Scalable applications for mapping stream channels from high-resolution terrain data

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Project goal

Develop a scalable approach for mapping streams that incorporates geographically-dependent variables that impact channel initiation

Key players

Peter Claggett, USGS, CBP

- Liaison with CPB to ensure that project meets CBP goals

Matt Baker, PhD, University of Maryland Baltimore County

- Academic oversight and guidance
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- Project researcher and GIS implementer
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- Project management and GIS support
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Key project components

Collection of field data

Literature review

Mapping protocol

Report

Definitions & concepts

Channel – path of concentrated flow and sediment transport between well-defined banks

Channel head – upstream terminus of channel

Channel initiation – the process by which channels form, typically a result of erosion by overland flow, subsurface flow intersecting the land surface, mass failure, or any combination of the three

Perennial stream – a channel with continuously flowing water year-round

Intermittent stream – a channel with flowing water only after a rain event or during a wet season

Drainage area – the area of land upslope from any given point (in this case, points along channels) to the drainage divide; also referred to as "contributing area" or "catchment"

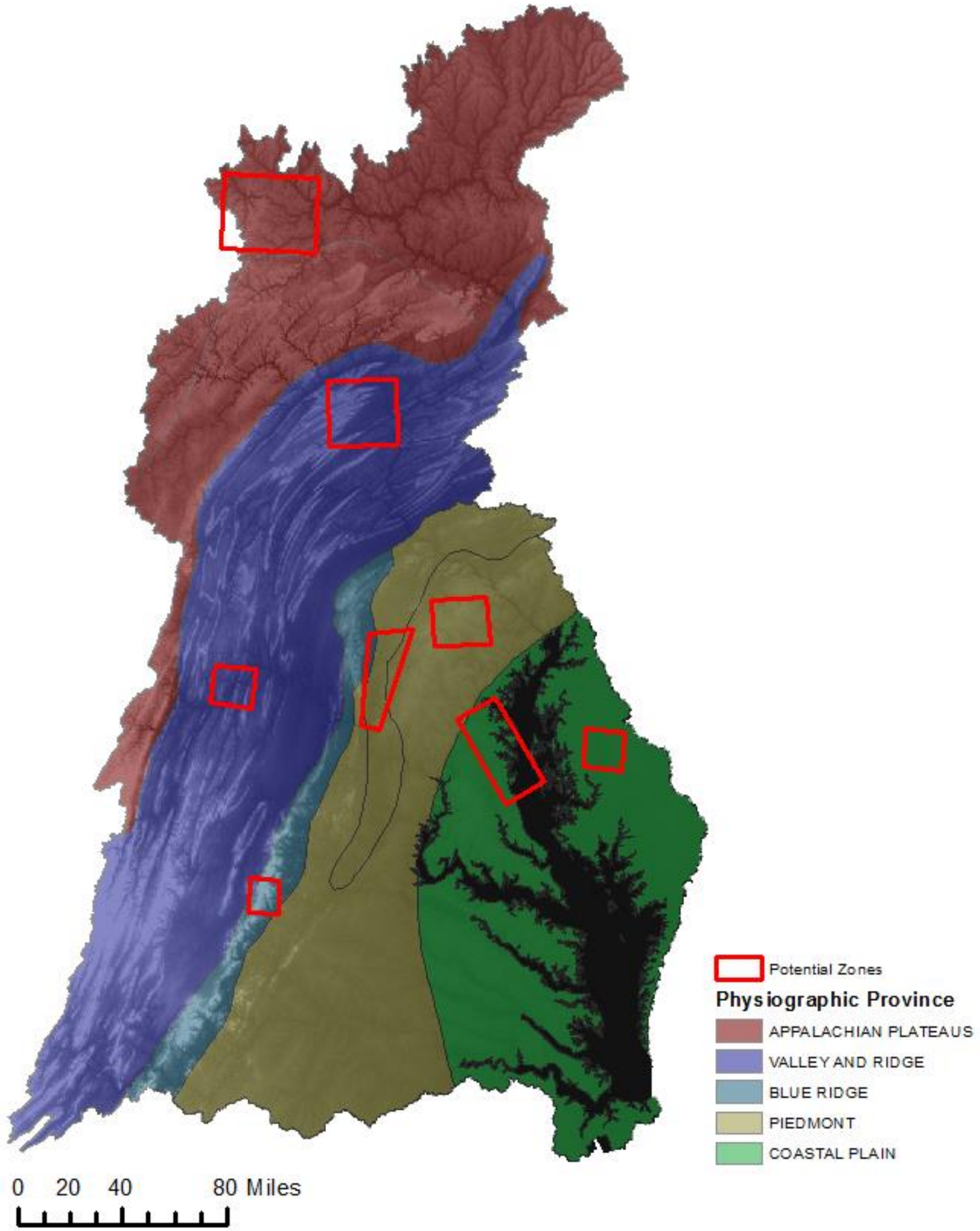
Field surveys - Location

8 “zones” were selected as areas to target field surveys

Each zone was selected to represent a different physiographic context across the Bay watershed

Geology, topography, LiDAR availability, public access, and other factors were taken into account when selecting zones

2 “sites” within each zone will be selected to reflect different land use contexts while keeping physiography constant



Field surveys – Study sites

2 “sites” within each zone will be selected for field surveying

- One site from each zone will be a forested catchment
- Other site from each zone will be a developed catchment
- If possible, an agricultural catchment will also be visited in each zone, though we expect this to be unlikely due to limited access

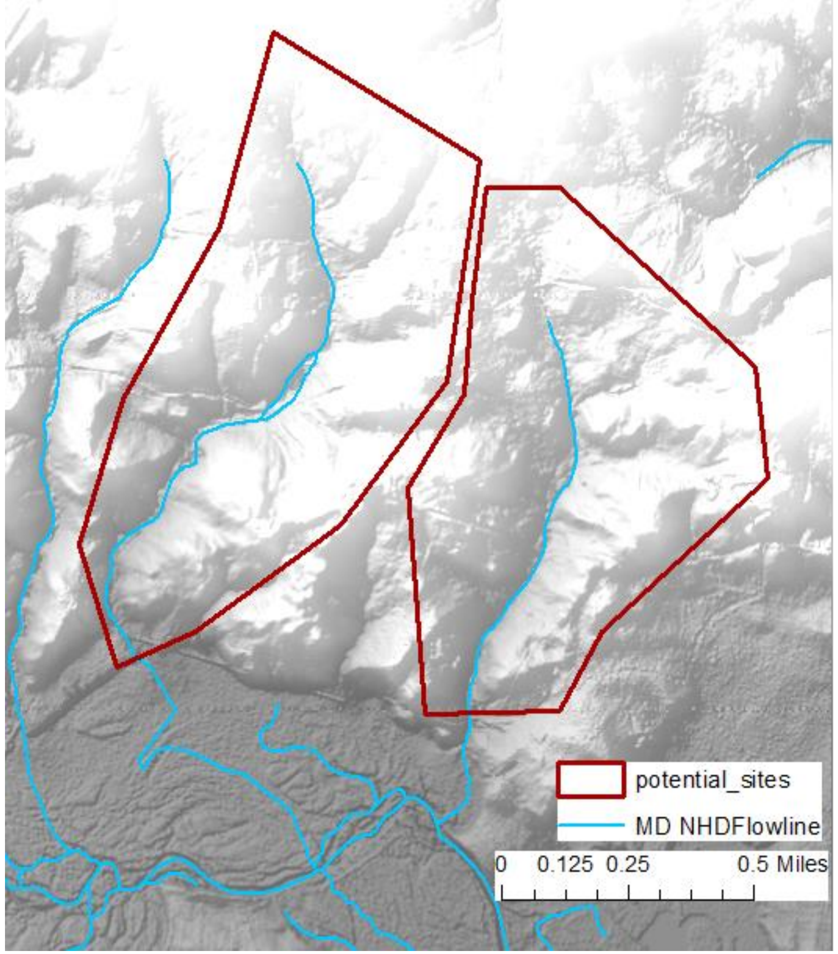
Sites will be small catchments – goal is to survey both sites in a zone within 1 or 2 days

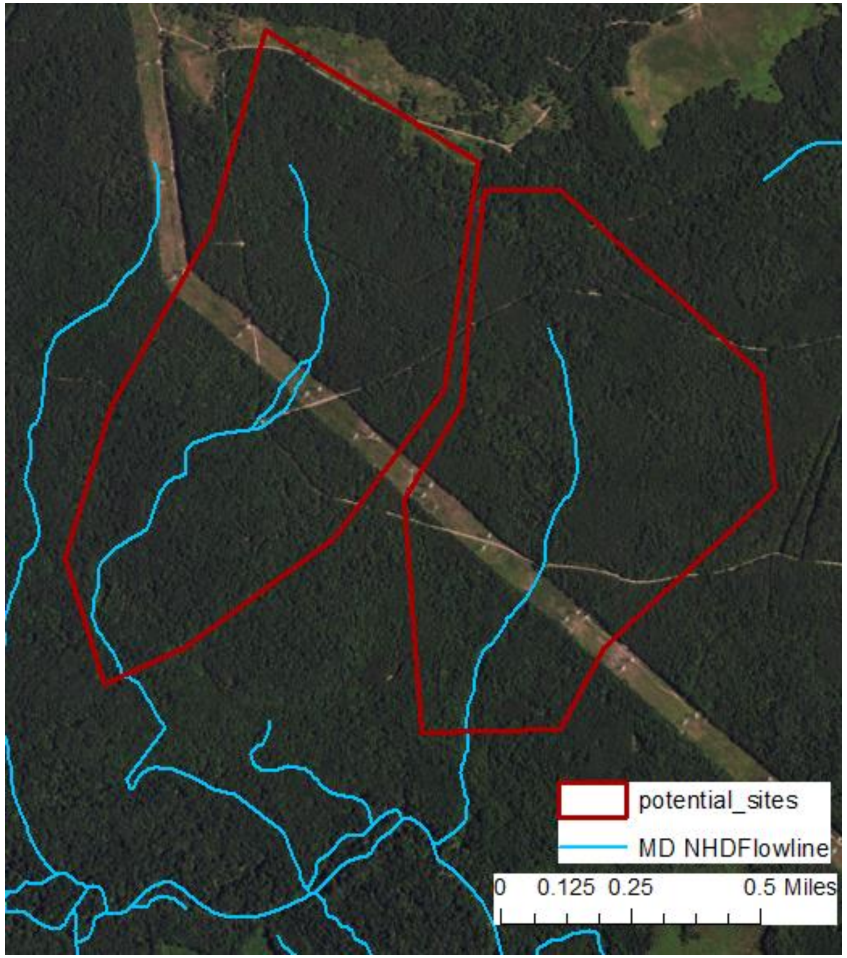
Sites selected based on public access, land use, presence of NHD blue lines

Example – Potential sites

Two candidate forested catchments in the Coastal Plain region

Catchments include mapped NHD blue lines as well as topographic concavities that could potentially support channels not mapped in NHD (visible in hill-shaded image on left)

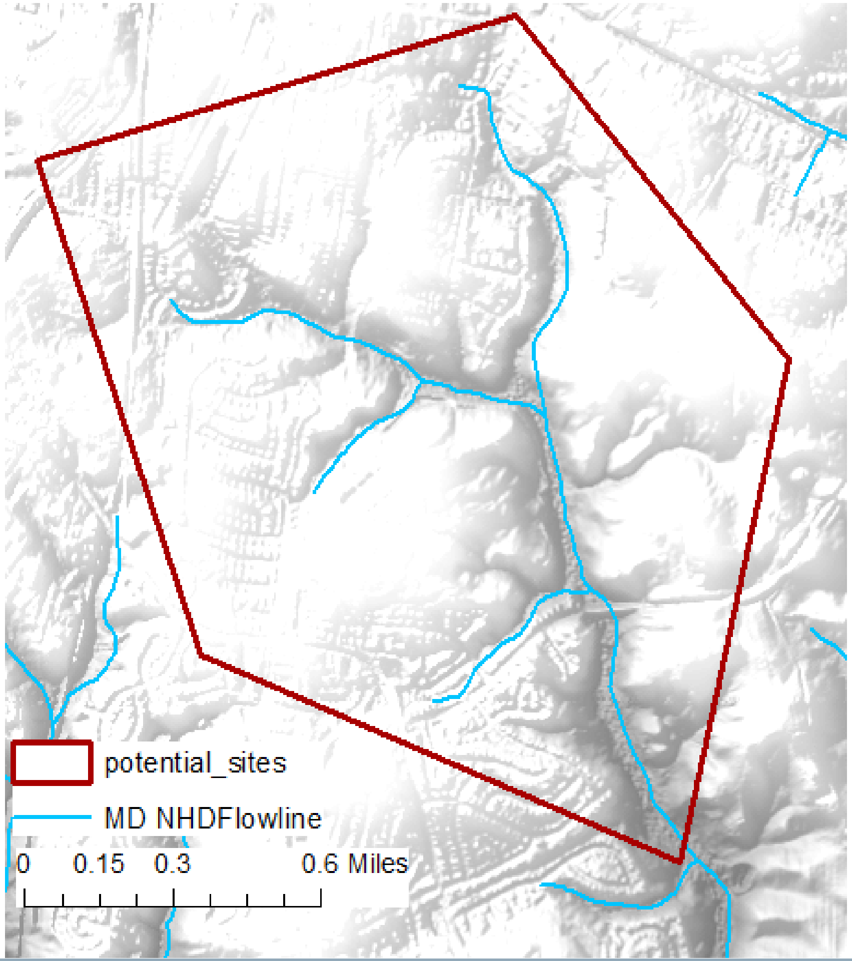


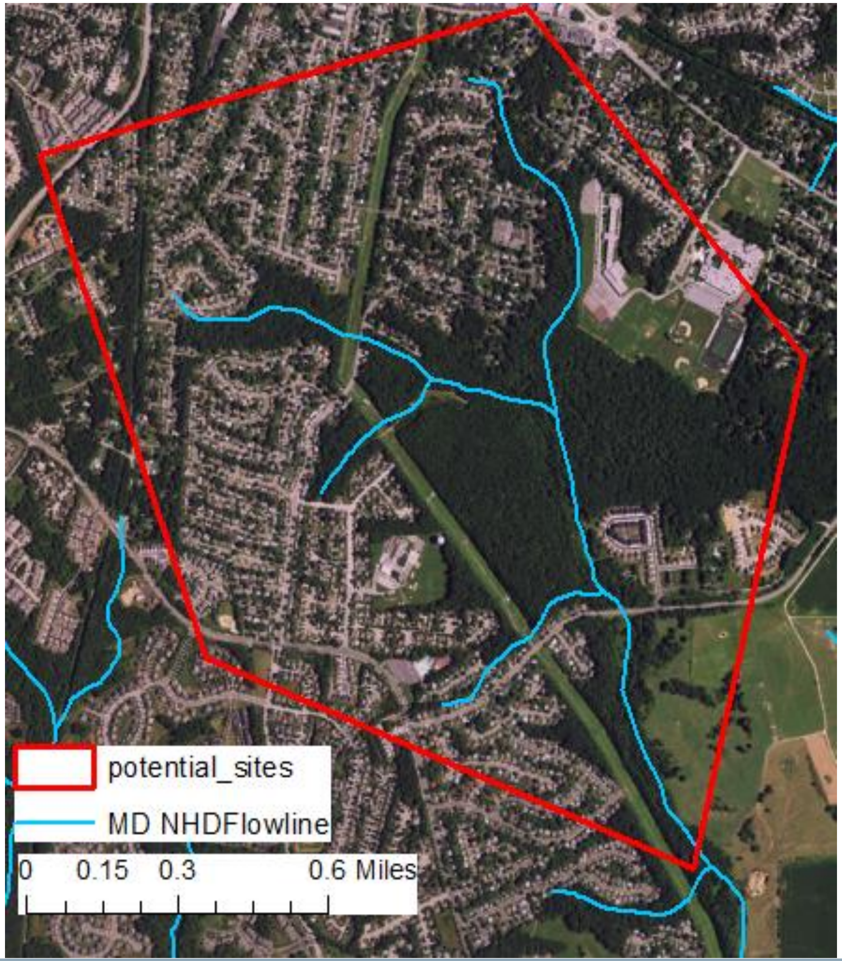


Example – Potential sites

A candidate developed catchment in the Coastal Plain region

Catchment includes mapped NHD blue lines as well as topographic concavities that could potentially support channels not mapped in NHD (visible in hill-shaded image on left)





Field survey methods

Appropriate materials will be carried on all field surveys – paper maps, reference materials, handheld GPS, charged cell phone with camera, first aid, etc.

Field crew will begin at a downstream channel location corresponding to mapped NHD blue lines

Field crew will walk upstream and note the presence of flowing water or evidence of channelized flow (bed load/debris sorting, definable banks, etc.) until channel head is encountered

Because of the potential for discontinuous channels, upon encountering a likely channel head, field crew will continue upslope to the drainage divide to ensure actual origin of channel is recorded

Photographs and GPS coordinates of channel features and channel heads will be recorded

Process will be repeated for all tributaries in each study catchment

Previous mapping efforts

Previous channel mapping efforts rely on a drainage area threshold, called ***constant critical support area***, as a condition for channel initiation

Channel initiation is not a constant phenomenon, and using a constant support area threshold at landscape scale can result in over- or under-inclusion of channels

Slope is sometimes taken into account to develop a threshold called ***slope-dependent critical support area***, but this still does not perform well at the landscape scale

Example: False "stream channel" originating in a field as a result of 60 acre constant critical support area threshold

Proposed mapping of channel networks

Evaluate mapping components and develop threshold criteria for isolating **local-scale** topographic signatures of channels (i.e. local incisions and depressions within the broader context of valley bottoms)

Incorporate **catchment-scale** indicators including drainage area, slope, and the product of the two

Assess channel network continuity using multiple flow algorithm

Estimate extent of perennial flow

- Water yield estimates from regional discharge equations
- Examine overlap in threshold extremes of TWI and slope-area product – overlap in extremes may indicate conditions sufficient for perennial discharge

Mapping component #1 – Curvature

Profile curvature – rate of change of slope *along* direction of steepest slope – indicative of acceleration (-) or deceleration (+) of flow

Planform curvature – rate of change of slope *perpendicular to* direction of steepest slope – indicative of divergence (+) or convergence (-) of flow

Combination curvature – incorporates profile and planform curvature

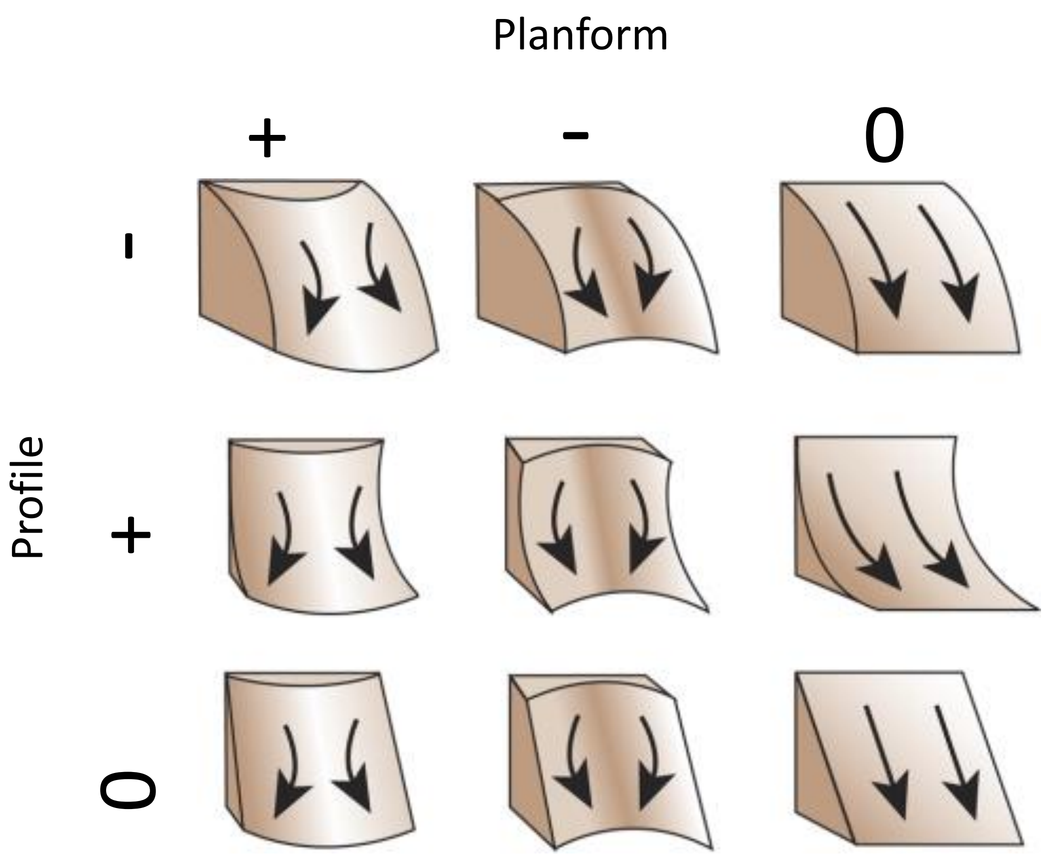
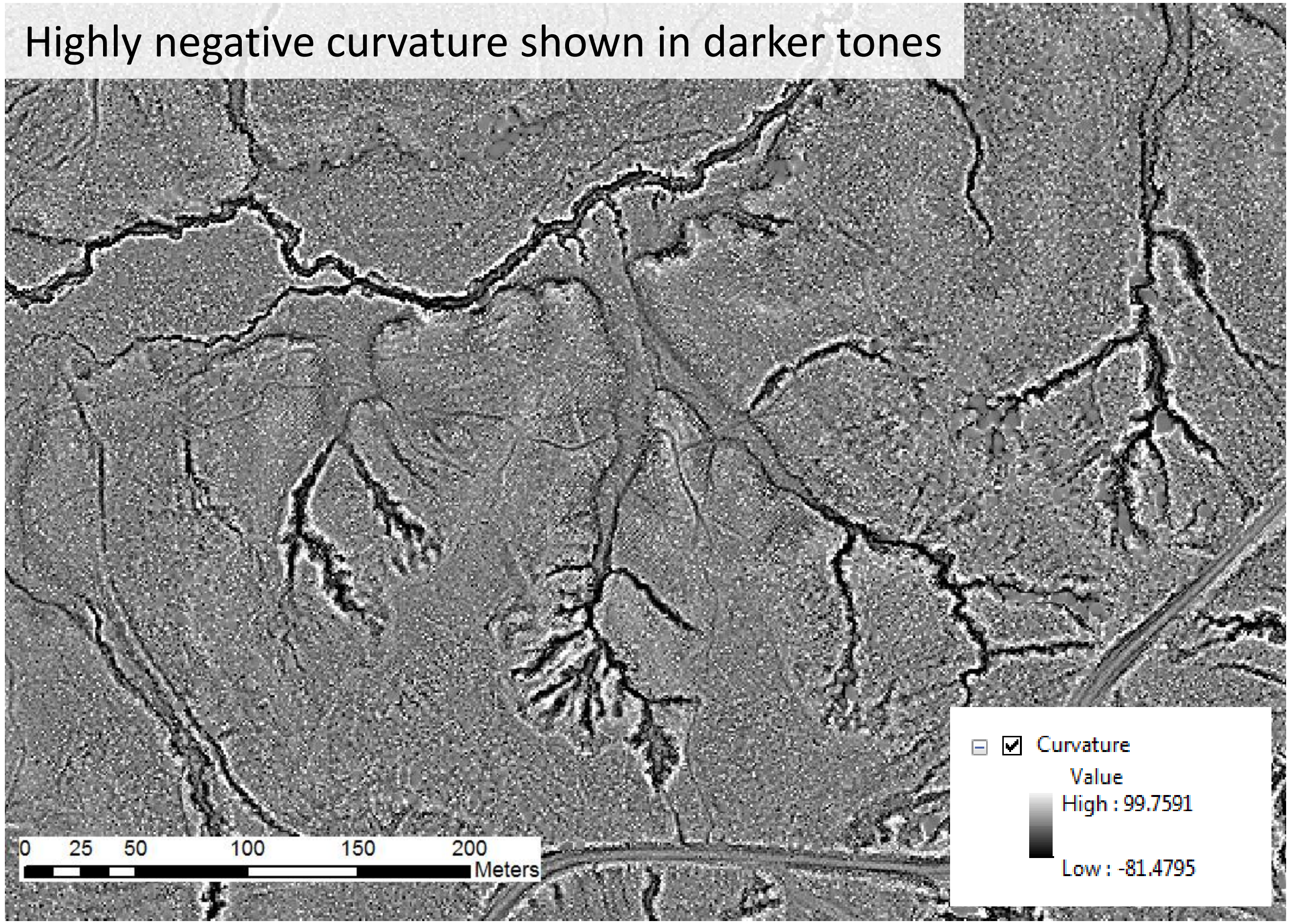


Image: Aileen Buckley

Mapping component #1 – Curvature

Identify region-specific thresholds of curvature to extract likely channelized pixels

Highly negative curvature values are convergent and, with sufficient contributing area, have the potential to be channelized



Mapping component #2 – Topographic Openness

Openness describes the degree of dominance or enclosure of a point relative to the surrounding terrain, in 8 different directions within a given radial distance

Measured above the surface, *positive openness* emphasizes convex features in the landscape

Measured below the surface, *negative openness* emphasizes concave features in the landscape

Degree of positive or negative openness is influenced, to an extent, by the radial limit of calculation

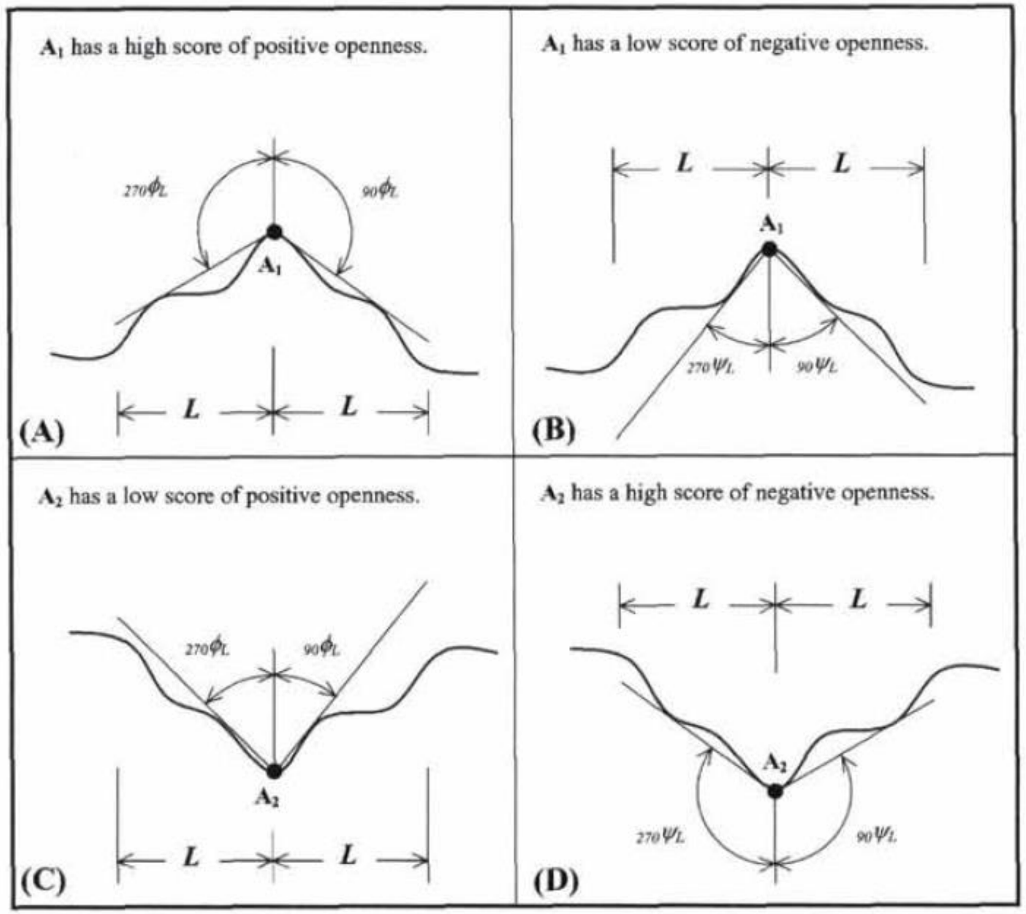
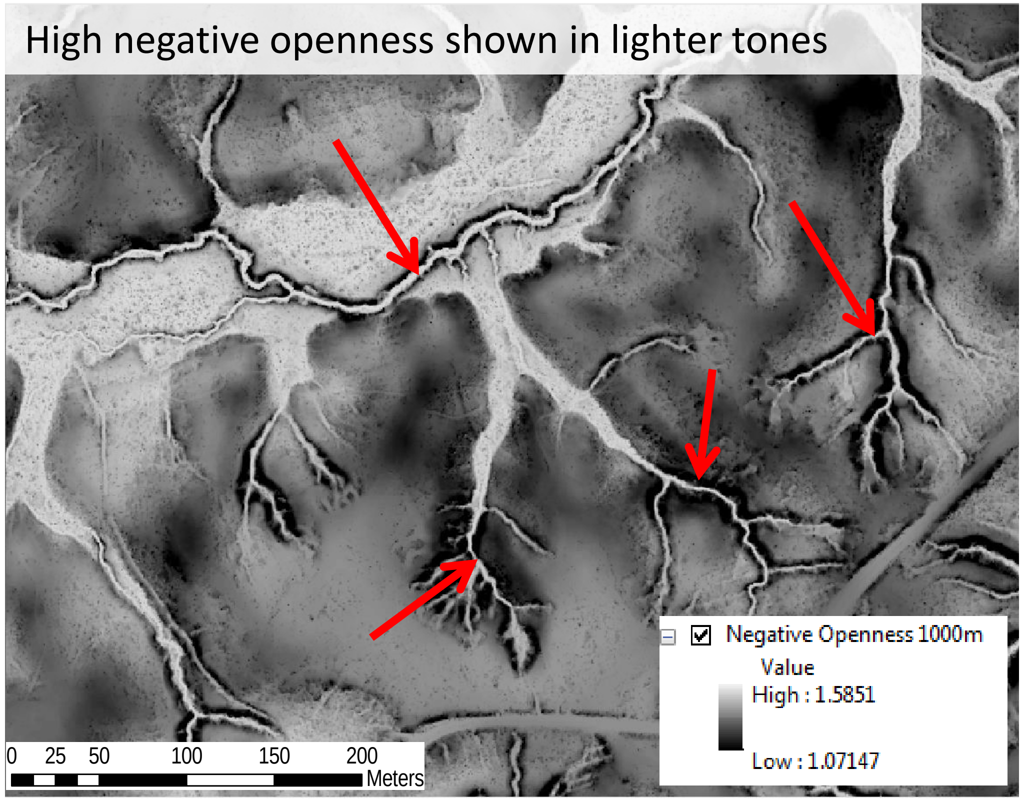
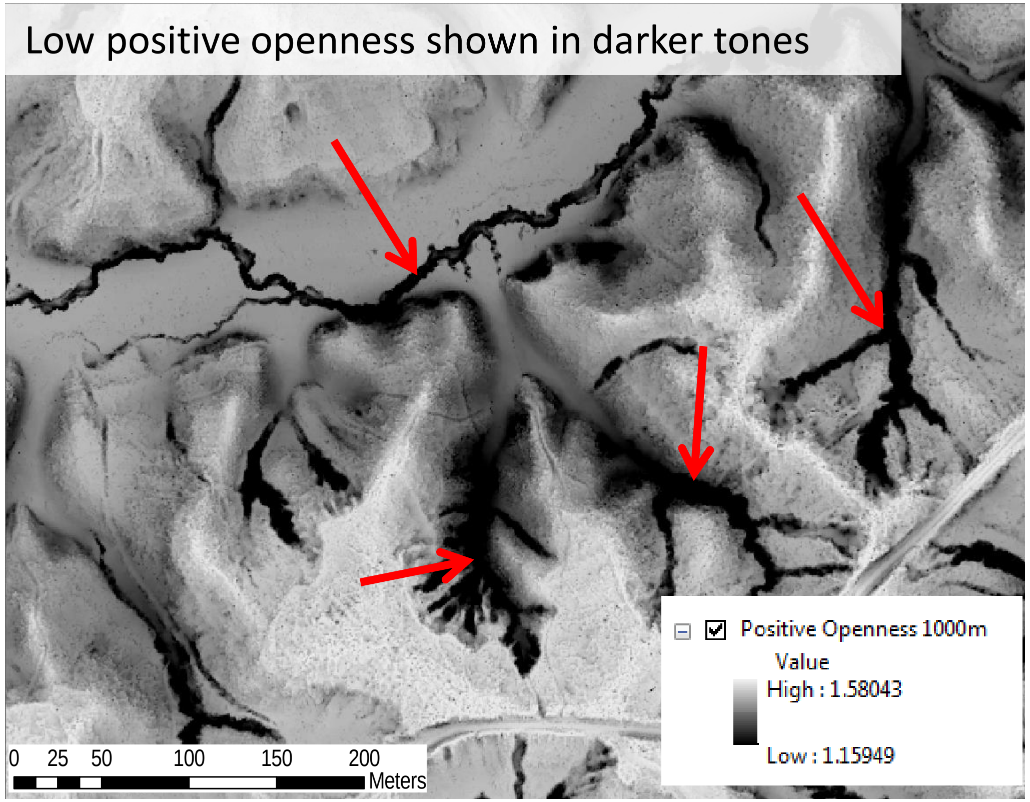


Image: Yokoyama et al. 2002

Mapping component #2 – Topographic Openness

Identify areas of high negative openness (local depressions – i.e. channel incisions) within areas of low positive openness (local concavities – i.e. valleys and hollows) to extract potentially channelized pixels



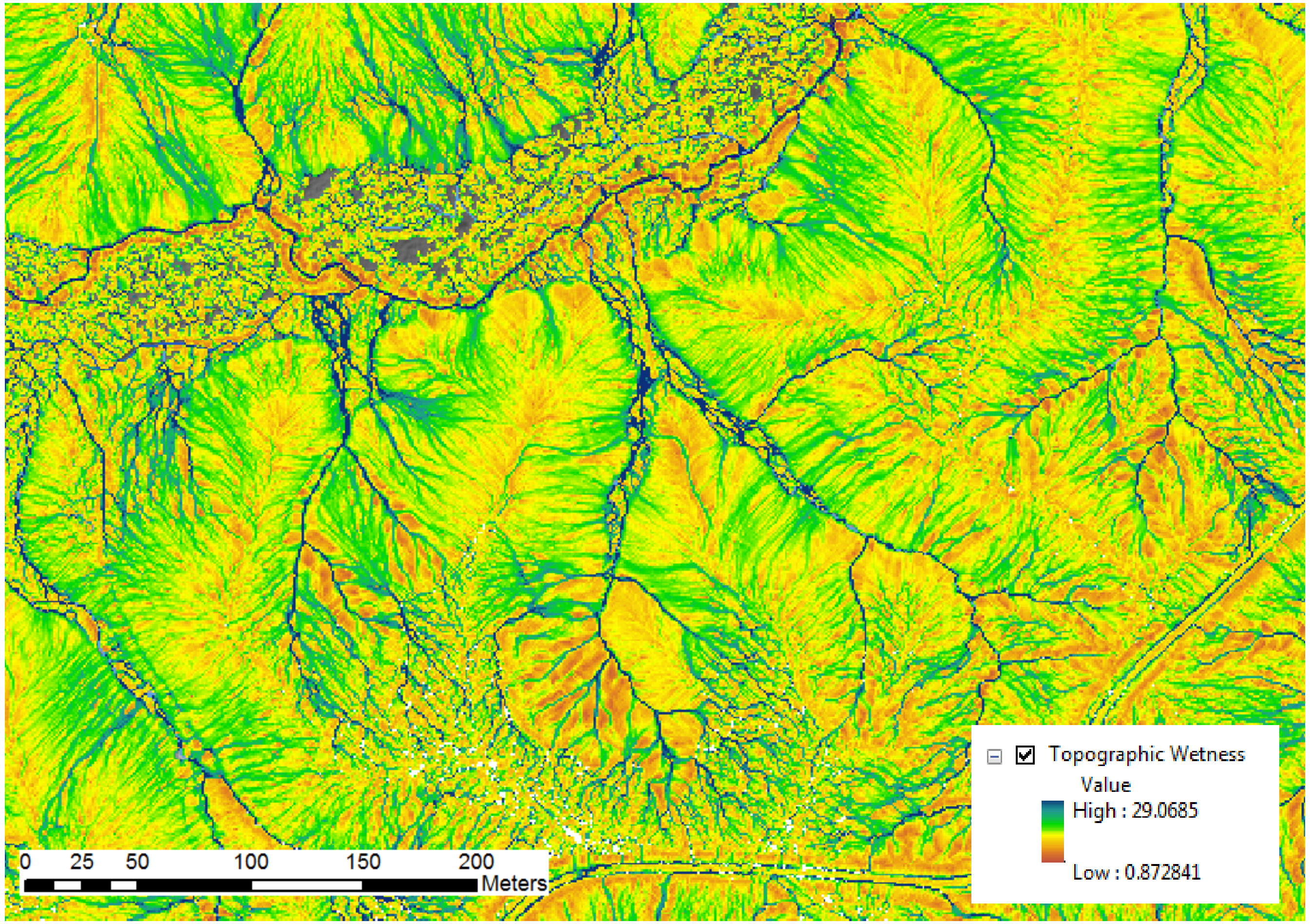


Mapping component #3 – Topographic Wetness Index

Topographic wetness index (TWI) is computed by calculating the natural log of the catchment area-to-slope ratio

Note – TWI will be null in perfectly flat areas with zero slope

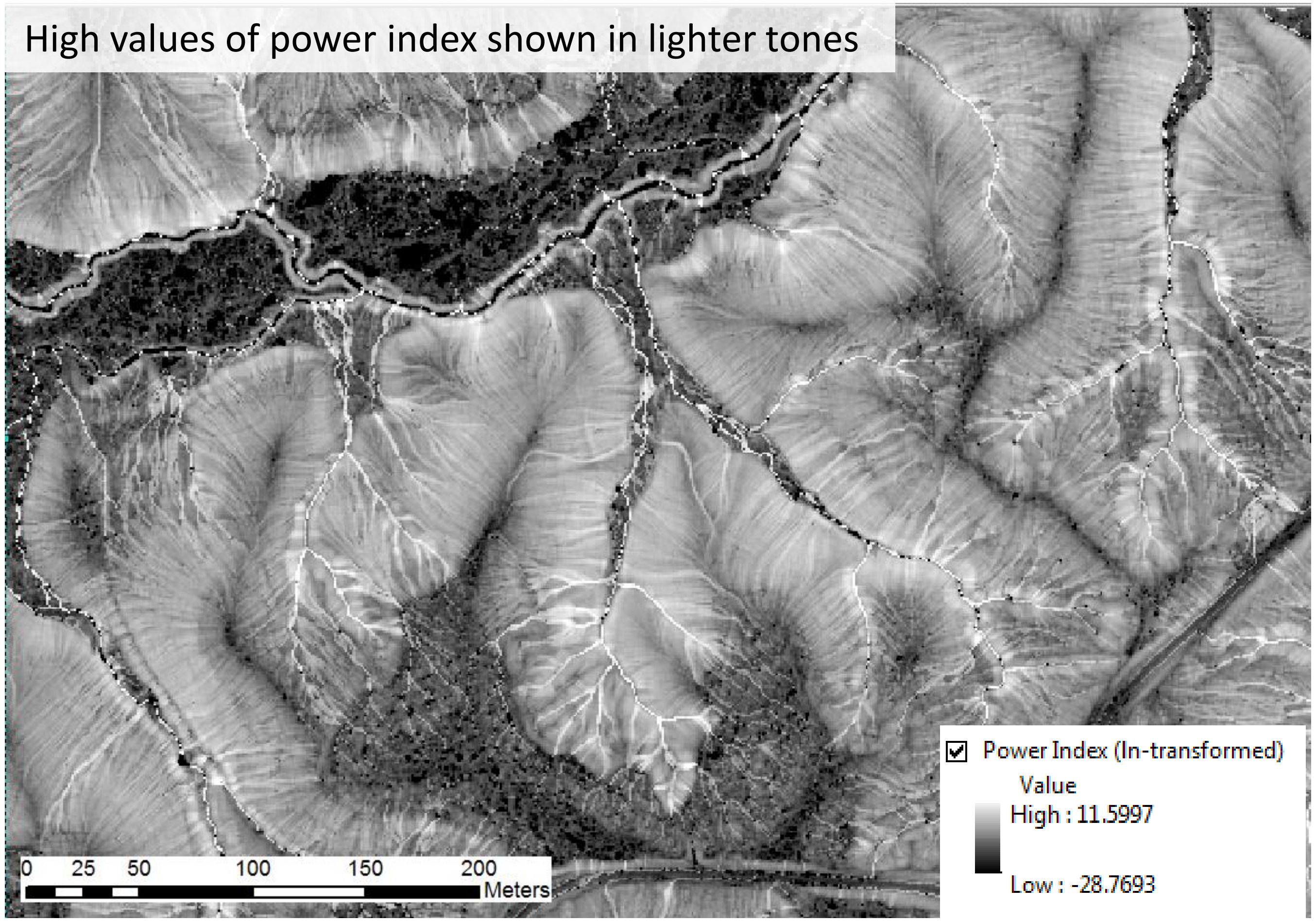
Areas with high TWI are likely to be wet



Mapping component #4 – Power Index

Power index is calculated as the natural logarithm of the product of slope and specific catchment area

Areas with high power index have higher erosive potential and thus the potential to be channelized

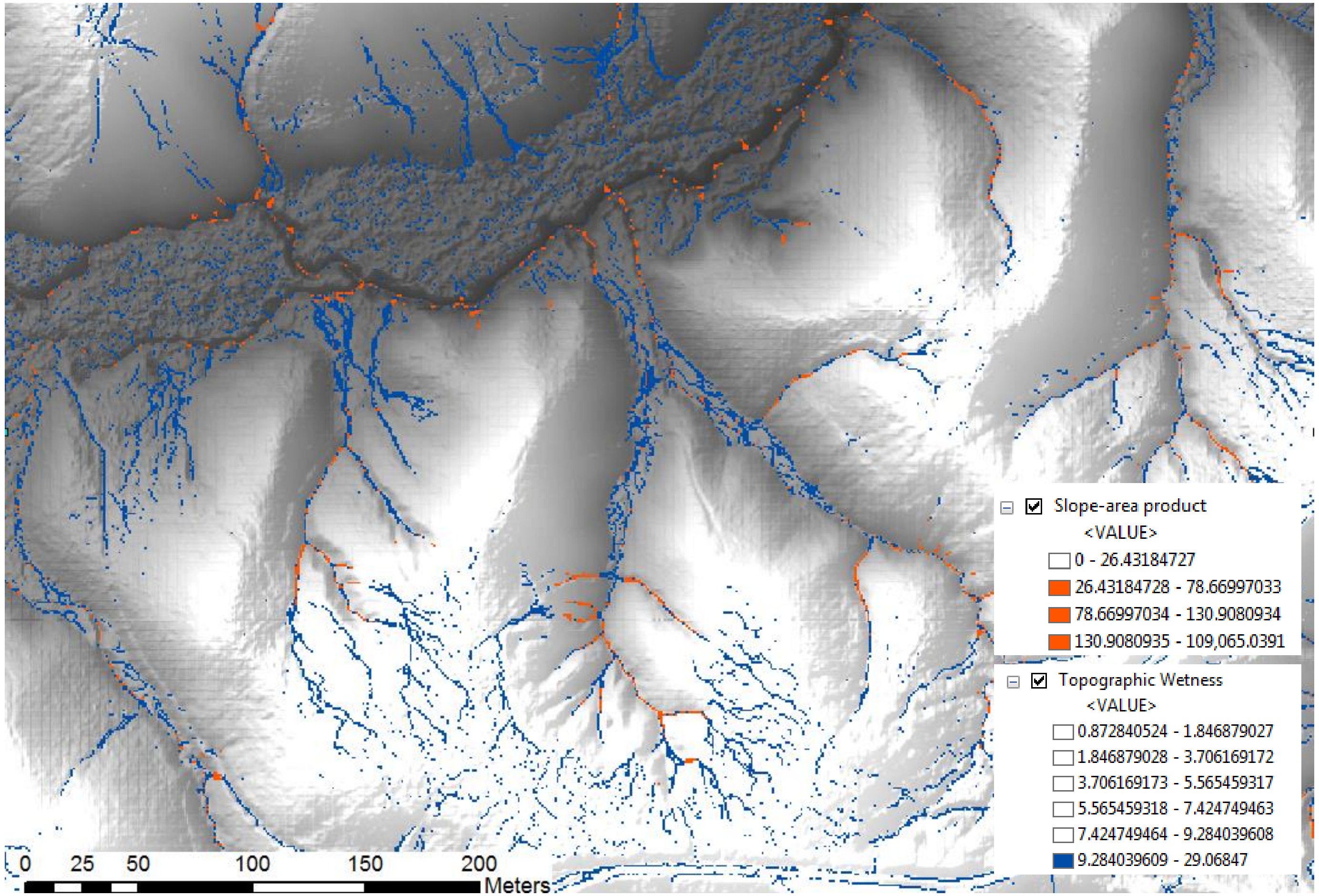


Mapping component #5 – TWI and Power Index

Examine overlap between threshold extremes of TWI and power index to delineate headward extent of perennial flow

Working hypothesis:

High power index identifies potentially channelized areas that may not necessarily be wet, high TWI identifies wet areas that may not necessarily flow, overlap in extremes identifies sufficient conditions to do both



Evaluating accuracy

Root mean square error will be calculated to assess the accuracy of the following:

- Location of mapped channel heads compared to field-verified channel heads
- Extent of mapped estimation of perennial flow compared to field-verified extent of perennial flow
- Mapped drainage density compared to observed drainage density
- Mapped channel discontinuities compared to observed discontinuities

Products

Protocol for generating channel network maps from terrain data

- Mapping components and calculation methods
- Set of objectively-based threshold values
- Thresholds likely to vary geographically

Channel network maps for pilot catchments

- Raster format
- Attributed vector format possible depending on users' needs
- Perennial/intermittent channel distinction

Report detailing methods and results

Next steps

1. Complete selection of field sites (April ‘17)
2. Conduct field assessment of channel heads (May-June ‘17)
3. Compile literature review (June – August ’17)
4. Present literature review to LUWG (August ‘17)
5. Perform tests of channel head and channel network mapping procedures (August ‘17–March ’18)
6. Draft report delivered (March ’18)
7. Report, data, and workflow finalization (March – June ’18)
8. Final presentation of findings (June ’18)

LUWG engagement

Feedback (*please*):

- Definitions (whether to include gullies with intermittent flow, or other management considerations)
- Final product format and attributes (essentials that would make the dataset usable vs useless)
- Site selection
- Mapping methods

Specification of next presentation time – August?