Programs for geomorphic analysis

Dan Miller
TerrainWorks, Inc.
M2 Environmental Services

CUGOS - Cascadia Users of Geospatial Open Source
October 6, 2019

Geomorphology – study of Earth's surface processes

- How do century-long sequences of fires, storms, and floods influence stream characteristics over entire river networks?
- How do salmon populations respond to those climate drivers?
- How do human alterations to these drivers affect those populations?

To answer such questions, we needed a

Conceptual Framework

Spatial Template –

Valley and Channel Form
Sediment Production, Delivery, Storage

Dynamic Drivers –

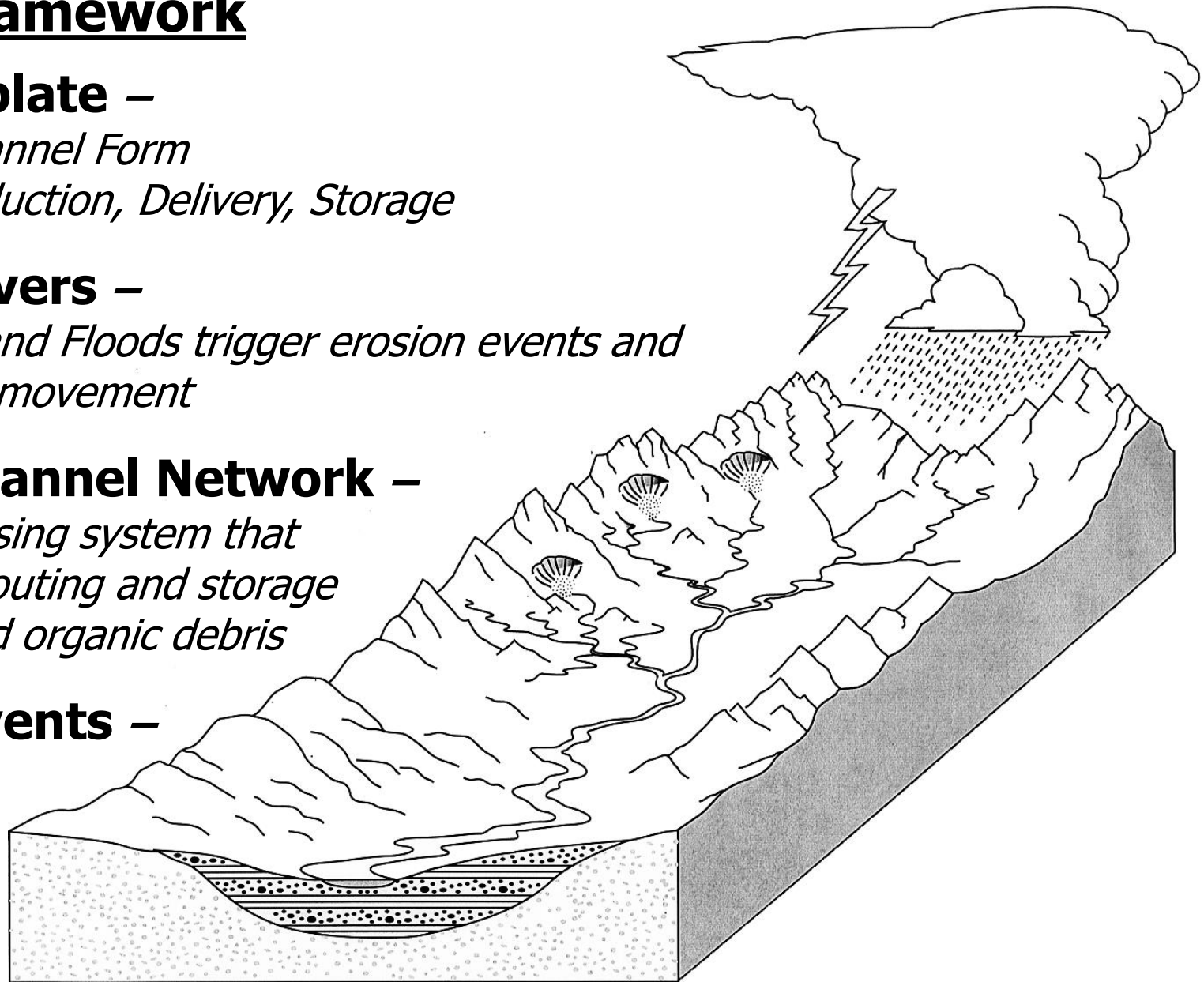
Storms, Fires, and Floods trigger erosion events and drive sediment movement

Branched Channel Network –

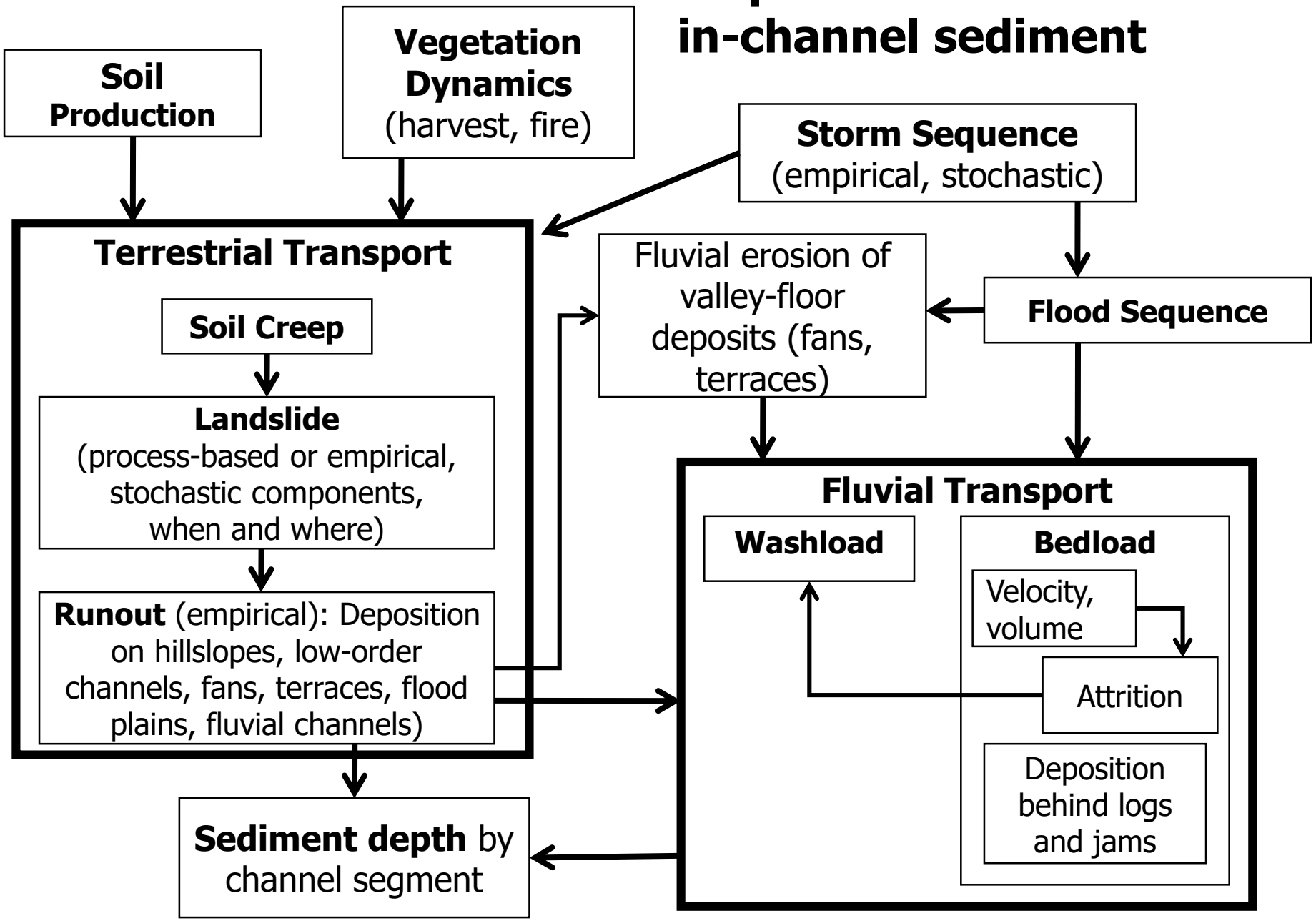
A signal-processing system that organizes the routing and storage of sediment and organic debris

History of Events –

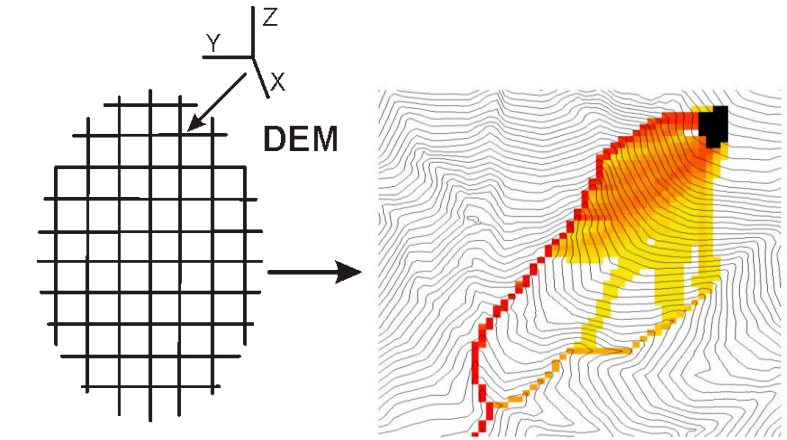
Determines antecedent conditions



Sequence of models for in-channel sediment

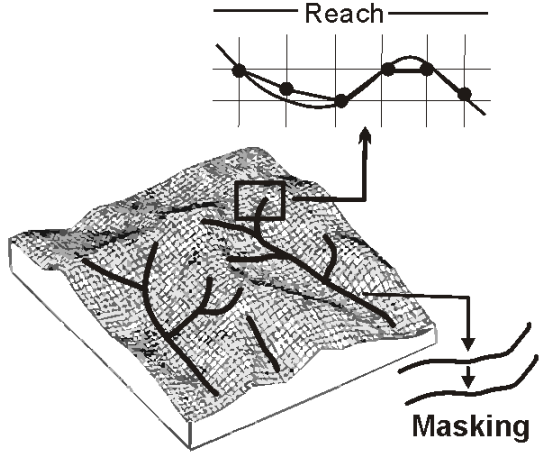


Data structures to characterize temporal and spatial interactions between landscape elements

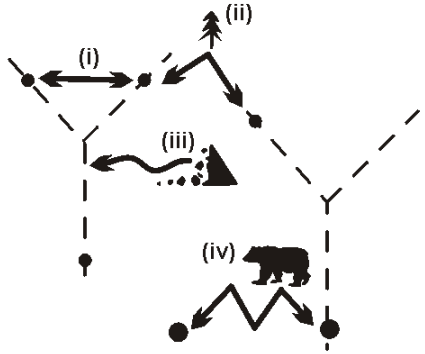


(1) Flow direction

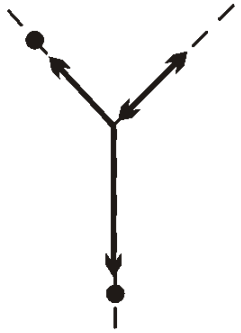
Flow accumulation



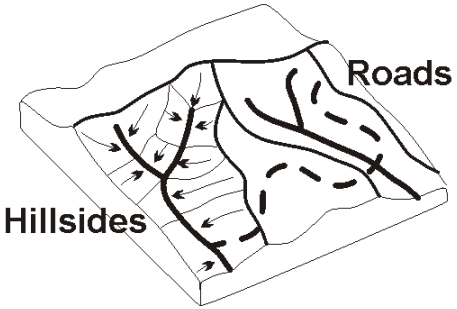
River Network



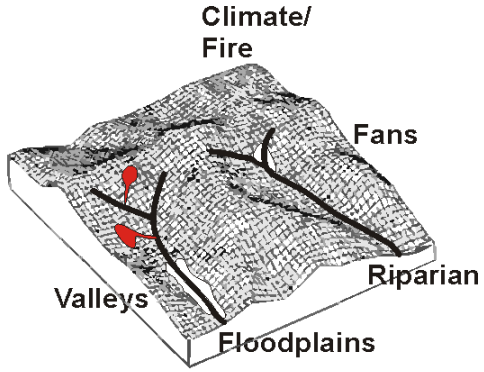
(2) Connecting



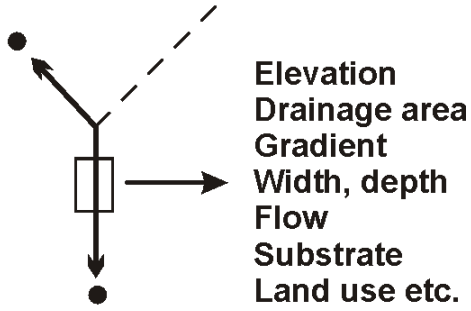
(3) Routing



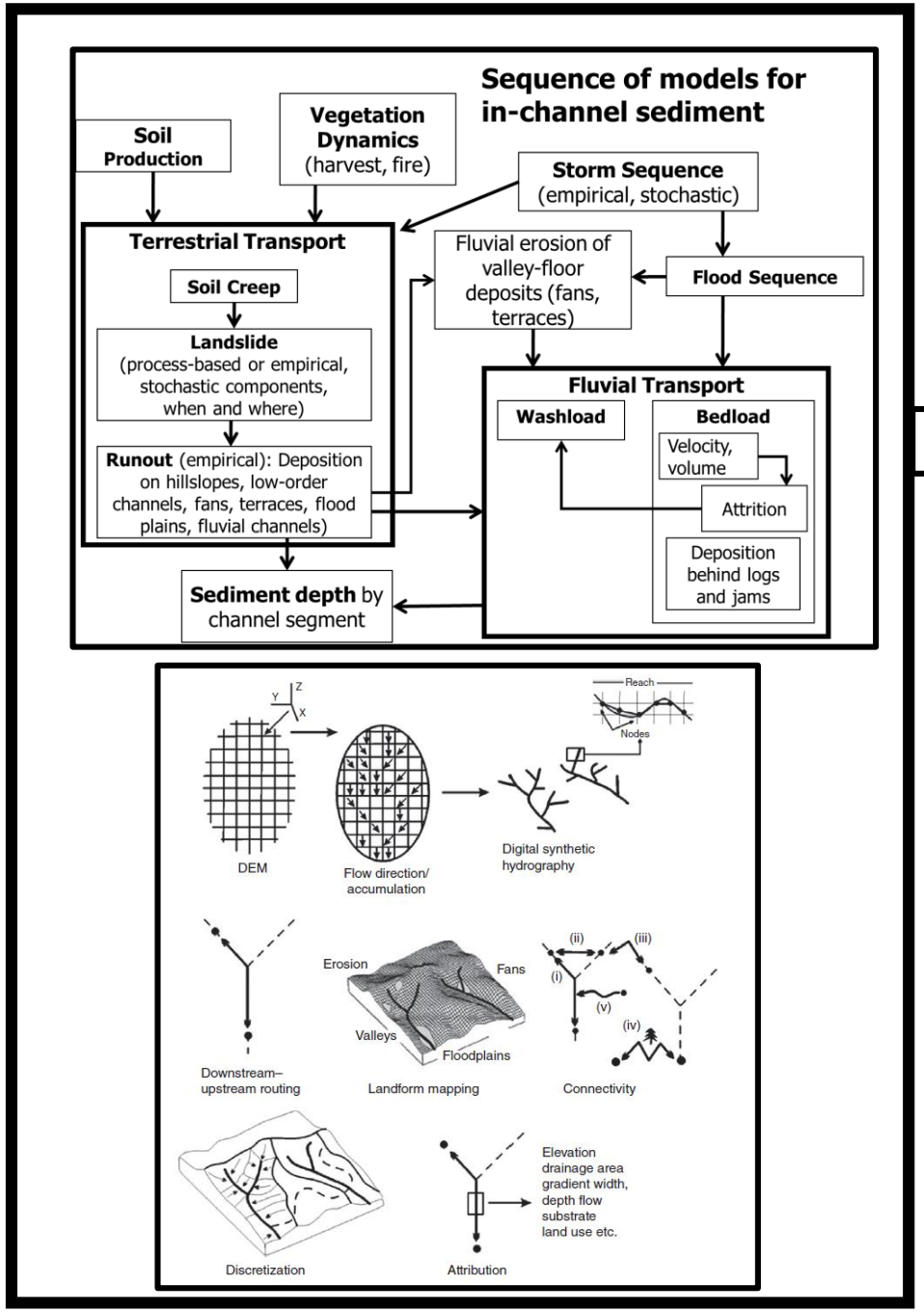
(4) Discretizing



(5) Landforms



(6) Attributing



NetStream

An integrated Fortran library:

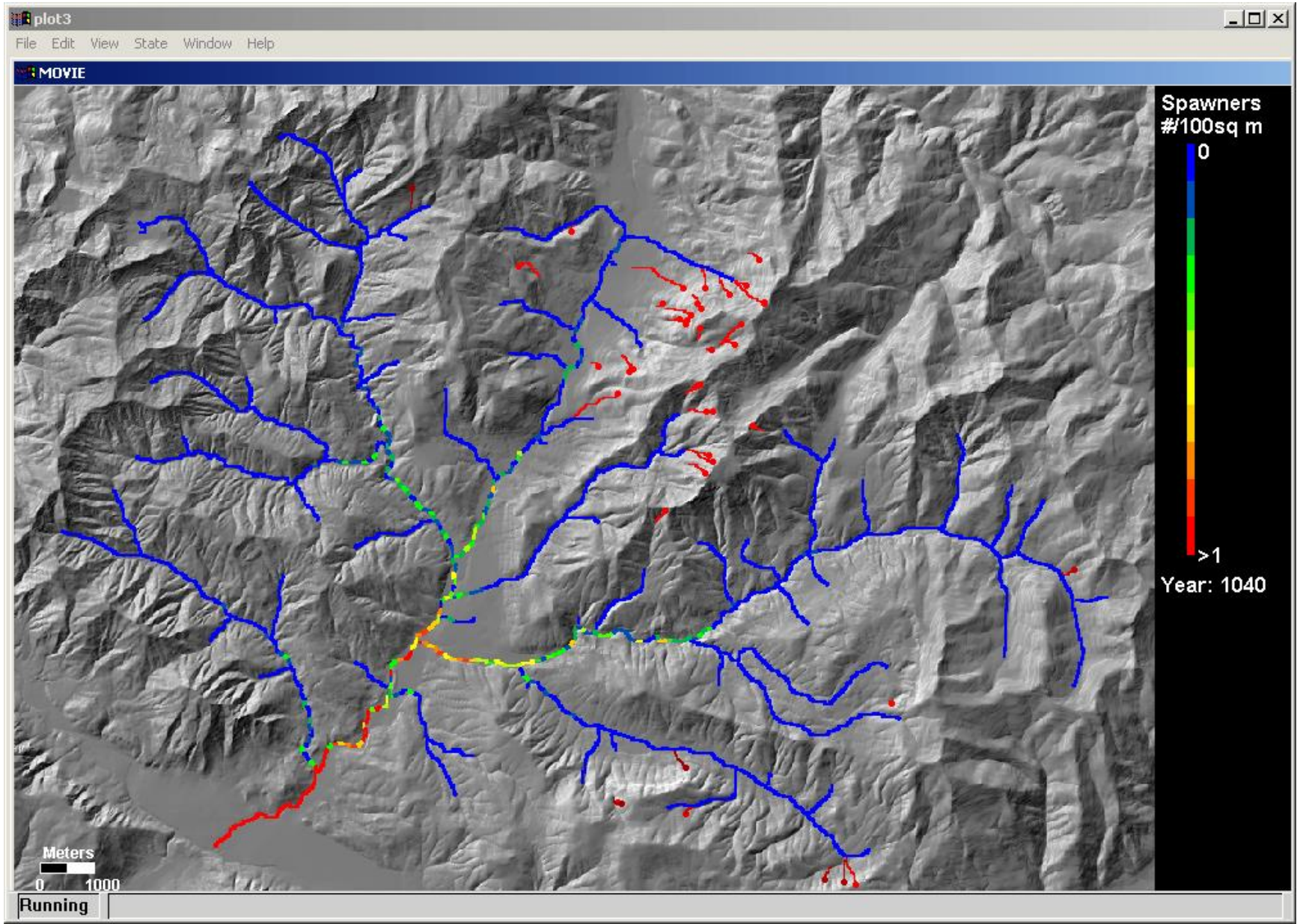
- DEM processing
  - ✓ Filtering, adaptive smoothing
  - ✓ Multi-scale surface metrics
  - ✓ Flow routing
- Hydrology
  - ✓ Network extraction
  - ✓ Linked-node network
- Floodplain delineation
- Landslide initiation and runout
- Image processing
  - ✓ Segmentation of water masks
- Tree-fall

Field observations => simulation models

Identify processes. Quantify rates. Model interactions over space and time.

Linked process-based and empirical, stochastic models:

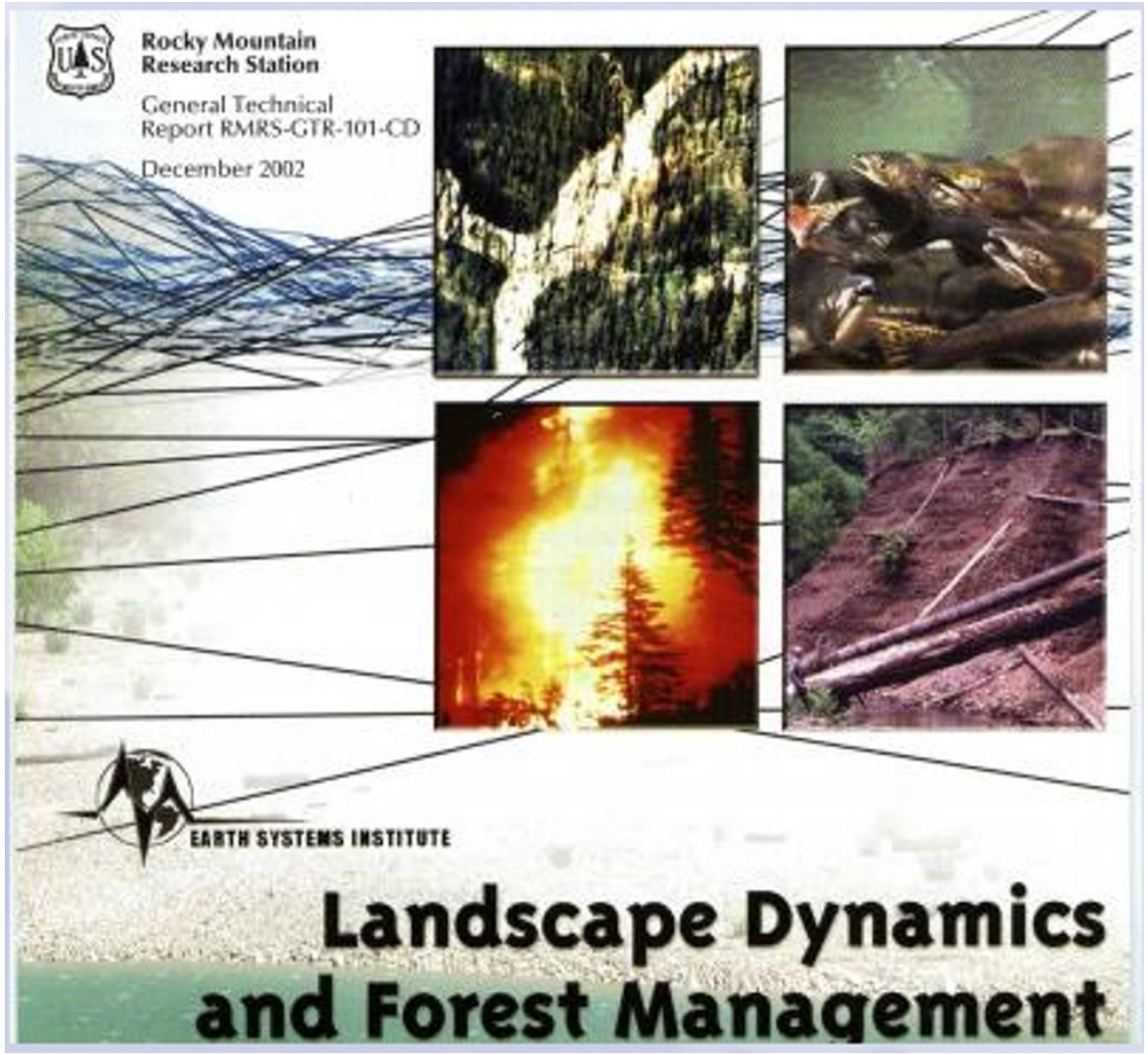
- Fires
- Storms
- Floods
- Forest growth
- Landslides
- Debris flows
- Bank slumps
- Soil Creep
- Fluvial transport
- Wood recruitment
- Jam formation
- Wood transport



US Forest Service

Rocky Mountain Research Station

General Technical Report RMRS-GTR 101-CD



Research questions:

- How do century-long sequences of fires, storms, and floods influence stream characteristics over entire river networks?
- How do salmon populations respond to these climate drivers?
- How do human alterations to these drivers affect those populations?

Applied questions:

- Which stream reaches have high potential for providing aquatic habitat?
- Which stream reaches are sensitive to increases in water temperature?
- How big do stream buffers need to be to maintain adequate shade?
- Which road segments produce the most sediment delivered to streams?
- Which slopes pose landslide hazards?
- Where would thinning (cutting trees) to reduce fuel loads produce the largest reduction in post-wildfire sediment production?

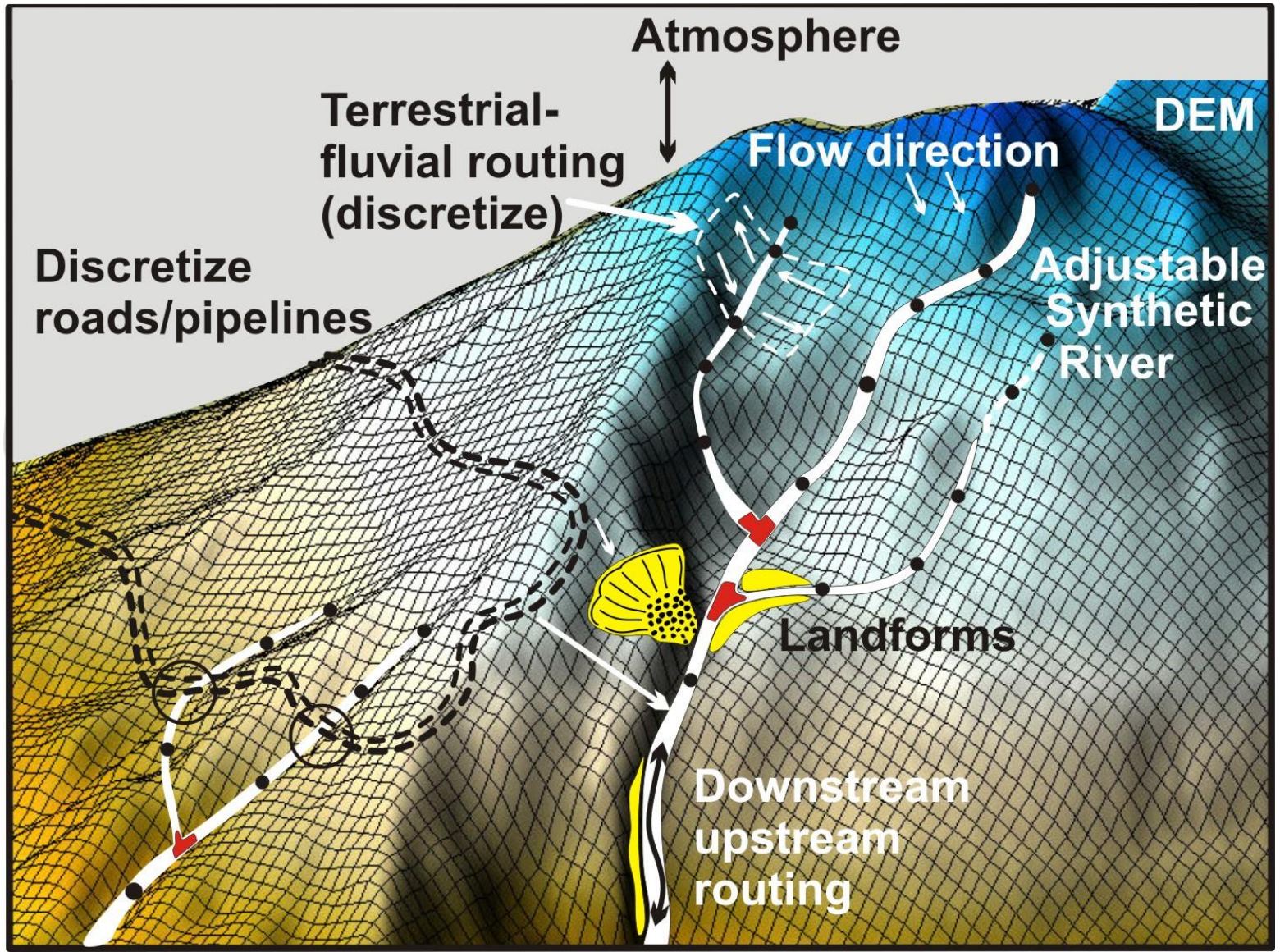
How applied questions often get addressed:

Virtual watershed: a digital environment linking landforms with physical and biological processes in context with human activities and infrastructure

Computer based
- Link existing models and data
- Simulate interactions
- Try different scenarios
- Consistent, objective

Spatially Explicit
- Visualize relationships
- See patterns
- Identify linkages

GIS user interface
- Share data
- Share tools
- Common methodology



NetStream

An integrated Fortran library:

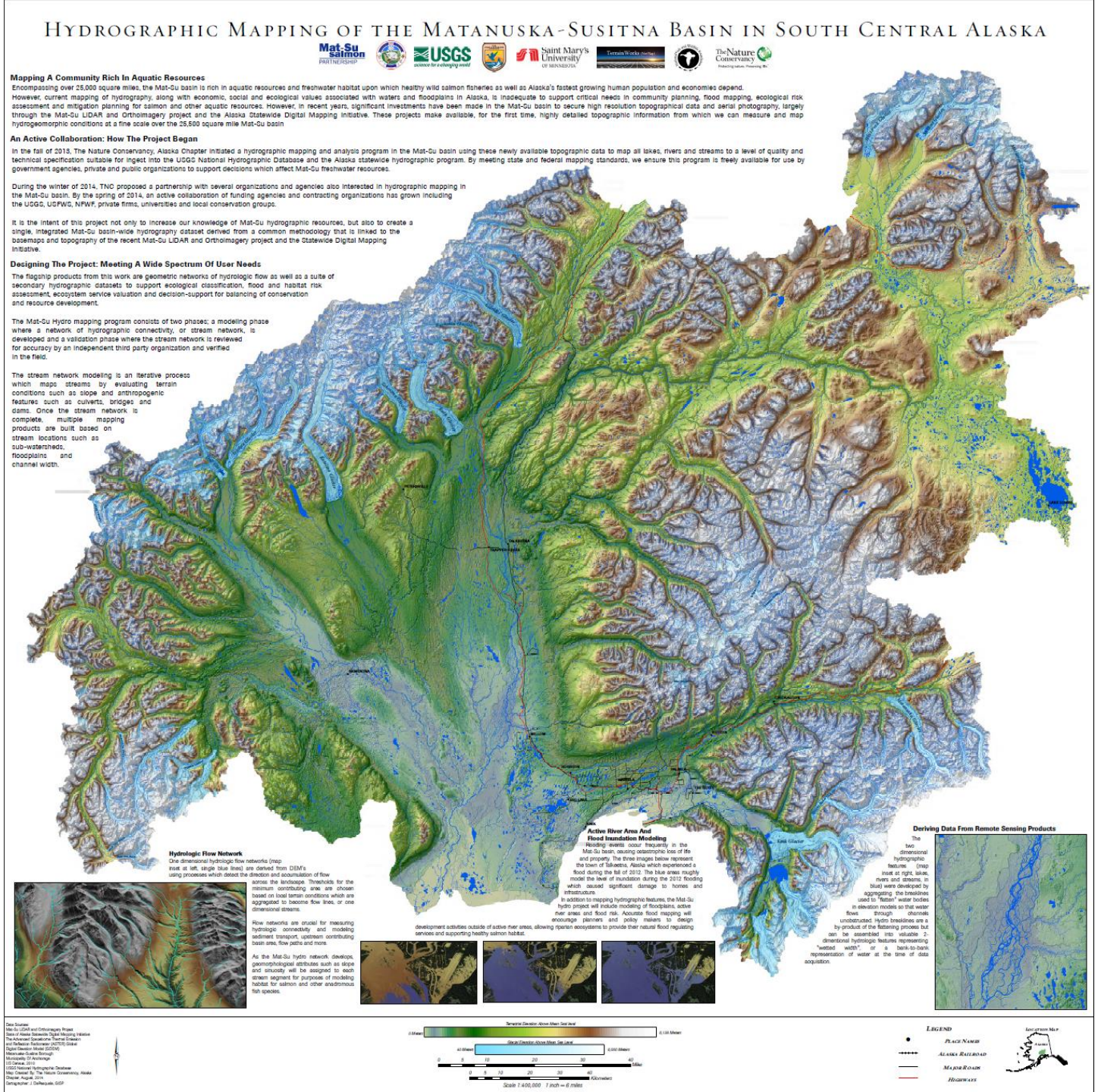
- DEM processing
  - ✓Filtering, adaptive smoothing
  - ✓Multi-scale surface metrics
  - ✓Flow routing
- Image processing
  - ✓ Segmentation of water masks
- Hydrology
  - ✓ Network extraction
  - ✓ Linked-node network
- Floodplain delineation
- Tree-fall
- Landslide initiation and runout
- Road network hydrographs and sediment flux

NetMap https://www.netmapportal.com/

Data sets for watershed characterization
Technical documentation
Web browsers
ArcGIS add-in with modules for:

- Channel network delineation and attribution
- Habitat intrinsic potential
- Solar insolation - shade
- Road-network analyses
- Floodplain elements
- Riparian zone delineation
- Wetland delineation
- Wood recruitment
- Pre- and post-fire erosion
- Ranking, prioritization

Updating the National Hydrographic Dataset using channel networks derived from digital elevation data in Alaska



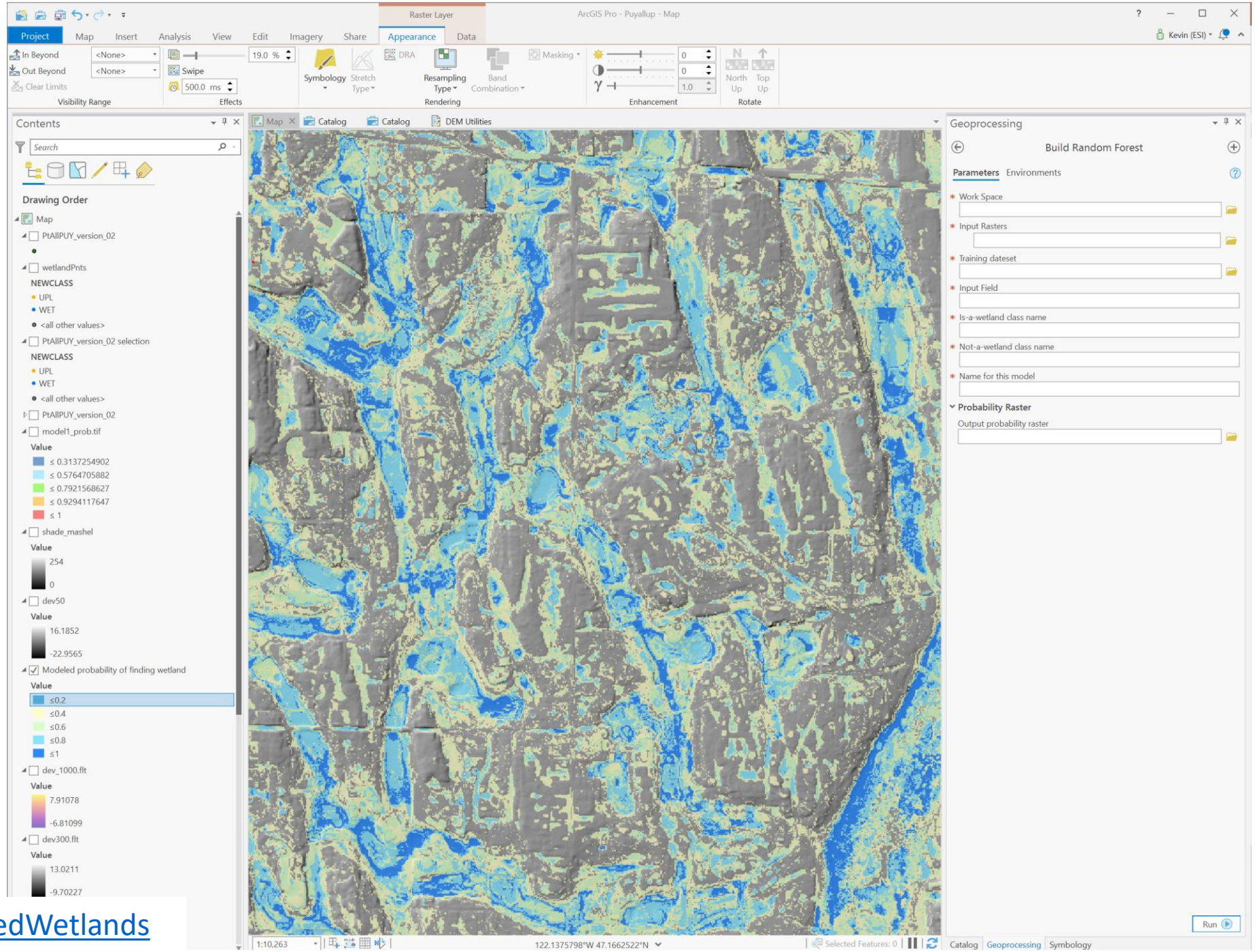
63,600 km^2

Relief > 6,000m

> 145,000 km of stream channels

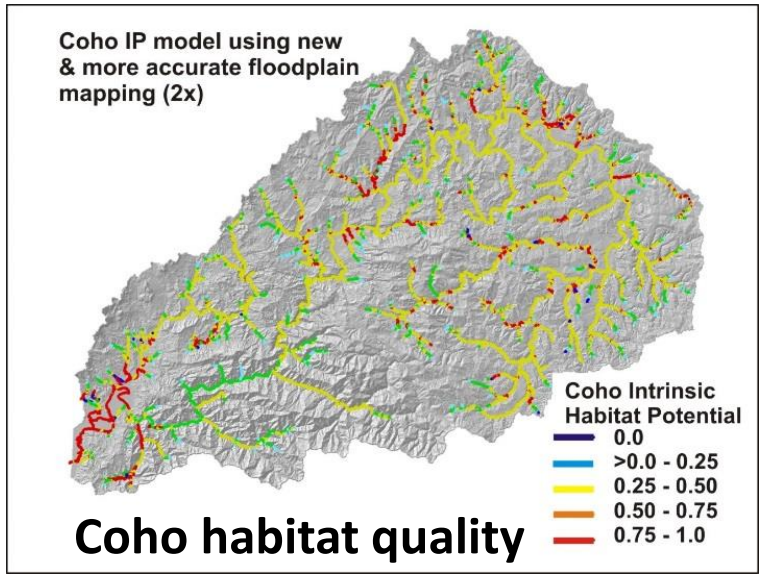
Linking to python and R scripts to build ArcGIS toolboxes

Probability of wetland occurrence derived from topographic attributes using machine learning



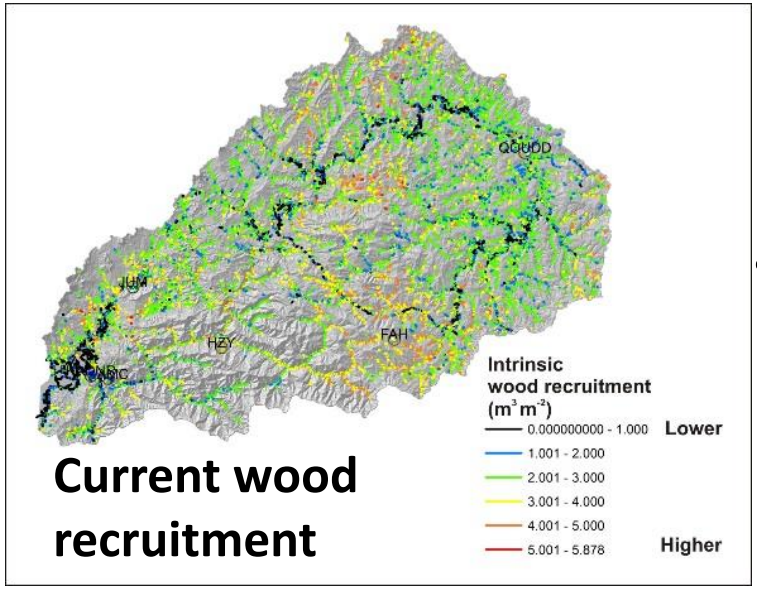
github.com/DanMillerM2/ForestedWetlands

Watershed restoration planning.



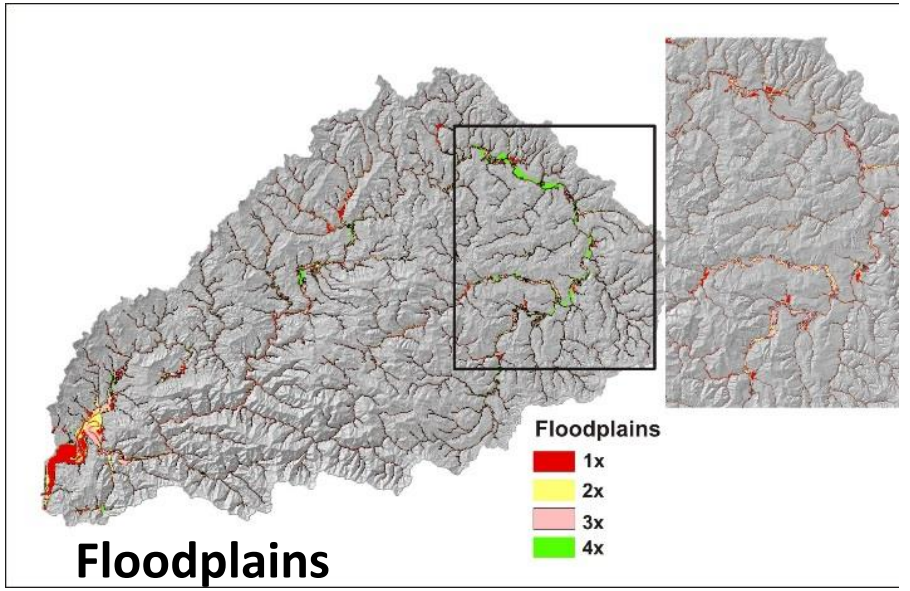
Coho habitat quality

+



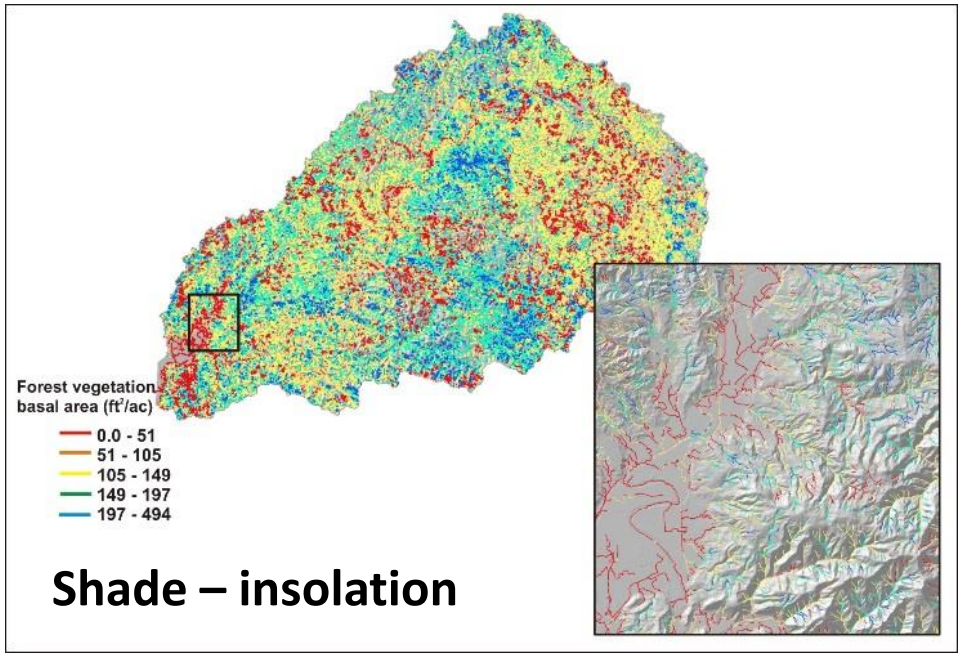
Current wood recruitment

+



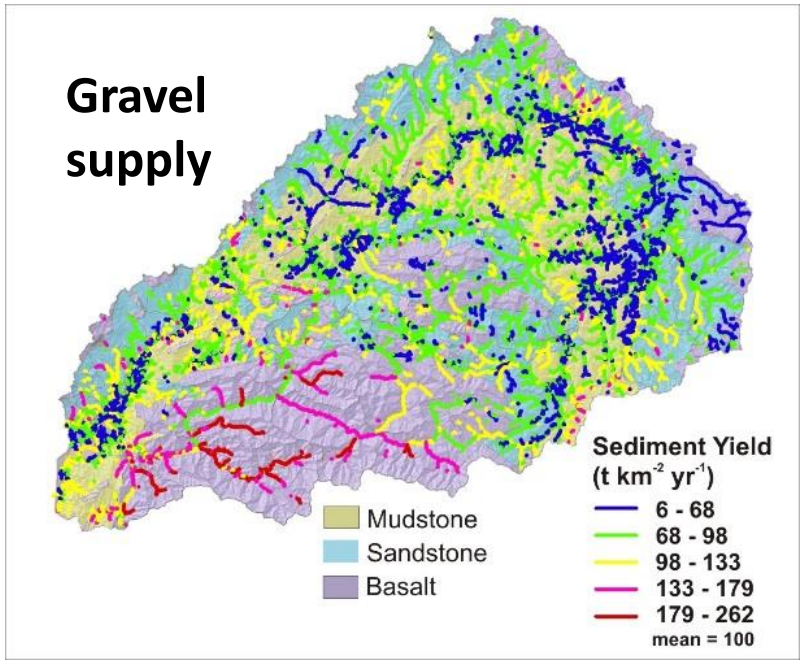
Floodplains

+



Shade – insolation

+



NOAA, ODFW & Nehalem Watershed Council

TerrainWorks (www.terrainworks.com)

Studies and analyses using this software are widely documented in published literature

Benda, L., et al. (2019). "Road Erosion and Delivery Index (READI): A Model for Evaluating Unpaved Road Erosion and Stream Sediment Delivery." JAWRA Journal of the American Water Resources Association **55**(2): 459-484

Spies, T. A., et al. (2018). Synthesis of Science to Inform Land Management Within the Northwest Forest Plan Area. USDA Forest Service, PNW-GTR-966.

González-Ferreras, A. M. and J. Barquín (2017). "Mapping the temporary and perennial character of whole river networks." Water Resour. Res., **53**, 6709– 6724.

Alvarez-Cabria, M., et al. (2017). "Modelling macroinvertebrate and fish biotic indices: From reaches to entire river networks." Sci Total Environ **577**: 308-318.

Bigelow, P., et al. (2016). "Delineating incised stream sediment sources within a San Francisco Bay tributary basin." Earth Surface Dynamics **4**(3): 531-547.

Reeves, G. H., et al. (2016). An initial evaluation of potential options for managing riparian reserves of the aquatic conservation strategy of the Northest Forest Plan, USDA Forest Service, PNW-GTR-937.

Barquin, J., et al. (2015). "Coupling virtual watersheds with ecosystem services assessment: a 21st century platform to support river research and management." WIREs Water.

Welty, E. Z., et al. (2015). "Multiscale Analysis of River Networks using the R Package linbin." North American Journal of Fisheries Management **35**(4): 802-809.

Benda, L. E., et al. (2015). "Thinning and in-stream wood recruitment in riparian second growth forests in coastal Oregon and the use of buffers and tree tipping as mitigation." Journal of Forestry Research **27**(4): 821-836.

Bidlack, A. L., et al. (2014). "Identifying suitable habitat for Chinook salmon across a large, glaciated watershed." Transaction of the American Fisheries Society **143**(3): 689-699.

An integrated Fortran library:

- DEM processing
  - ✓Filtering, adaptive smoothing
  - ✓Multi-scale surface metrics
  - ✓Flow routing
- Image processing
  - ✓ Segmentation of water masks
- Hydrology
  - ✓ Network extraction
  - ✓ Linked-node network
- Floodplain delineation
- Tree-fall
- Landslide initiation and runout
- Road network hydrographs and sediment flux

Source on Subversion repositories
- move to github (?)
- GPL v3

Compiled binaries available for windows

Not well documented (yet)

dan@terrainworks.com

github.com/DanMillerM2