate and invertebrate wildlife communities
Rationale:

• Species found in and around streams often are unique and not found in other ecosystems

• Responsible for secondary productivity and energy flows among trophic levels
Impacts to the Wildlife Community Influence:

- Secondary productivity
- Carbon and nutrient export/transport
- Biological diversity including richness and evenness of the animal community itself and of the plant community
  - Patch level
  - Landscape level
- Trophic level processes
Impacts to Wildlife

- Hydrologic alteration
  - Scouring decreases habitat availability
  - Increases in fine sediment inhibit respiration
  - Turbidity slows primary production
  - Increased flows wash away fish eggs and young
Impacts to Wildlife (cont.)

- Channel vegetative cover
  - Water temperature and light levels
  - Detritus inputs to channel
    - Food availability
    - Breeding sites
    - Refugia

- Riparian and watershed vegetation
  - Amphibian habitat and dispersal
  - Erosion and sedimentation reduction
Variables for Habitat Function – Headwater Streams:

- Channel Canopy Cover \( (V_{CCANOPY}) \)
- Channel Substrate Embeddedness \( (V_{EMBED}) \)
- Channel Substrate Size \( (V_{SUBSTRATE}) \)
- Channel Bank Erosion \( (V_{BERO}) \)
- Large Woody Debris \( (V_{LWD}) \)
- Riparian/Buffer Zone Tree Diameter \( (V_{TDBH}) \)
Variables for Habitat Function – Headwater Streams (cont.):

- Riparian/Buffer Zone Snag Density ($V_{SNAG}$)
- Riparian/Buffer Zone Vegetation Species Richness ($V_{SRICH}$)
- Riparian/Buffer Zone Soil Detritus ($V_{DETRITUS}$)
- Watershed Land-use ($V_{WLUSE}$)
- Riparian/Buffer Zone Herbaceous Cover ($V_{HERB}$)
- Riparian/Buffer Zone Sapling/Shrub Density ($V_{SSD}$)

Only for streams with <20% canopy cover
Habitat Functional Capacity Index – Headwater Streams

Streams with \( \geq 20\% \) canopy cover:

\[
FCI = \left\{ \frac{V_{\text{CCANOPY}} + \min(V_{\text{EMBED}}, V_{\text{SUBSTRATE}})}{2} \right\} \times \left\{ \frac{V_{LWD} + V_{\text{DETRITUS}}}{2} + \frac{V_{\text{SNAG}} + V_{TDBH} + V_{\text{SRICH}}}{3} \right\}^{\frac{1}{2}} + V_{\text{WLUSE}}
\]
Habitat Functional Capacity Index – Headwater Streams (cont.)

Streams with <20% canopy cover:

\[
FCI = \min(V_{EMBED}, V_{SUBSTRATE}) \times \left( \frac{V_{LWD} + V_{DETRITUS}}{2} + \left[ \frac{V_{SNAG} + V_{SSD} + V_{HERB} + V_{SRICH}}{6} \right] + V_{WLUSE} \right)^{\frac{1}{2}}
\]

Channel characteristics
Riparian condition and seral stage
Watershed condition
Variables for Habitat Function – Perennial Streams:

- Channel Canopy Cover ($V_{CCANOPY}$)
- Channel Substrate Embeddedness ($V_{EMBED}$)
- Channel Substrate Size ($V_{SUBSTRATE}$)
- Large Woody Debris ($V_{LWD}$)
- Percent Forest ($V_{FOREST}$)
- Riparian/Buffer Zone Tree Diameter ($V_{TDBH}$)
- Coefficient of Conservatism ($V_{CVALUE}$)
Habitat Functional Capacity Index – Headwater Streams

\[
FCI = \left\{ \frac{V_{\text{CANOPY}} + \min (V_{\text{EMBED}}, V_{\text{SUBSTRATE}})}{2} \right\} \times \left\{ \frac{V_{\text{LWD}} + V_{\text{FOREST}} + \left( \frac{V_{\text{DBH}} + V_{\text{CVALUE}}}{2} \right)}{3} \right\}^{1/2}
\]

- Channel characteristics
- Riparian and channel woody debris
- Watershed condition
- Riparian/buffer zone
  - Species composition
  - Seral stage
Questions?