

# Incorporating stream-wood dynamics into landscape-scale management and restoration planning

Large wood is recognized as an important component for development of high-quality aquatic habitat; likewise, timber harvest, road building, and land conversions are recognized as important influences on processes of wood recruitment. Management agencies are seeking to understand and incorporate wood recruitment processes into management, conservation, and restoration planning. I'll describe my experience in development and application of landscape-scale wood recruitment and wood budgeting models for evaluating management alternatives and for identifying restoration opportunities.

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## What do people want to know?

- How will different management alternatives influence future wood abundance?
- How important are upland wood sources?
- Where are the best locations for harvest restrictions to ensure future sources of in-stream wood (e.g., buffers on debris-flow-prone headwater streams)?
- Where are the best locations for silvicultural treatments (e.g., thinning) to enhance wood recruitment? What should those treatments be?
- How do current and future wood loads compare to those that would exist under a natural disturbance regime?
- What are appropriate targets for wood abundance?
- Where are the best locations for in-stream wood placement?

Future conditions

Stochastic systems:

- large temporal and spatial variability;
- appropriate spatial and temporal scales to adequately characterize these processes can be very large

Along with field data, use computer simulations to explore interactions between the processes that affect habitat development.

# A Conceptual Framework for Process Interactions at the Watershed Scale

## Spatial Template –

Valley and Channel Form  
Sediment + Wood Production, Delivery, Storage

## Dynamic Drivers –

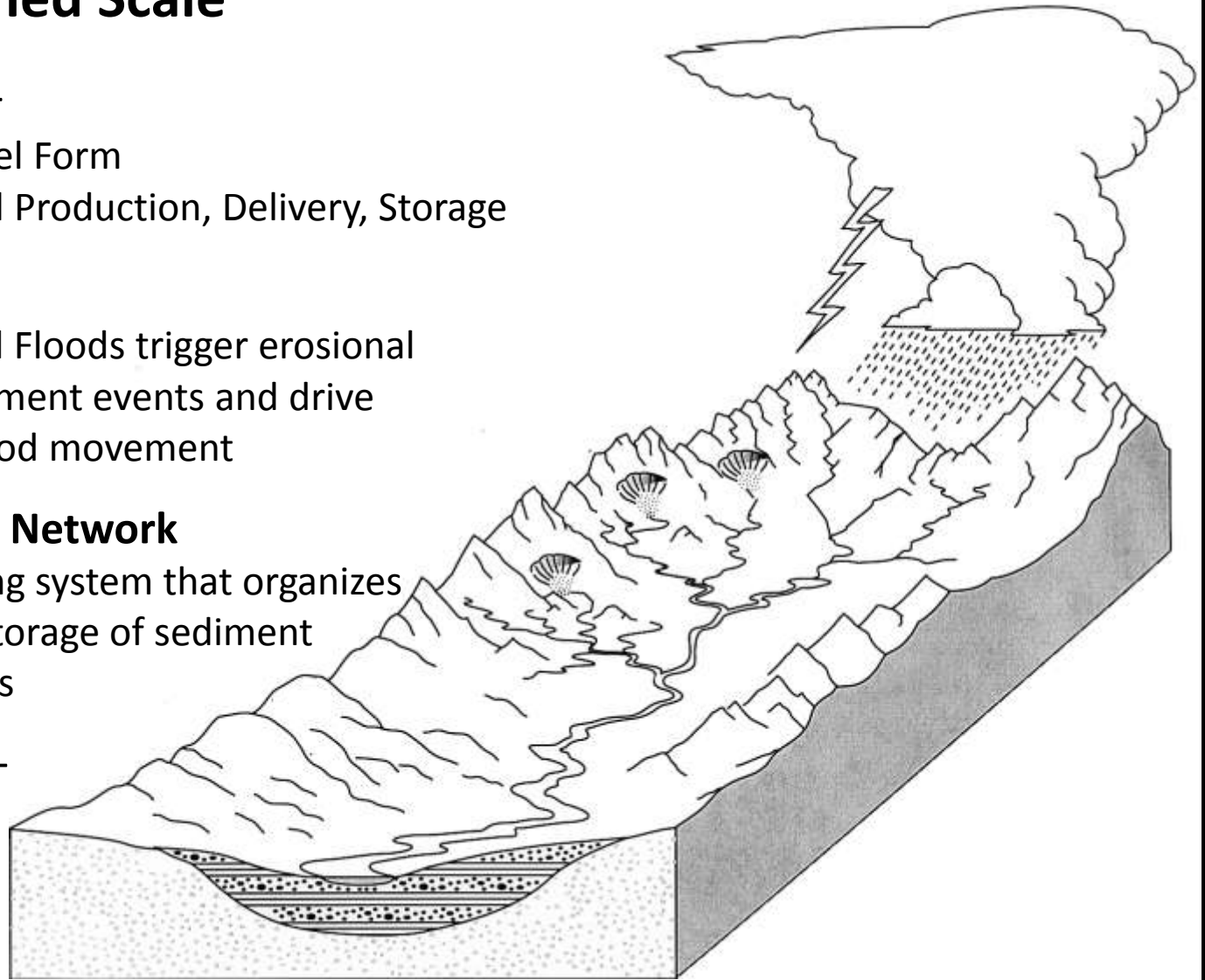
Storms, Fires, and Floods trigger erosional and wood recruitment events and drive sediment and wood movement

## Branched Channel Network

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

## History of Events –

Determines antecedent conditions



How does wood fit into this picture?



# Dynamic Drivers –

Storms, Fires, Floods:

Trigger erosion and wood recruitment

Drive sediment and wood movement



Fire-killed snags  
can be a  
primary source  
of in-stream  
wood



Fires are sometimes followed by big storms, triggering erosion and deposition on valley floors

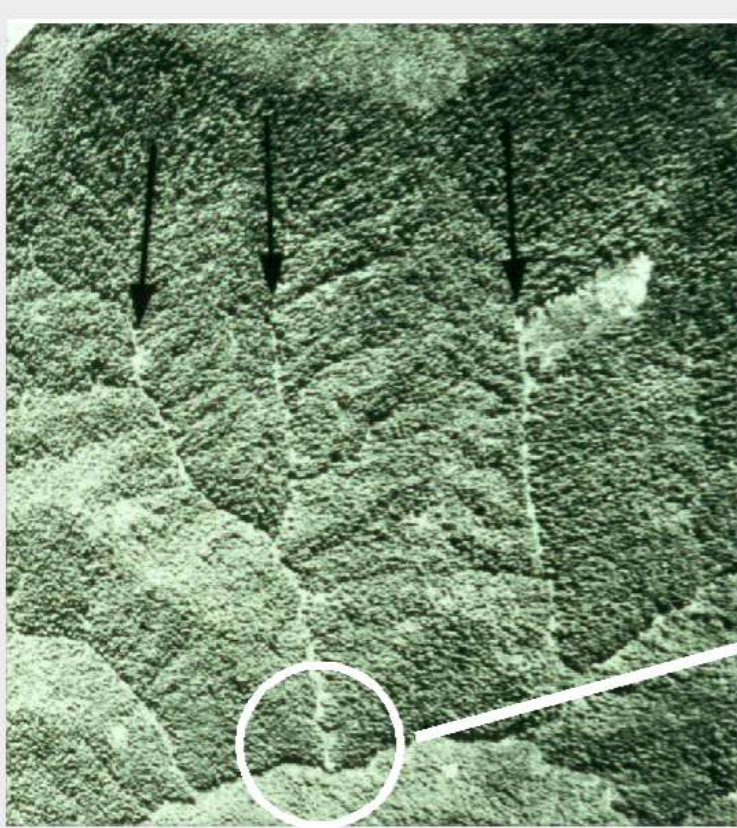


providing a wood legacy that can persist for thousands of years



**Terrace**

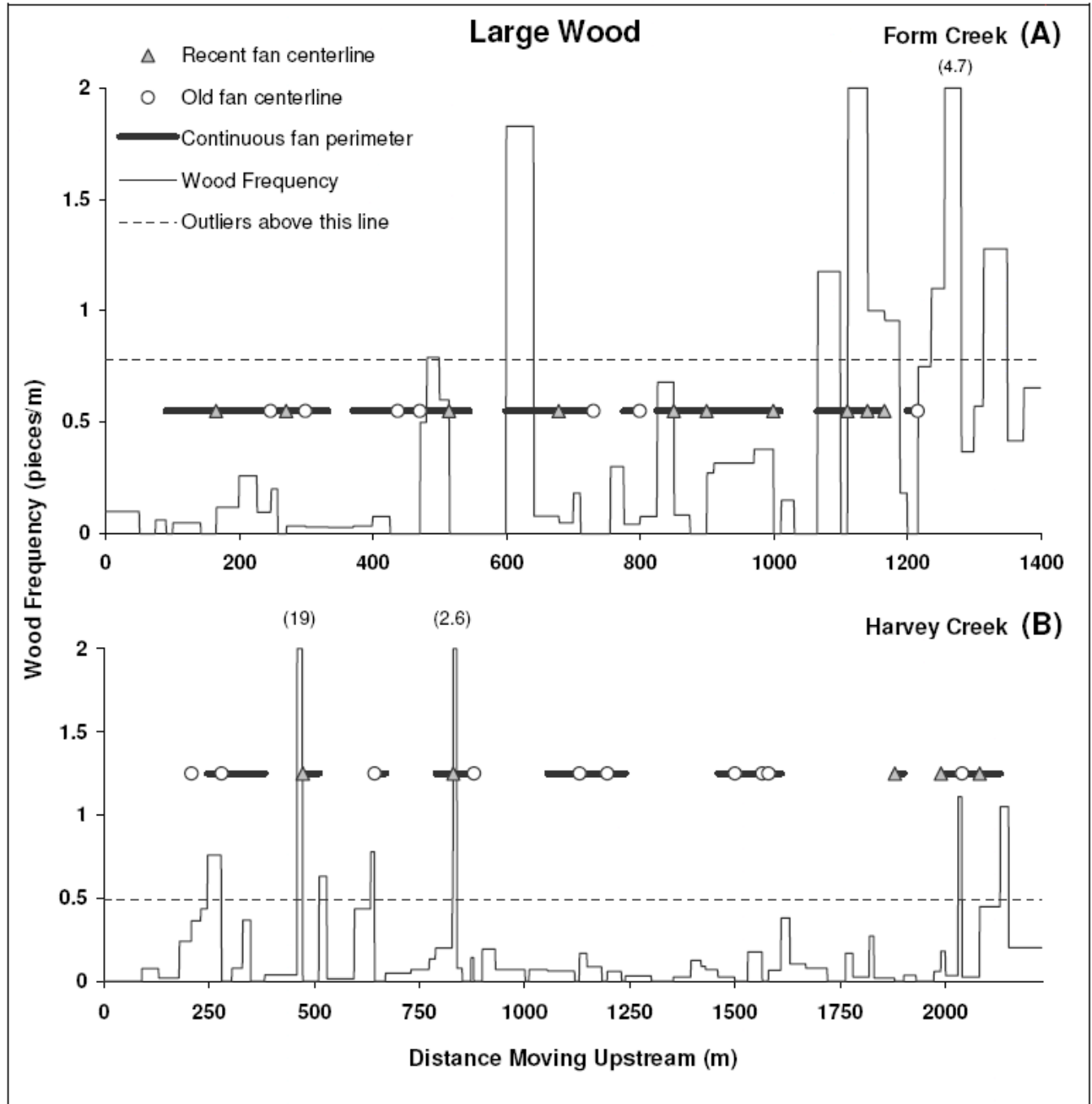
**Buried Trees**



Debris flows are another locally important source of wood



In steep, landslide-prone terrain, accumulations of wood are commonly found near junctions with steep, low-order tributary channels.



Sometimes, a  
significant local  
source



With a legacy  
that persists for  
decades,  
centuries if the  
wood is buried



Here's a nice, somewhat aggraded channel



That aggradation pushed the channel into the trees



# A Spatially Explicit, GIS-Based Wood Recruitment Model

## Recruitment processes

- Riparian tree fall
- Channel migration
- Debris flow

## Input data

- DEM (10-m)
- Forest Cover (stand tables)

## Output -- mean annual wood input by each recruitment process

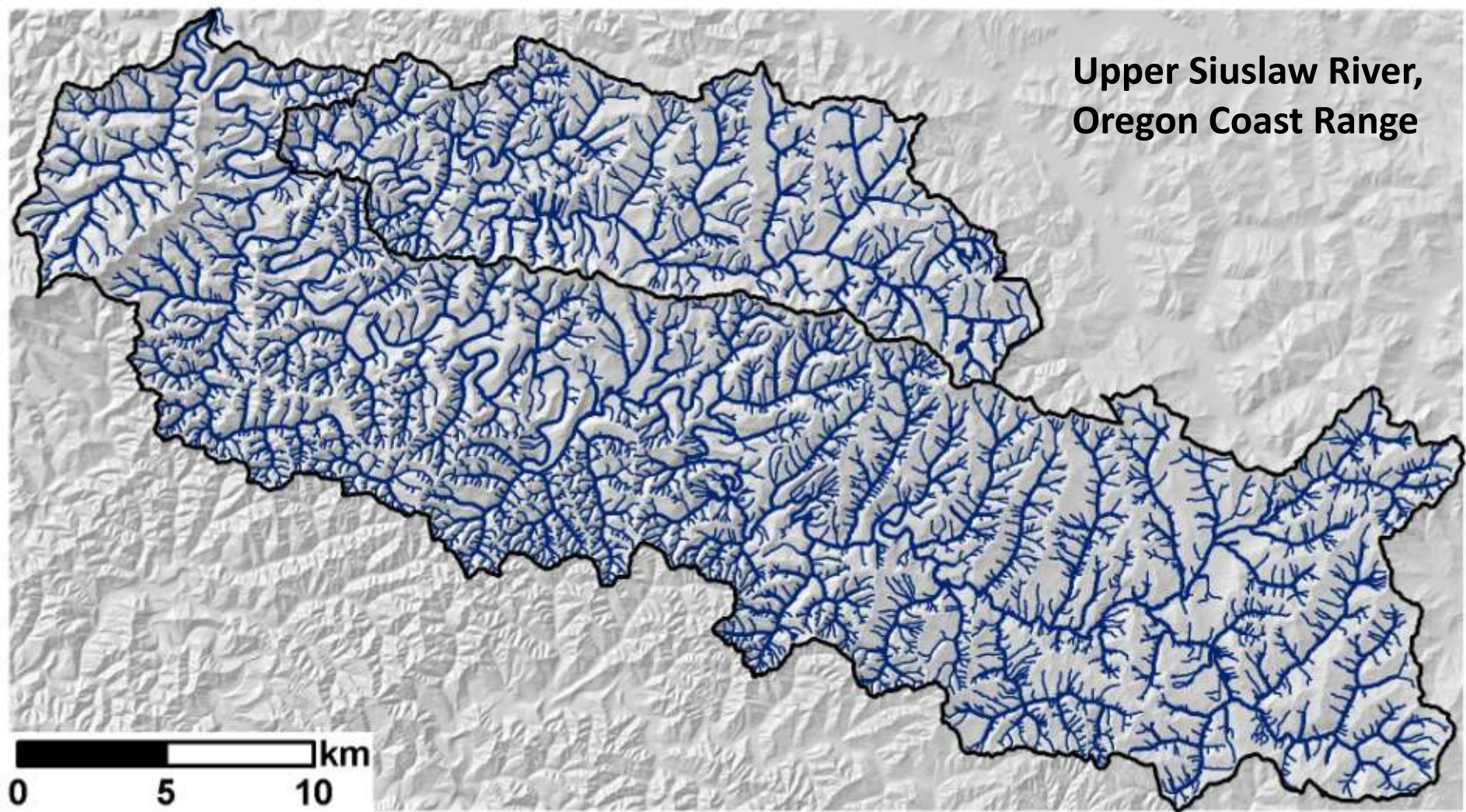
- For each DEM cell
- For each stream reach



## Information to estimate recruitment from riparian tree fall:

- How many trees will fall over a specified period of time
- Locations of those trees
- Size (species) of those trees
- Channel-edge locations
- Channel-adjacent topography

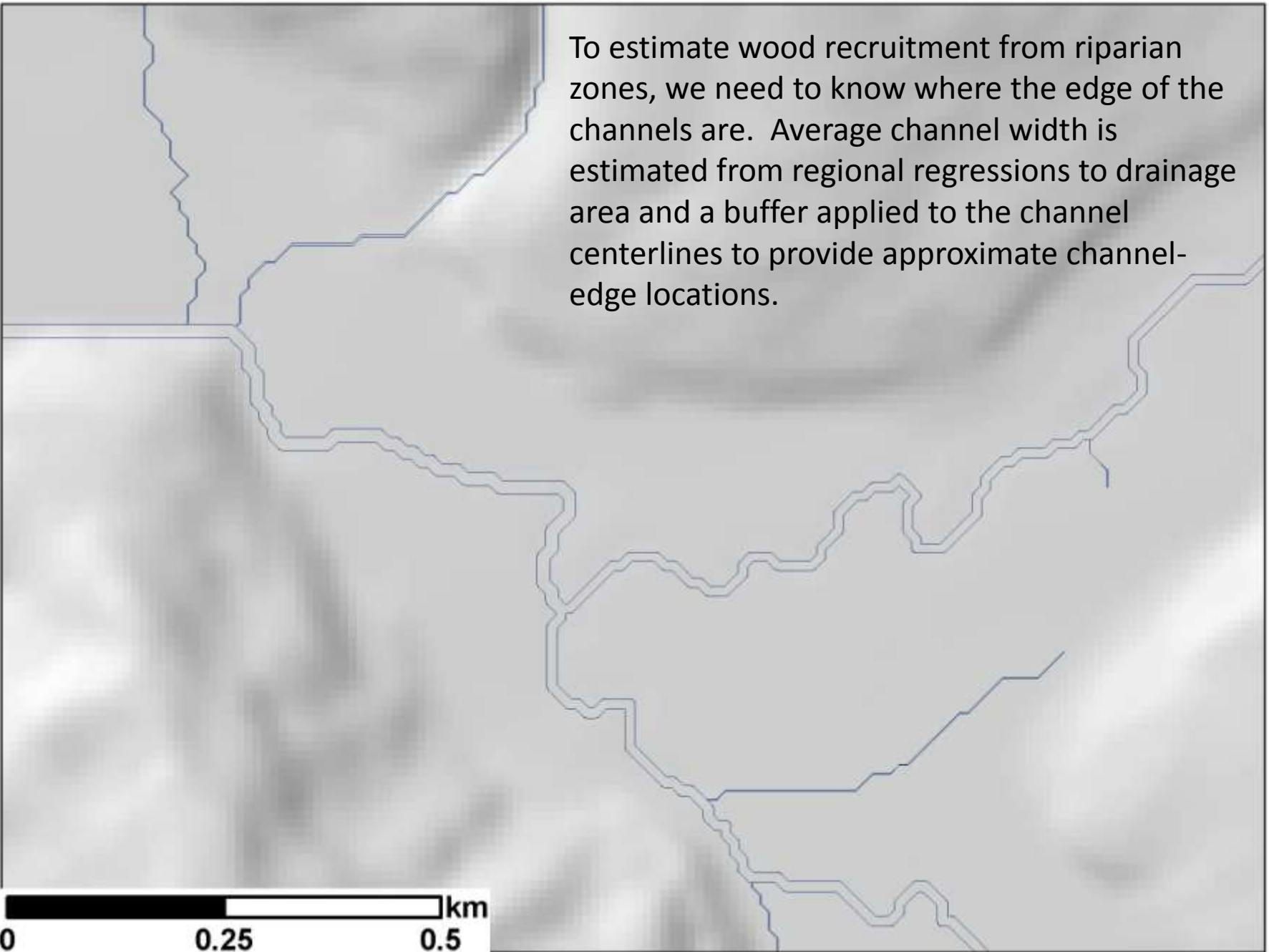
Stand-type basis: number of trees (by size class and species) per unit area defined for stand-type polygons

## Upper Siuslaw River, Oregon Coast Range

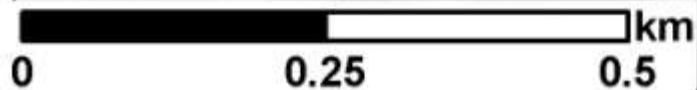


-  Fish-bearing channel
-  Non-fish-bearing channel

A digital elevation model (DEM) provides topographic information and flow directions inferred from the DEM are used to trace a channel network.

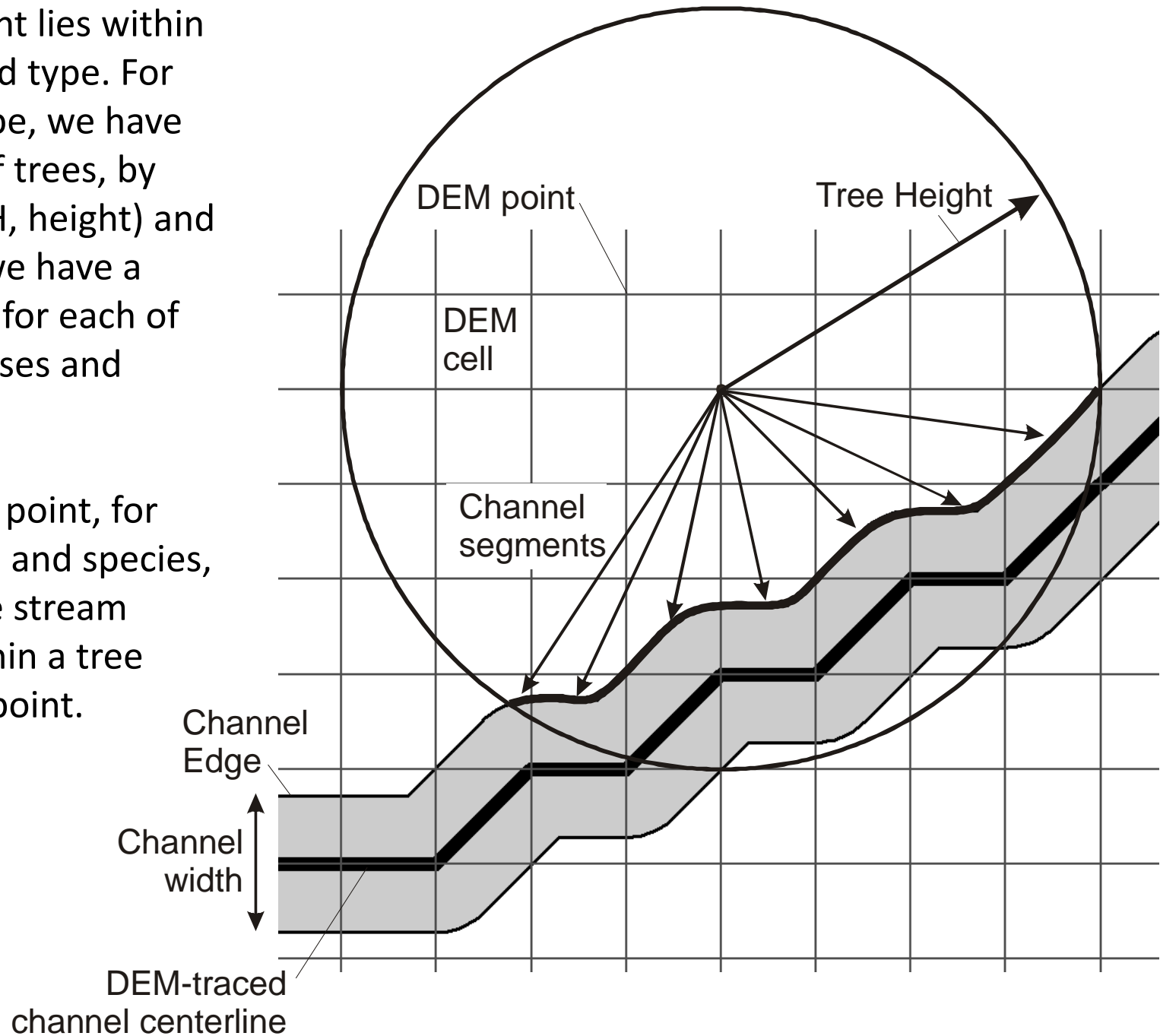


To estimate wood recruitment from riparian zones, we need to know where the edge of the channels are. Average channel width is estimated from regional regressions to drainage area and a buffer applied to the channel centerlines to provide approximate channel-edge locations.



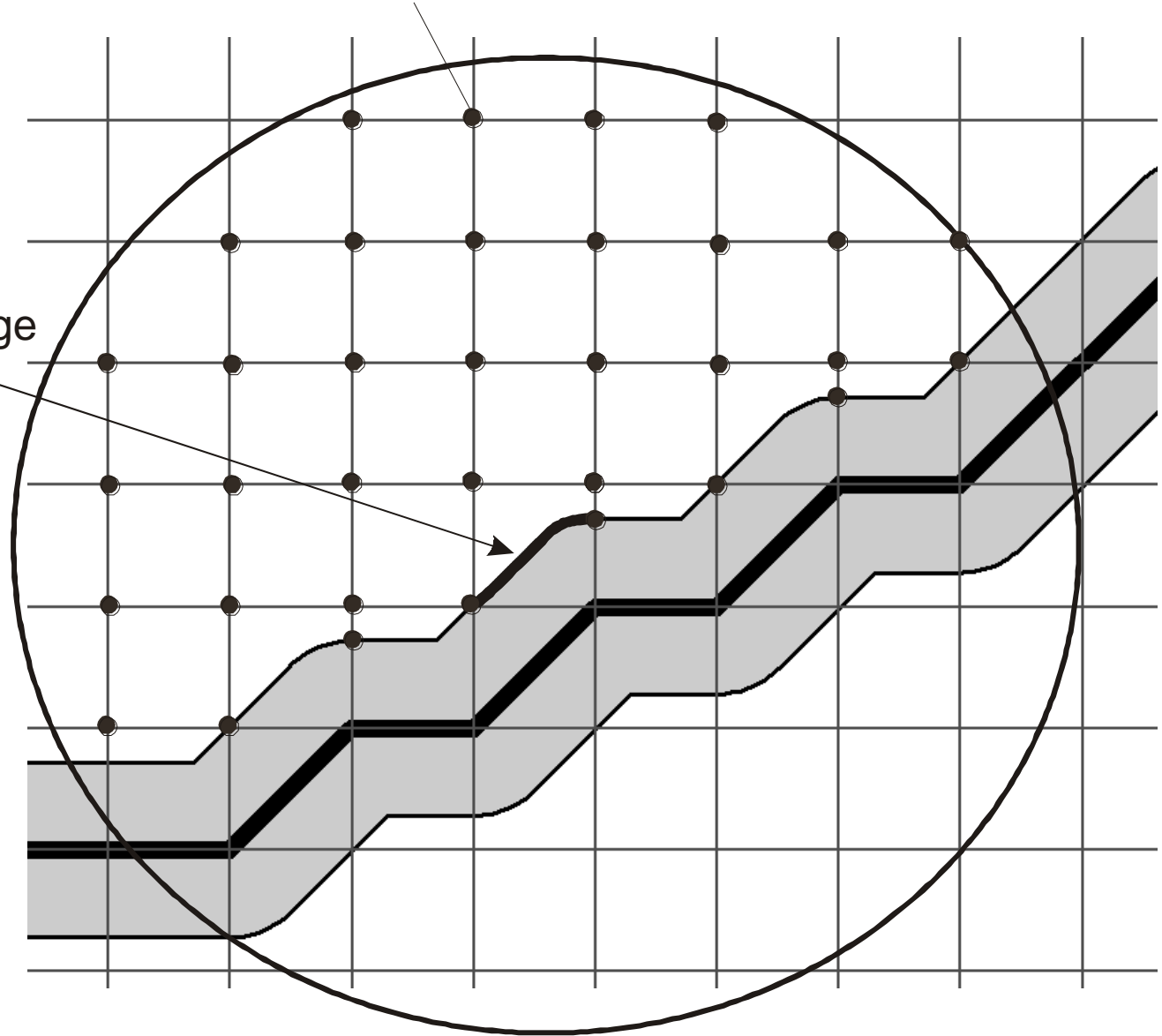
Each DEM point lies within a specific stand type. For each stand type, we have the number of trees, by size class (DBH, height) and species, and we have a mortality rate for each of these size classes and species.

For each DEM point, for each size class and species, identify all the stream segments within a tree height of the point.



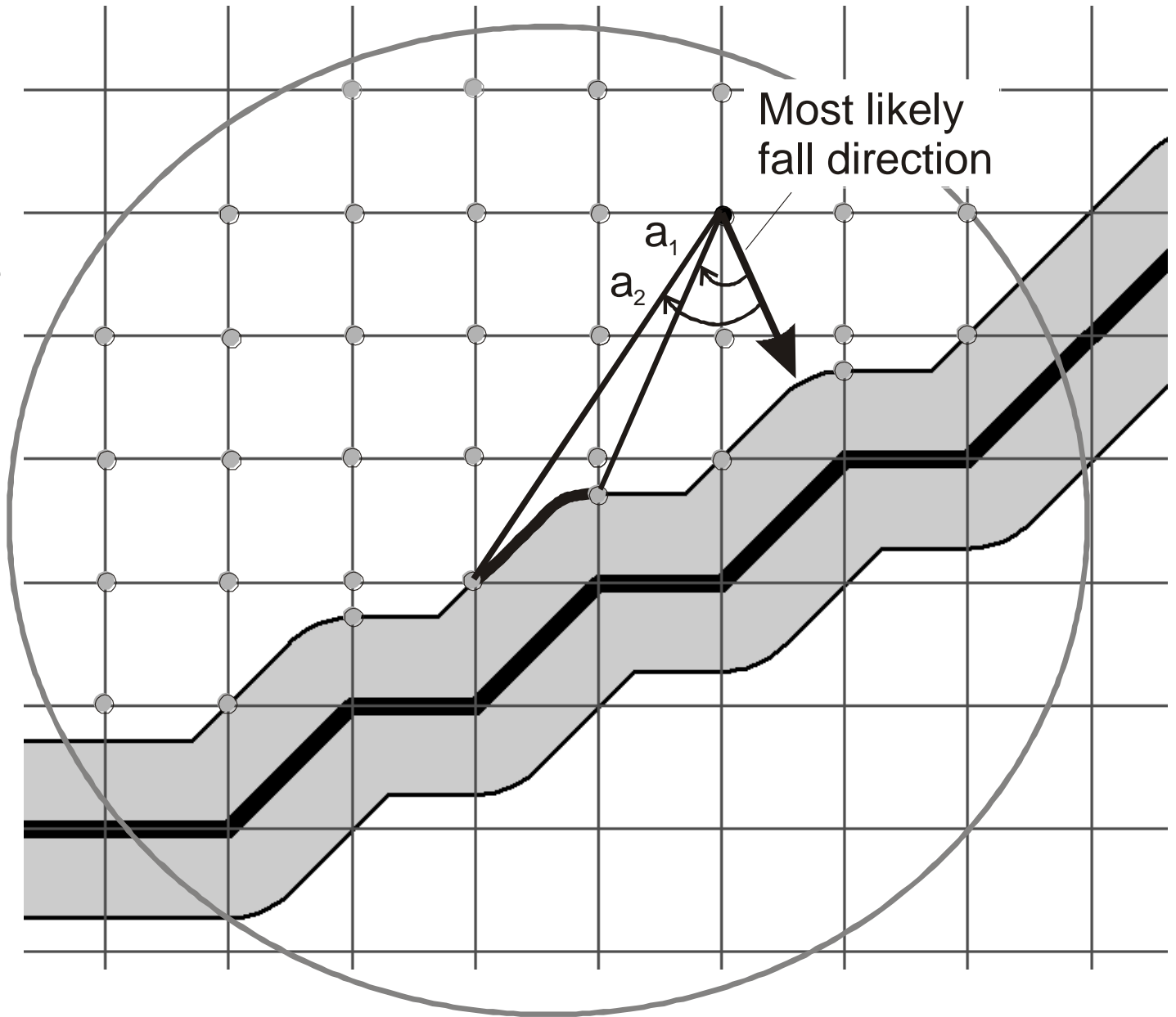
DEM points

Channel edge  
segment



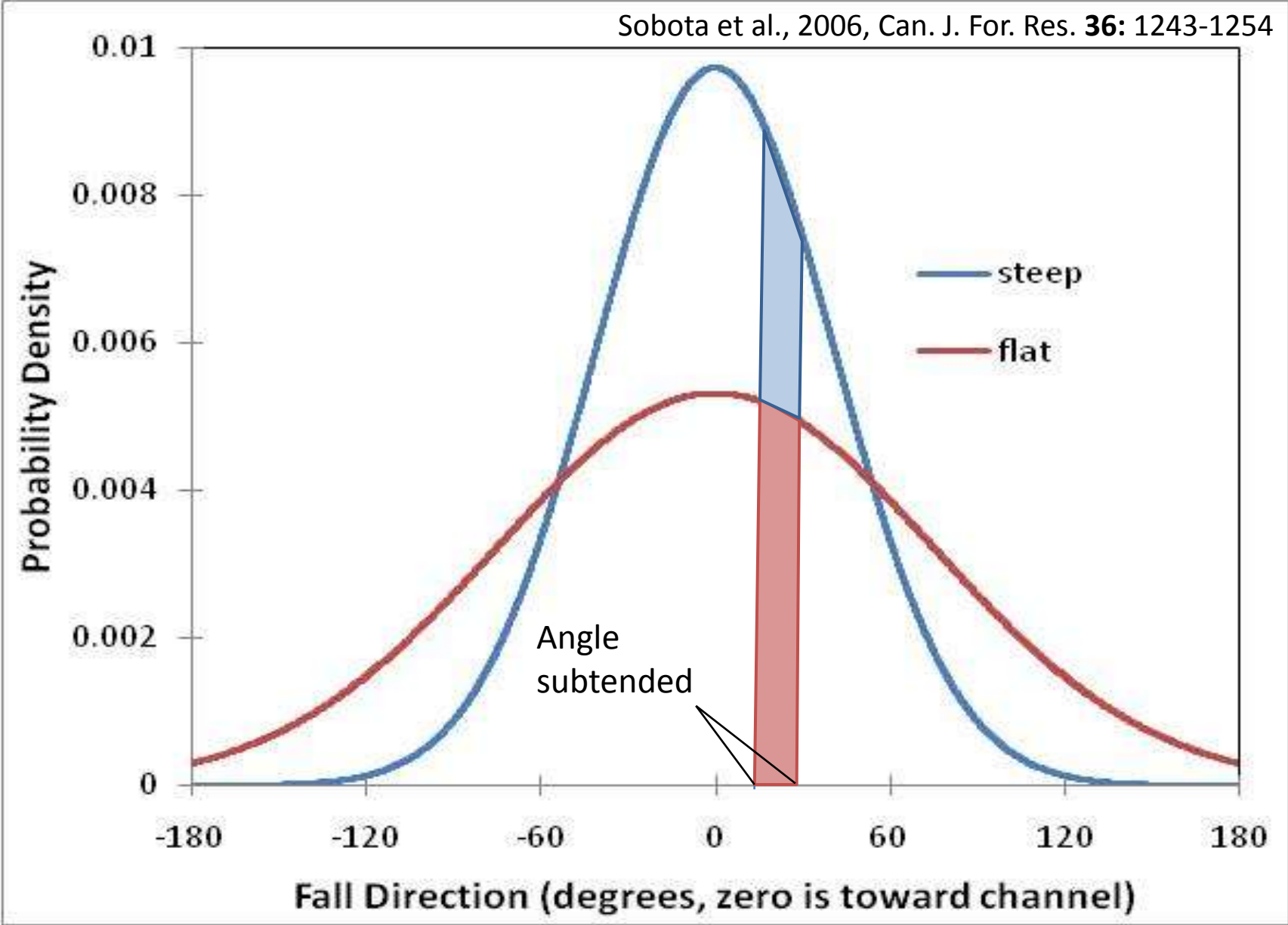
Then, for each  
stream segment,  
find every DEM  
point for which a  
tree standing at the  
point could  
potentially fall into  
the segment.

The probability that a tree at a DEM point falls into a channel segment depends on the angle subtended by the fall directions to the segment



The probability that a falling tree hits a channel depends on steepness of the channel-adjacent slope

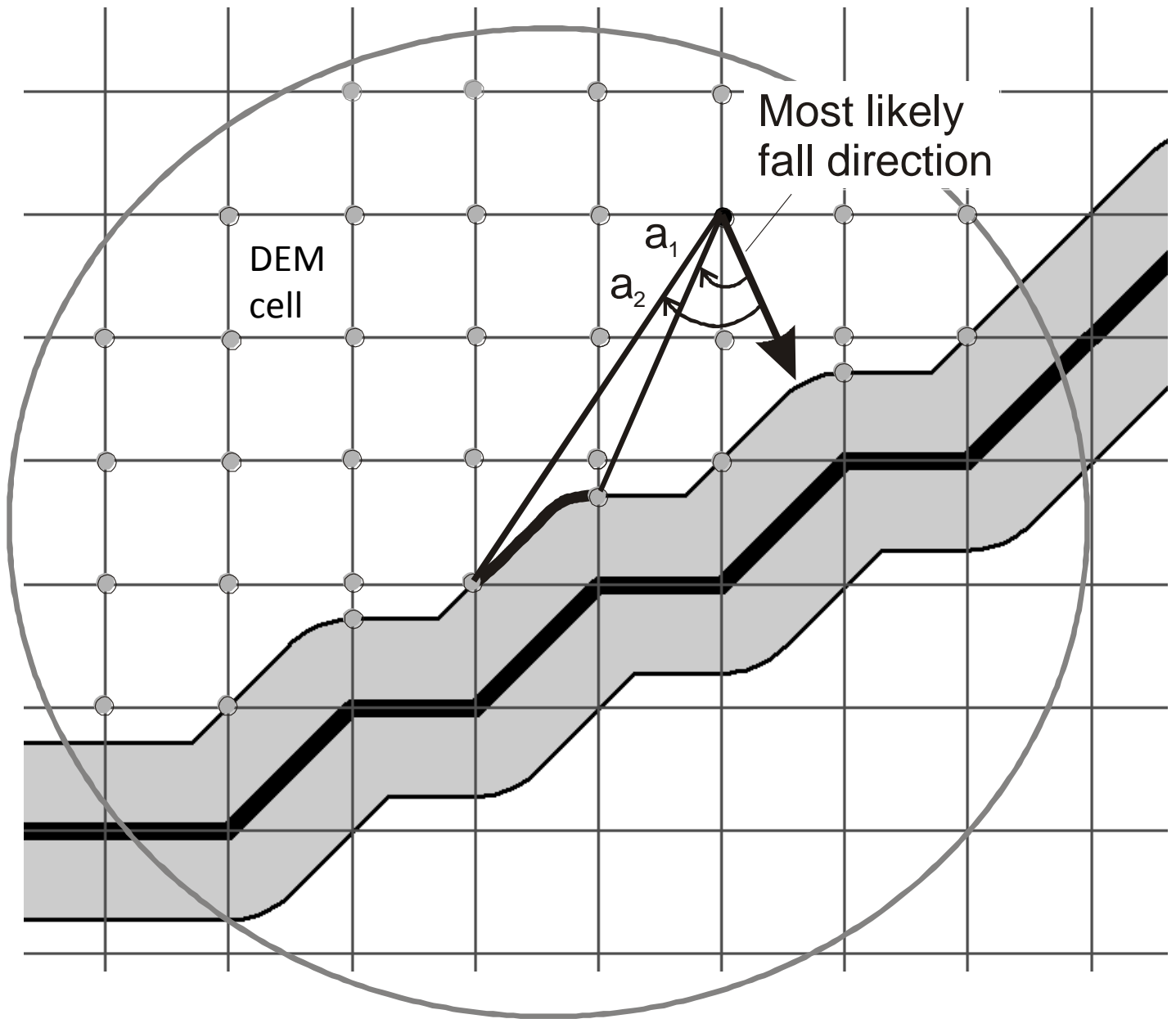
Sobota et al., 2006, Can. J. For. Res. 36: 1243-1254



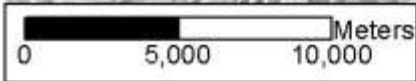
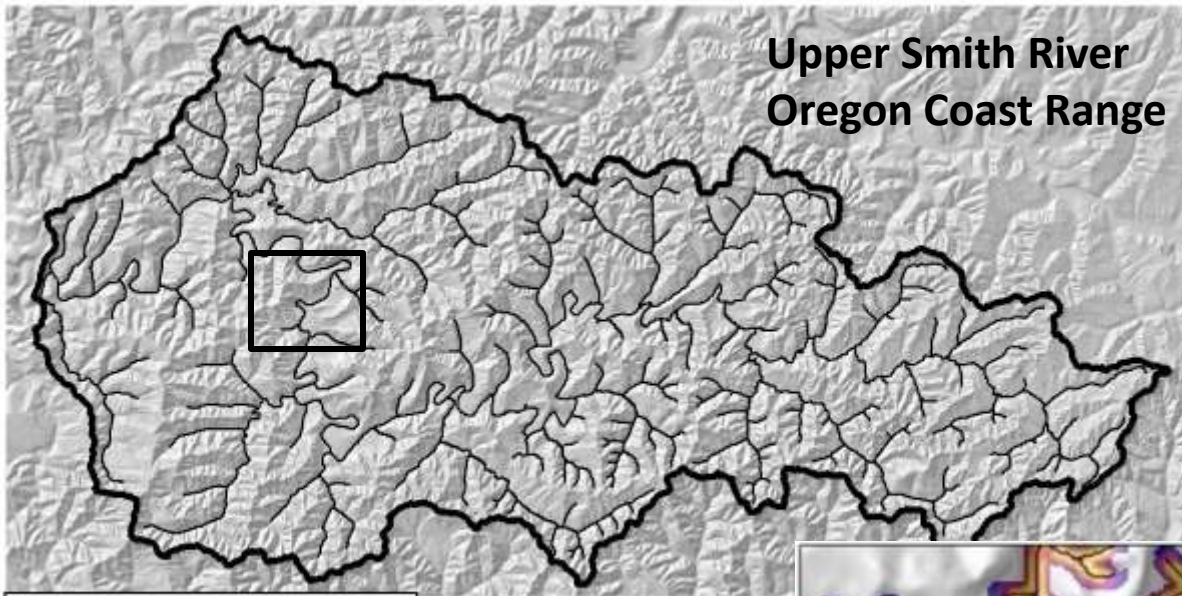
Every four DEM points define a DEM cell.

Integrate the probability of the four corners over the cell to estimate the probability that a tree in the cell will fall into the segment.

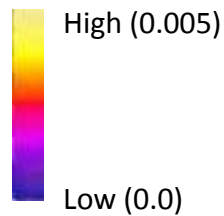
Repeat for all stream-edge segments.



## Upper Smith River Oregon Coast Range



### Pieces per year

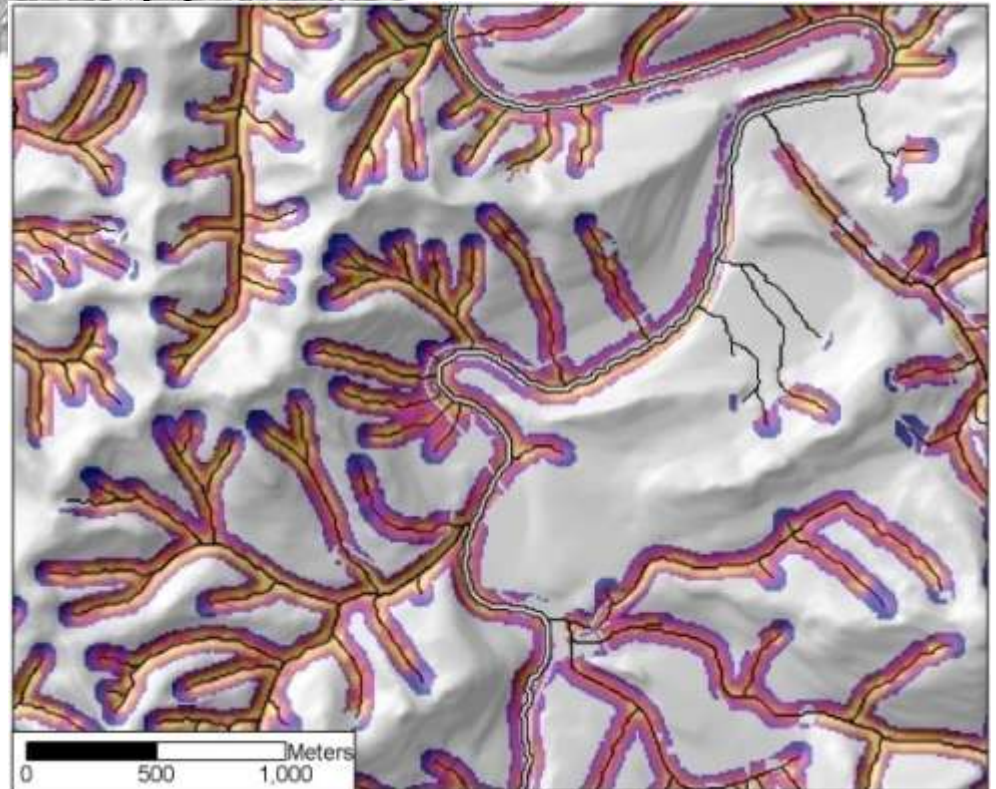


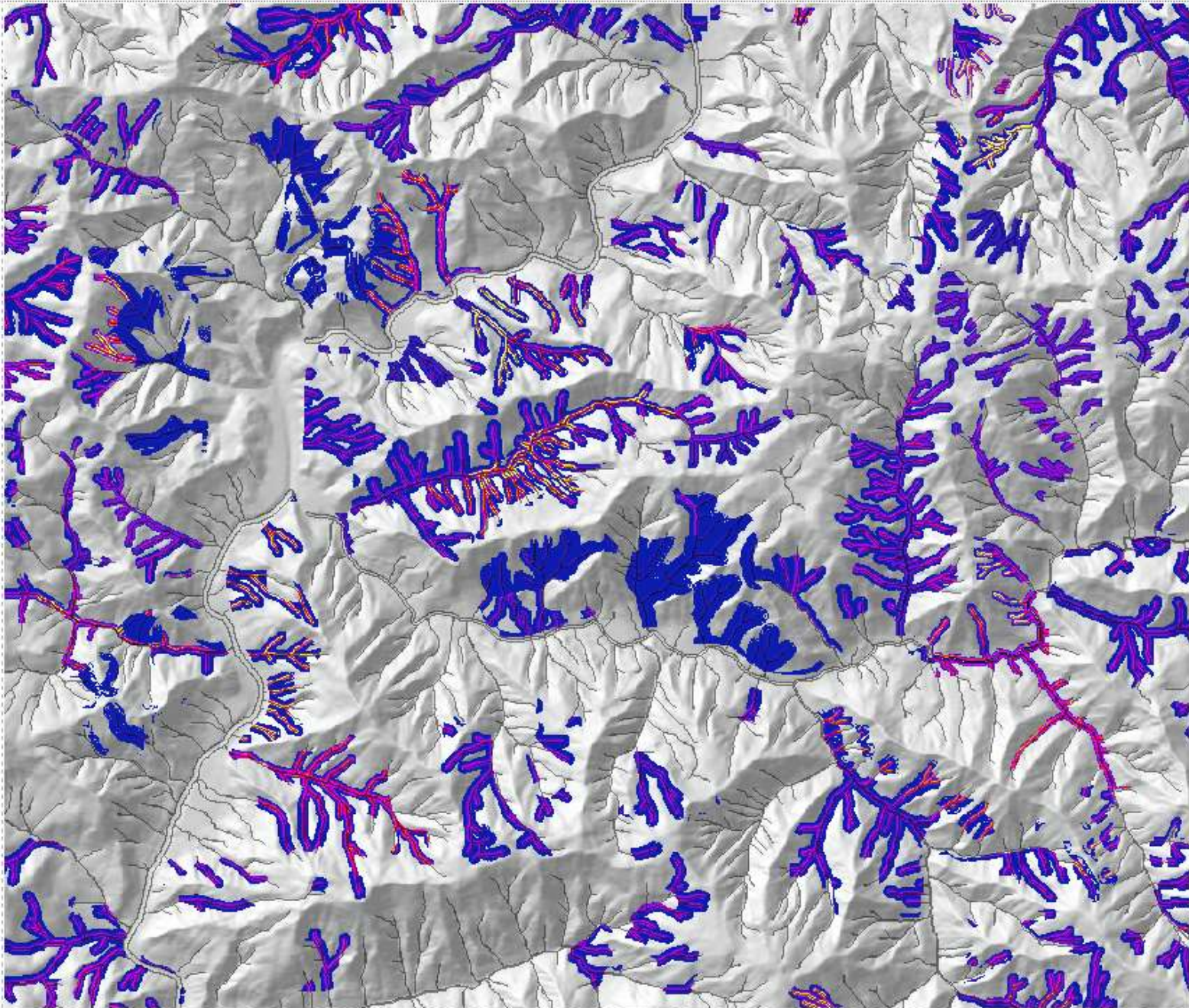
Mortality rates based on current stand inventories grown out in time with ORGANON

### Tree fall from riparian areas

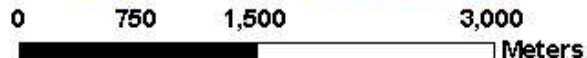
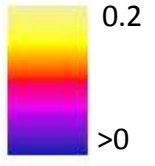
Dependent on:

- Forest cover
- Hillslope gradient
- Distance to stream channel
- Channel planform geometry



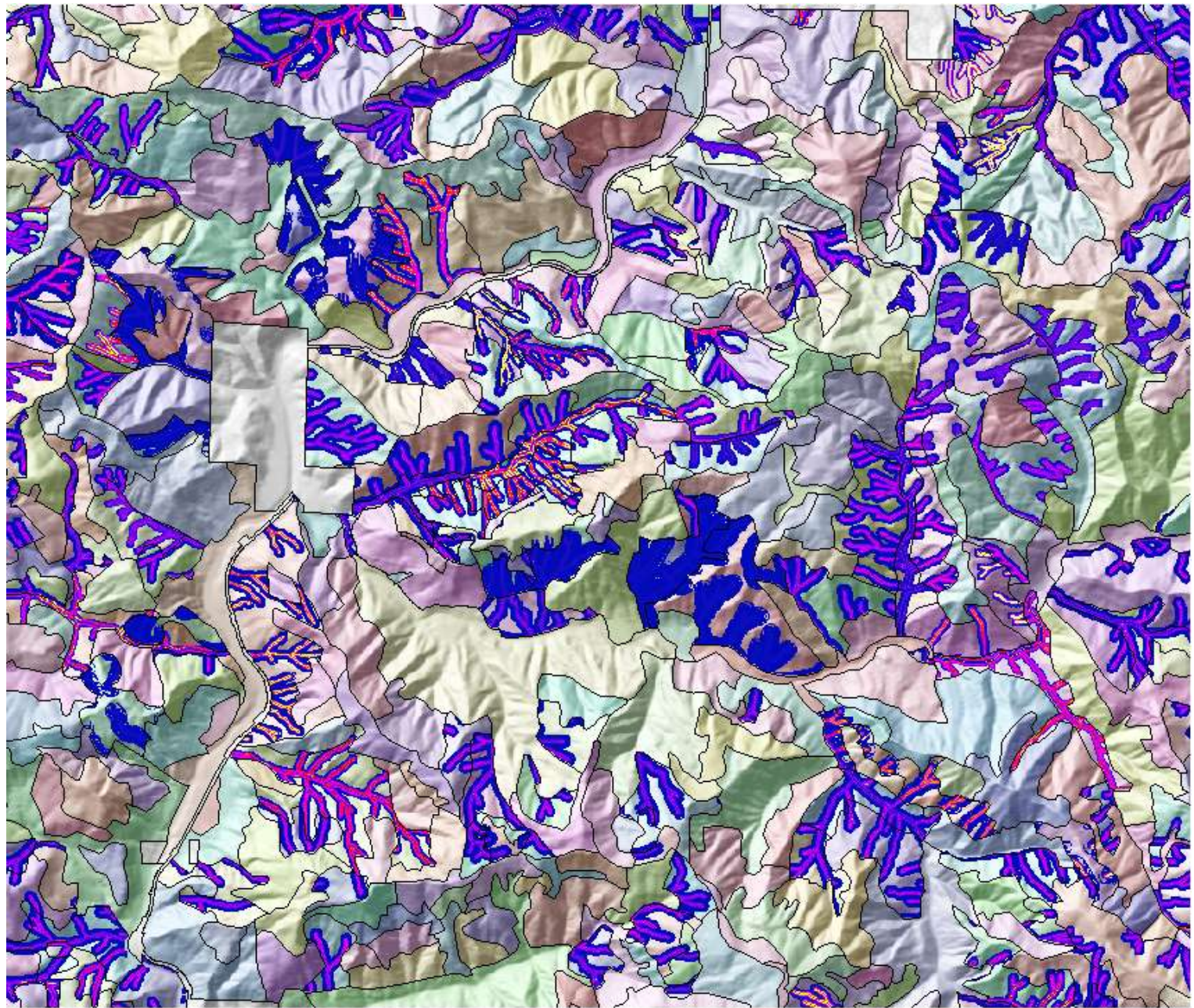


0.1 – 0.2 m diameter  
# pieces/yr



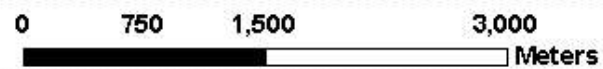
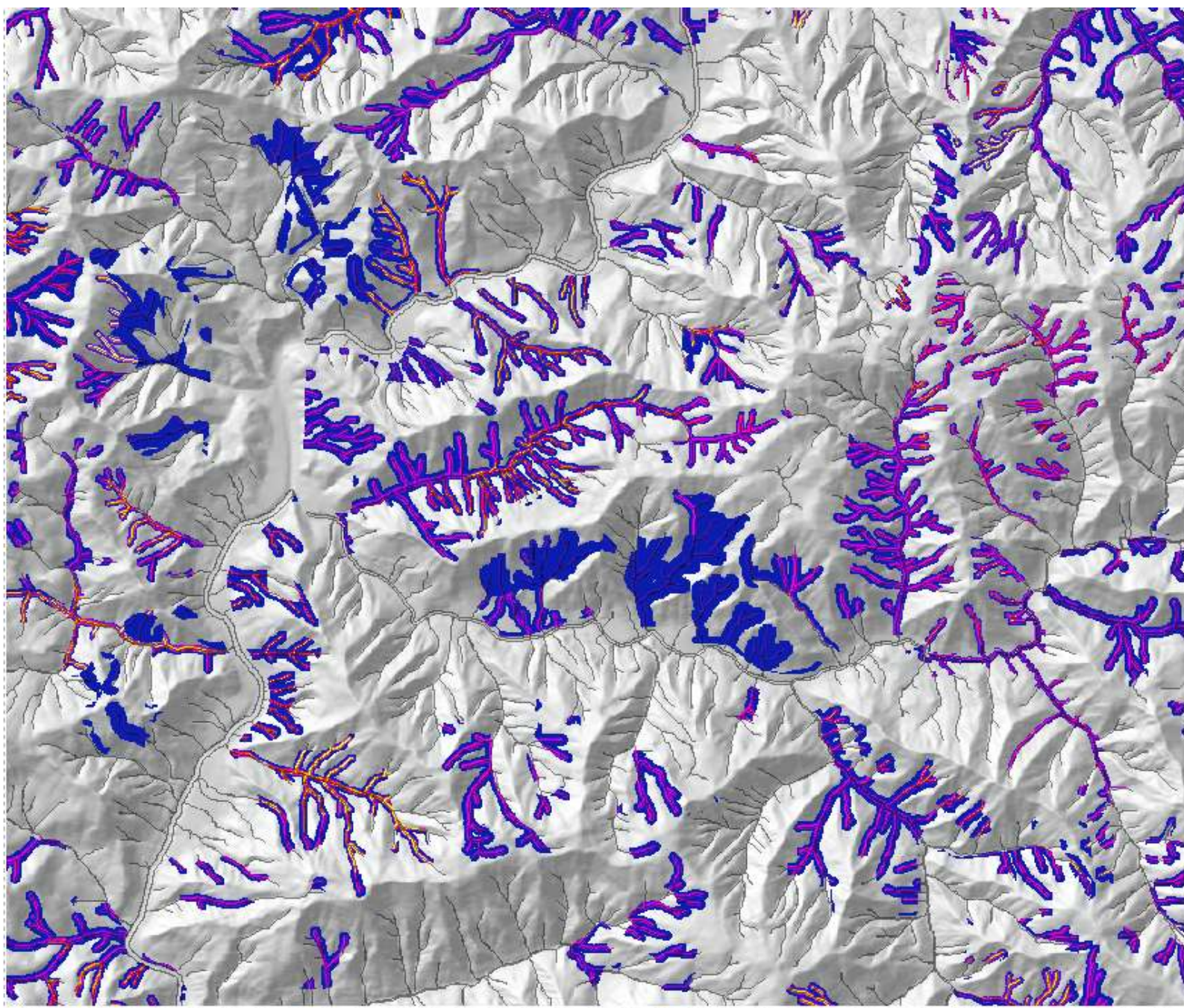
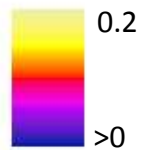
Riparian inputs  
overlay on  
stand  
inventory  
polygons.

Each polygon  
represents a  
different  
combination  
of stem  
density by  
size class (dbh  
+ height) and  
species.

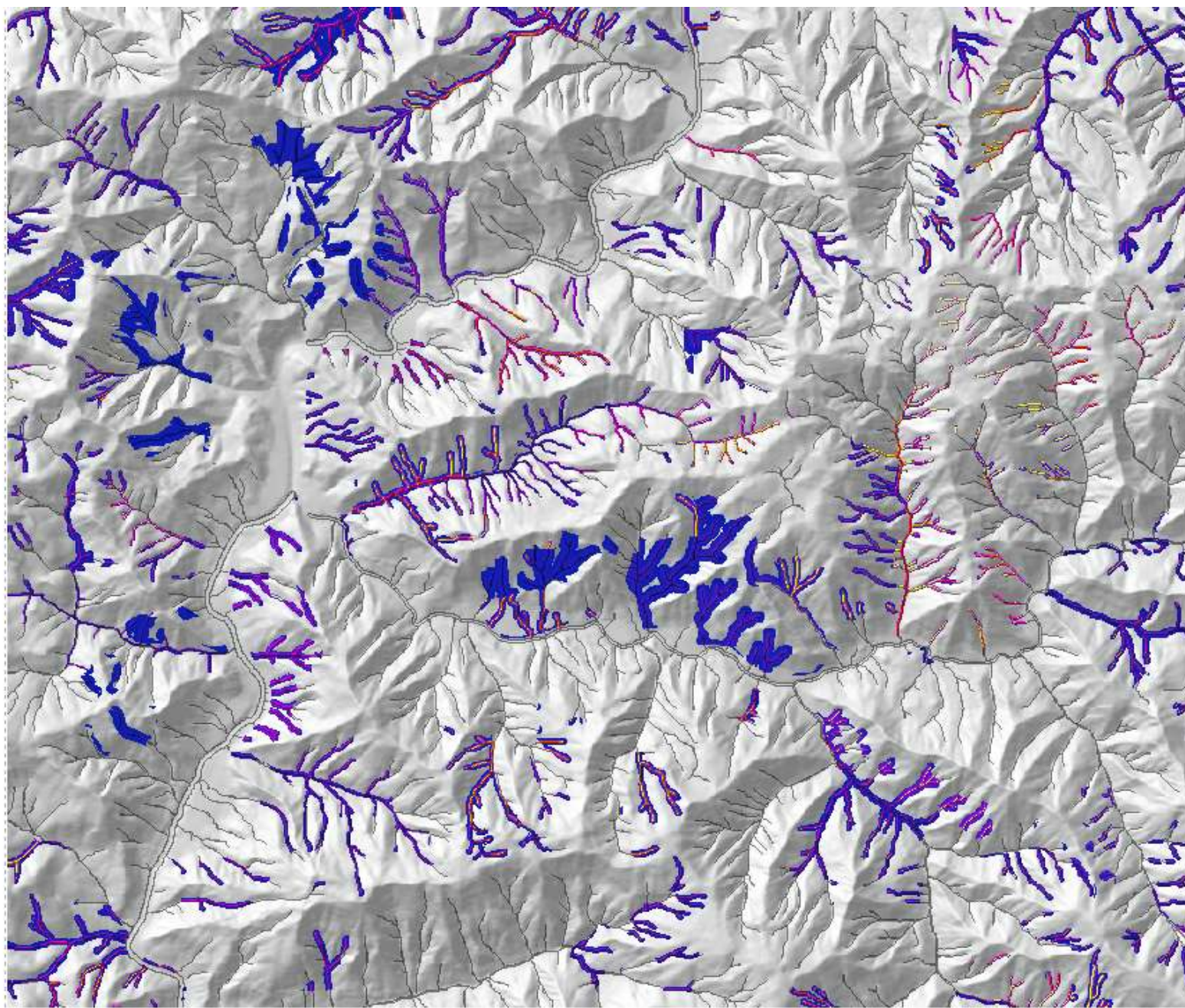
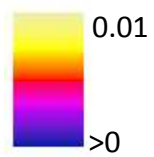


0 750 1,500 3,000  
Meters

0.2 – 0.5 m diameter  
# pieces/yr



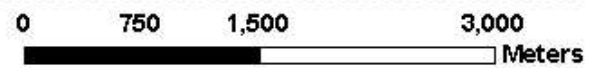
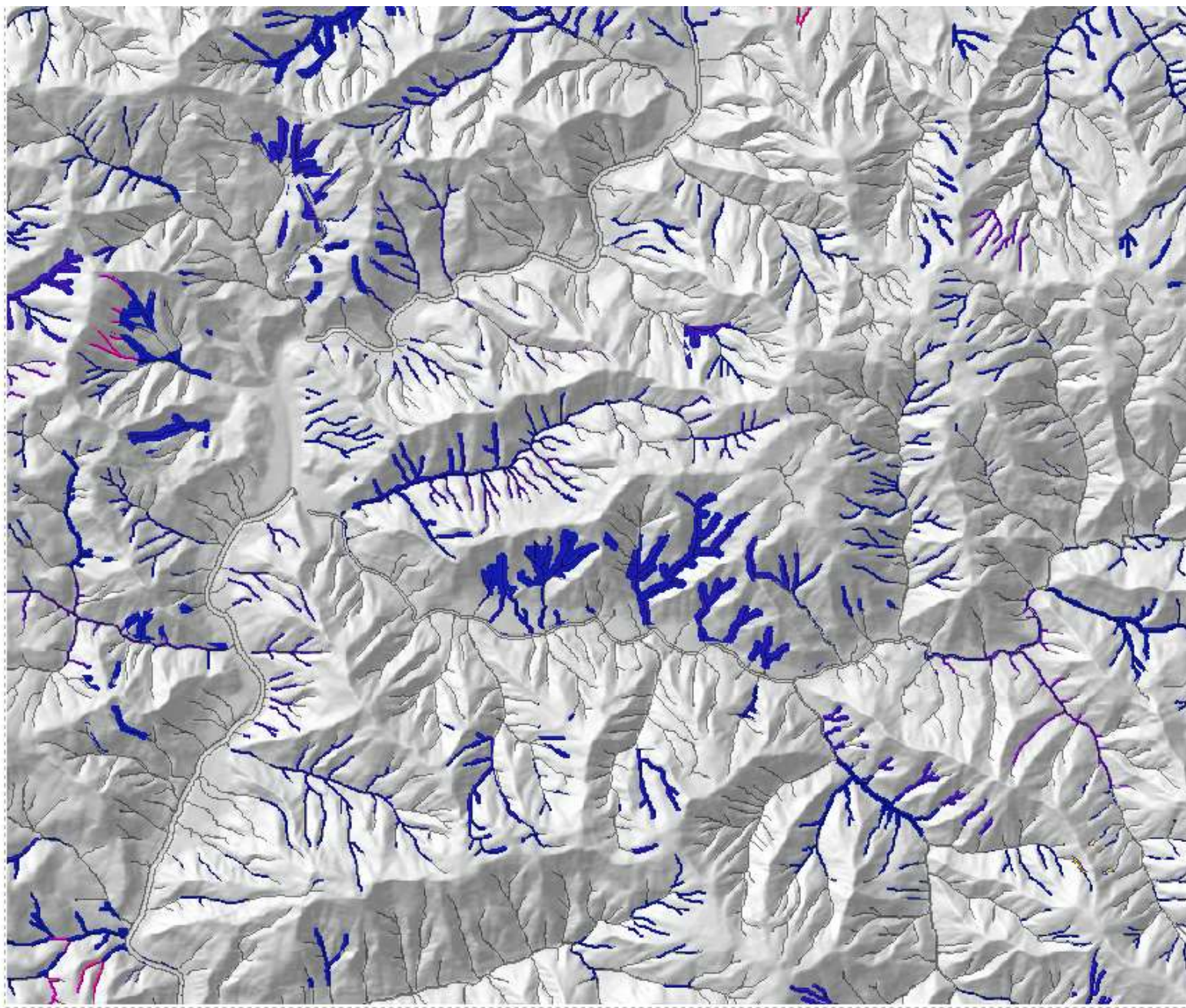
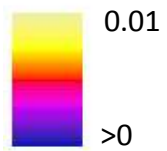
0.5 – 0.8 m diameter  
# pieces/yr



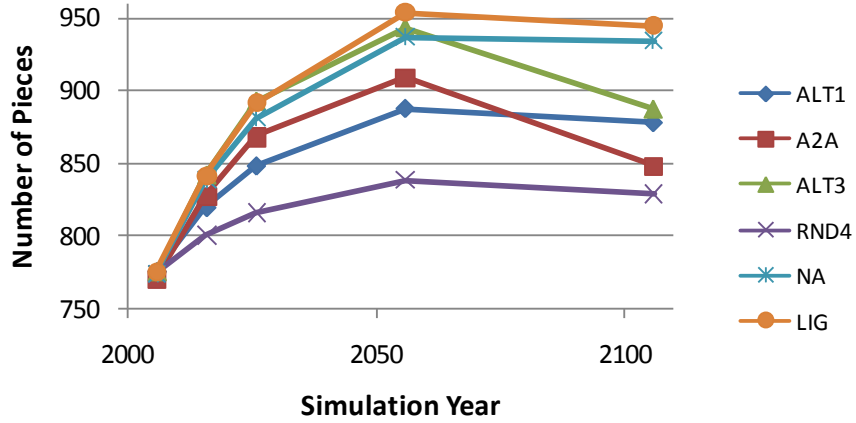
0 750 1,500 3,000  
Meters

A horizontal scale bar with tick marks at 0, 750, 1,500, and 3,000 meters.

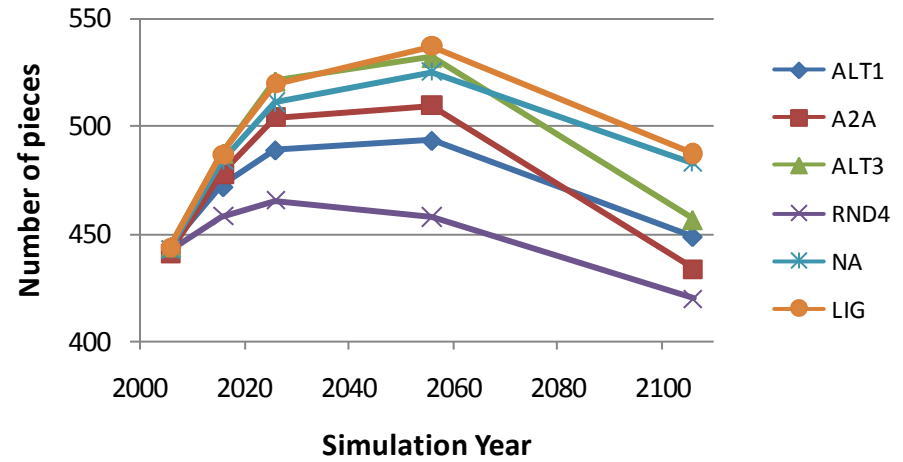
> 0.8 m diameter  
# pieces/yr



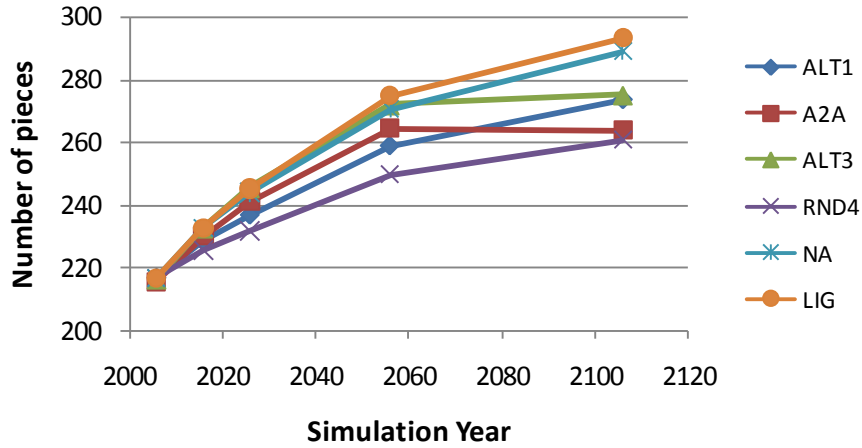
**Cascades Province, Mean Annual Wood Recruitment to Fish Bearing Channels, All Size Classes and Species**



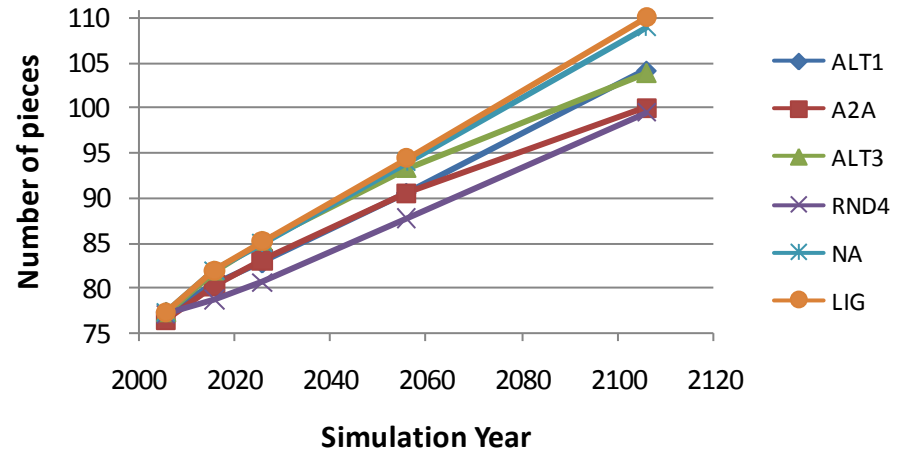
**4-10 inches diameter**



**10-20 inches diameter**



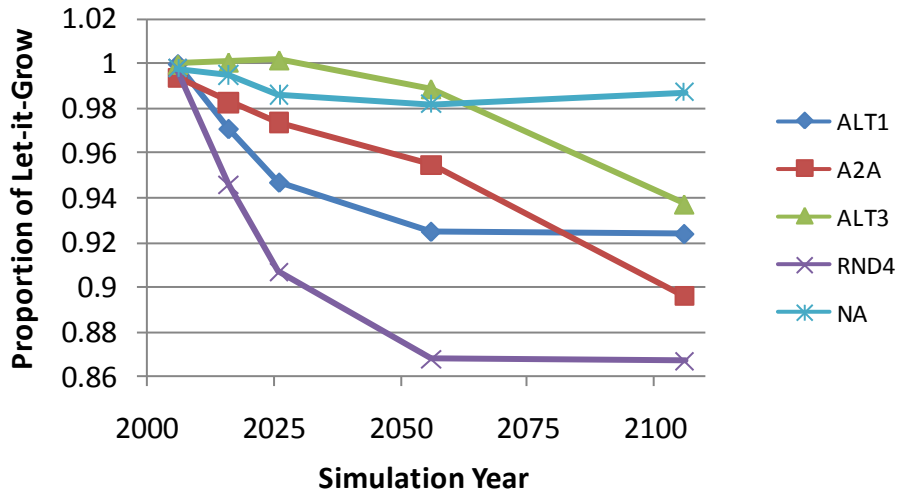
**20-30 inches diameter**



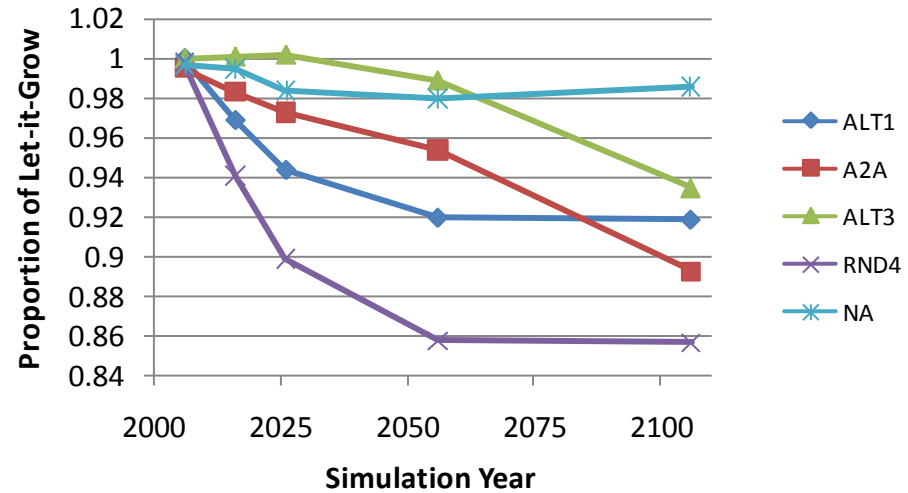
What's this imply for habitat?

Let's look at "functional" wood – wood of sufficient size to provide a habitat function in a stream. The size of wood that is functional increases with increasing stream size.

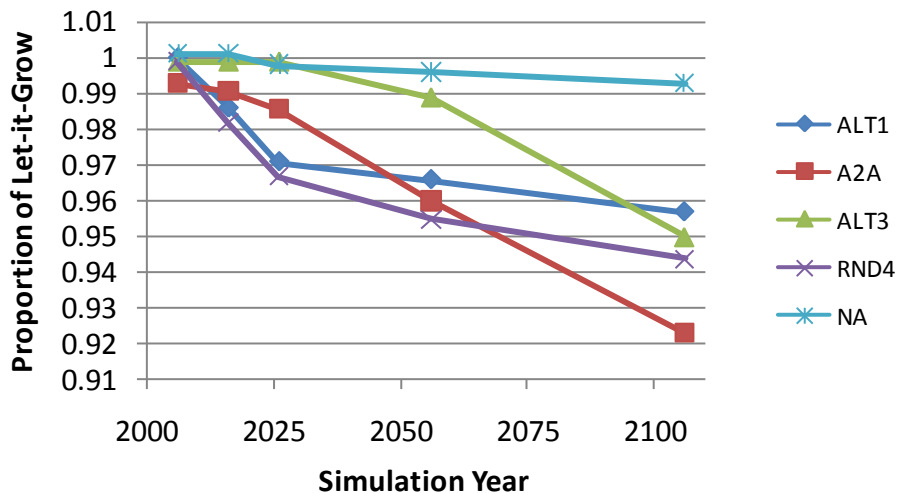
Functional Pieces, All Fish-Bearing Channels



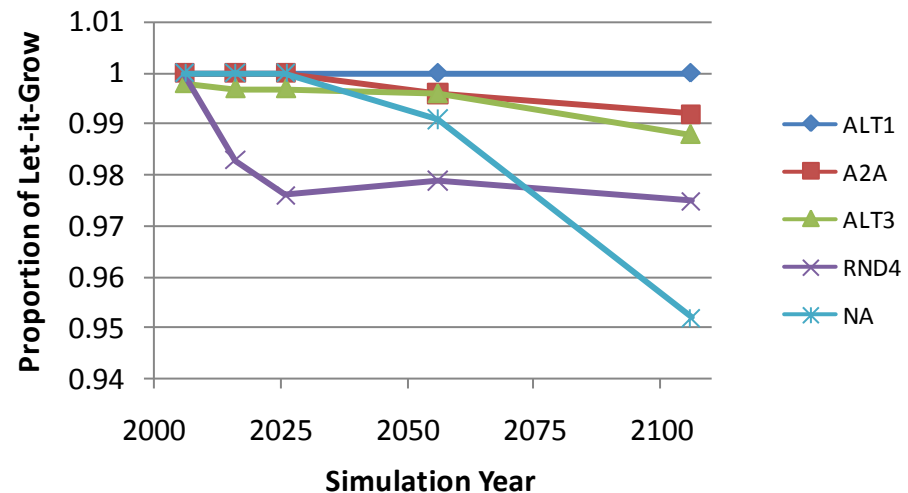
Channels less than 13 feet wide



Channels 13-33 ft wide

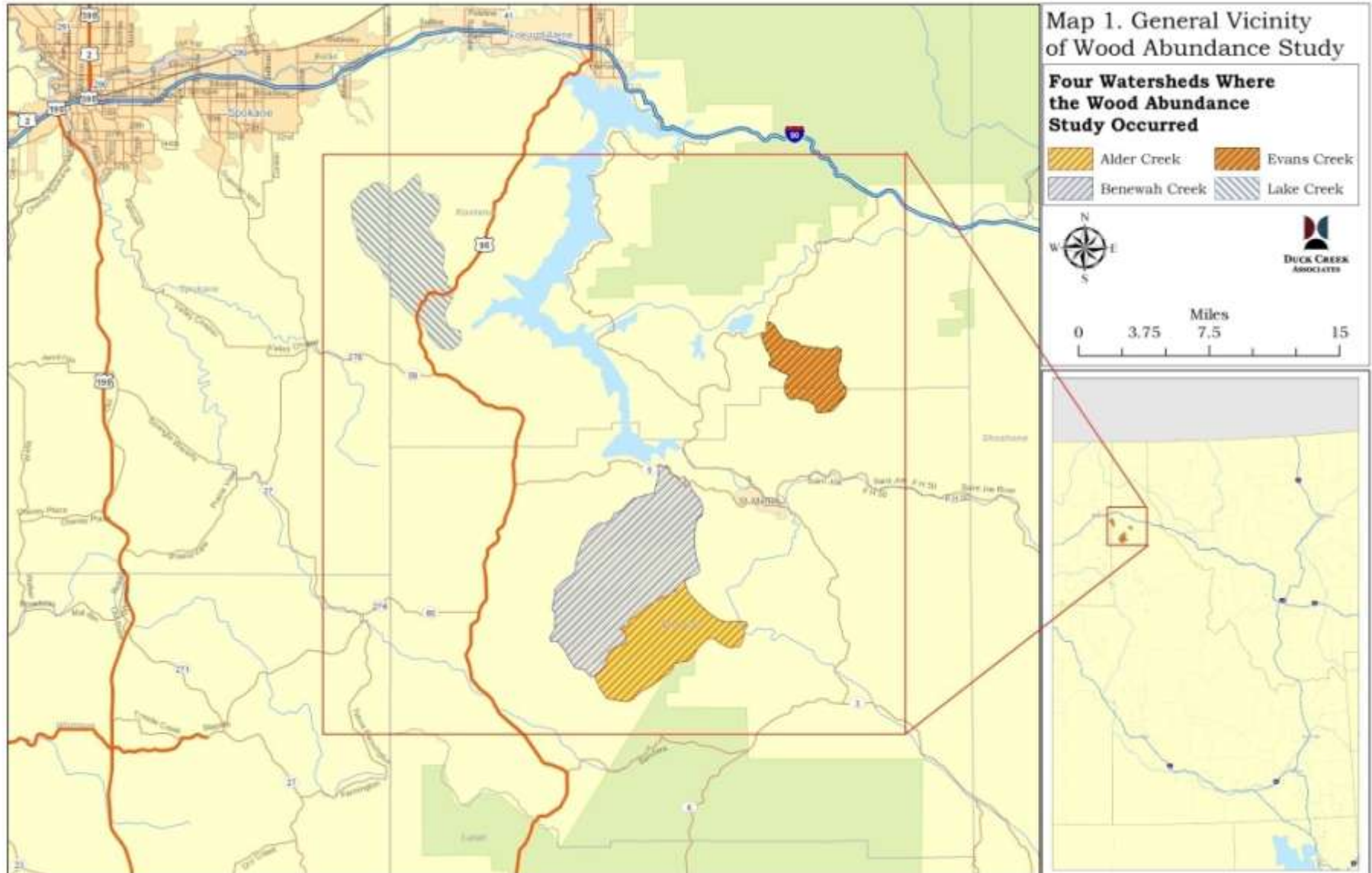


Channels 67 - 100 ft wide

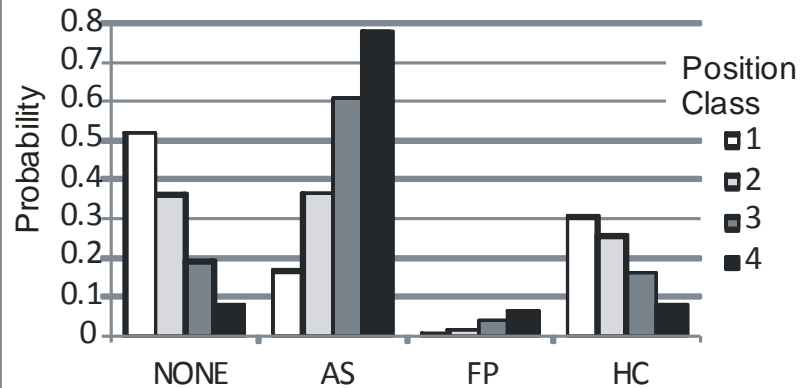


# Wood to Habitat

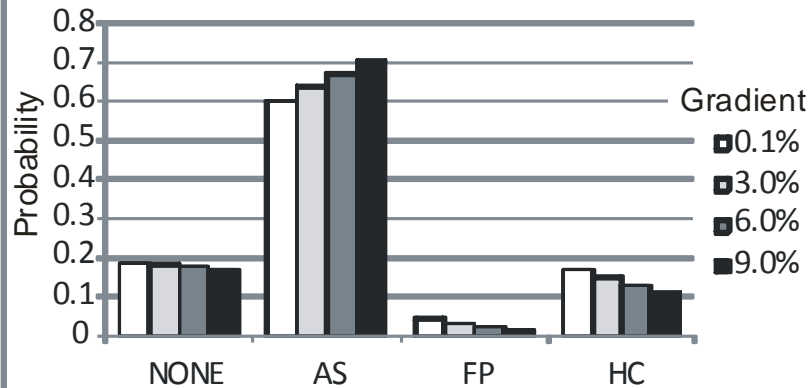
- 1) Wood recruitment to wood abundance  
Integrate inputs and outputs (decay, fluvial transport) over time
- 2) Relate wood function to piece and channel characteristics



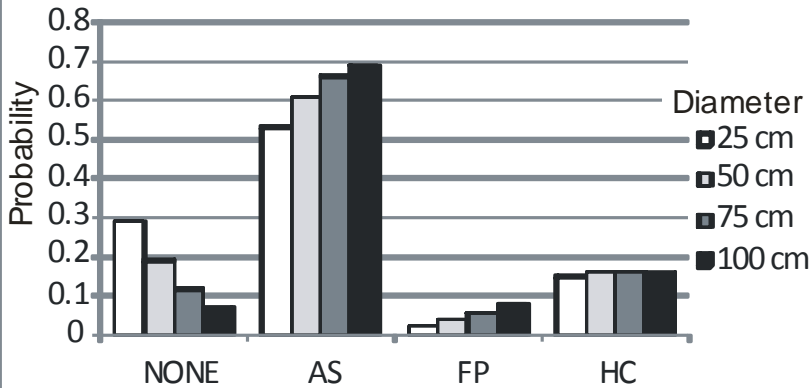
**Effect of piece position on habitat function**



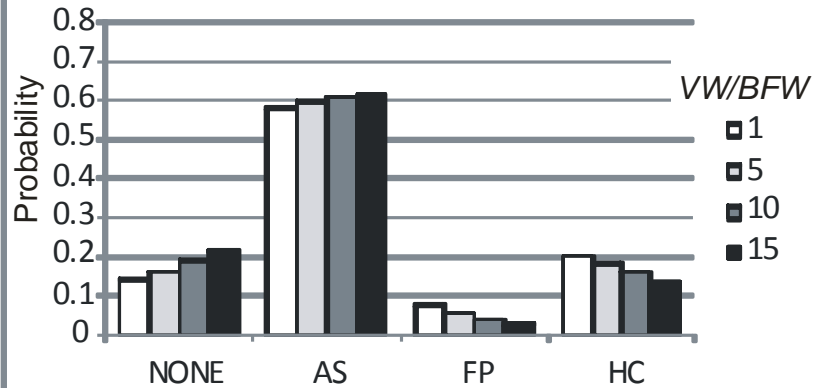
**Effect of channel gradient on habitat function**



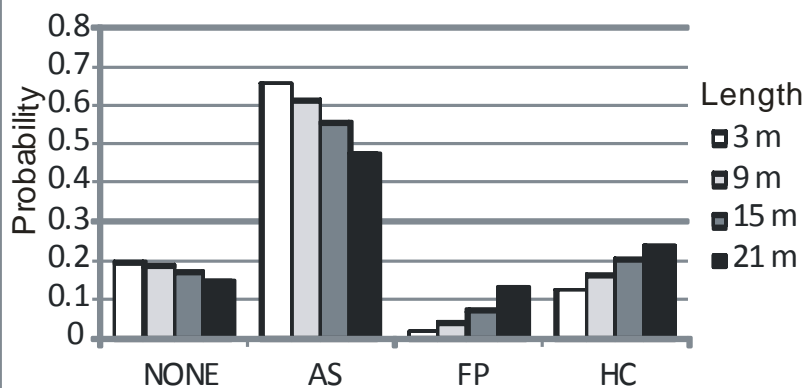
**Effect of piece diameter on habitat function**



**Effect of ratio  $VW/BFW$  on habitat function**



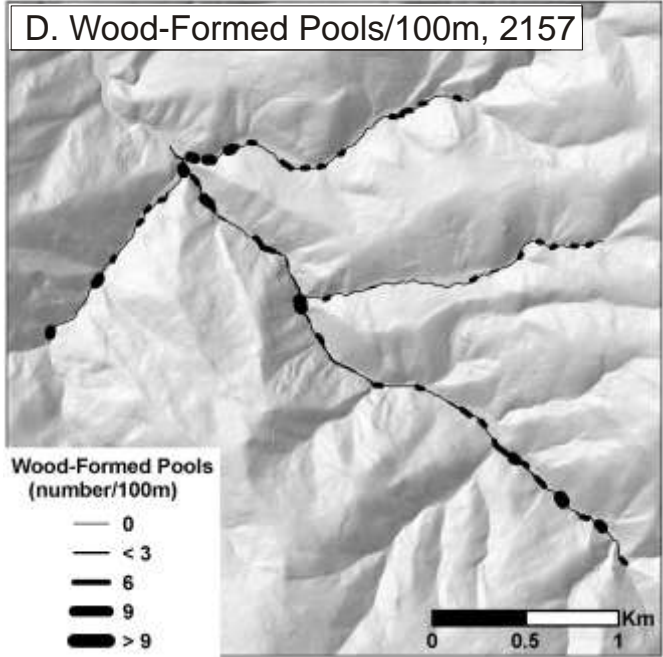
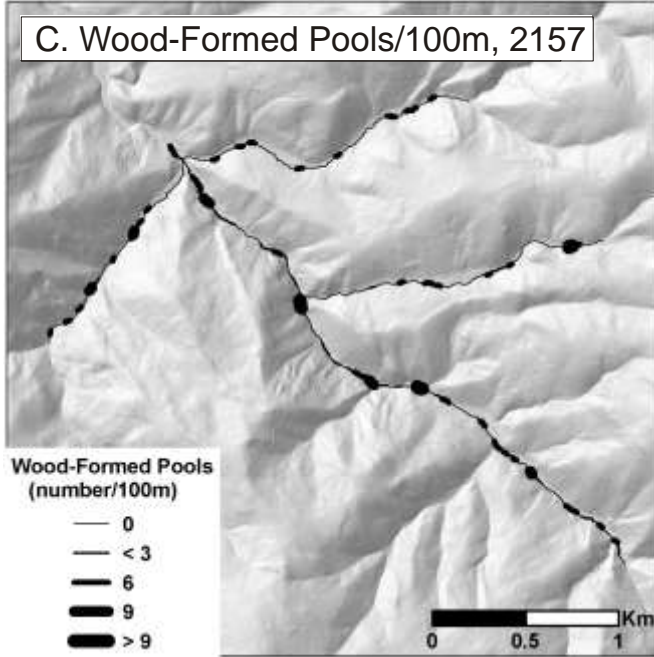
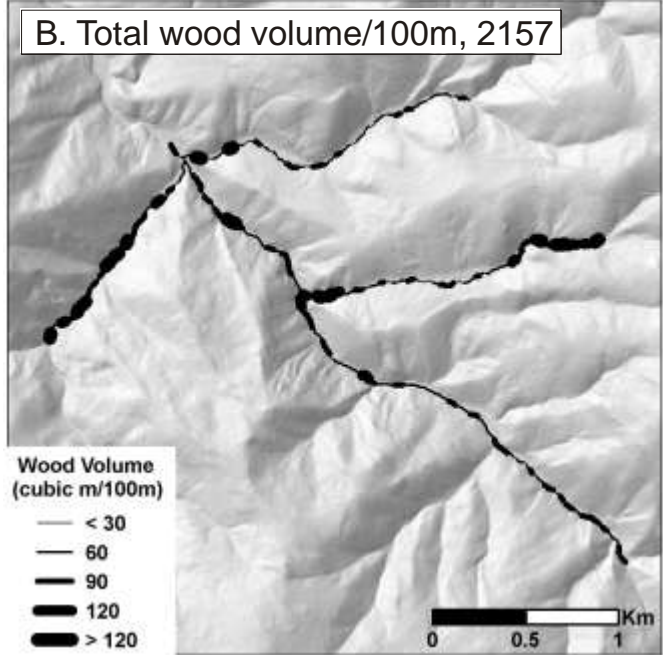
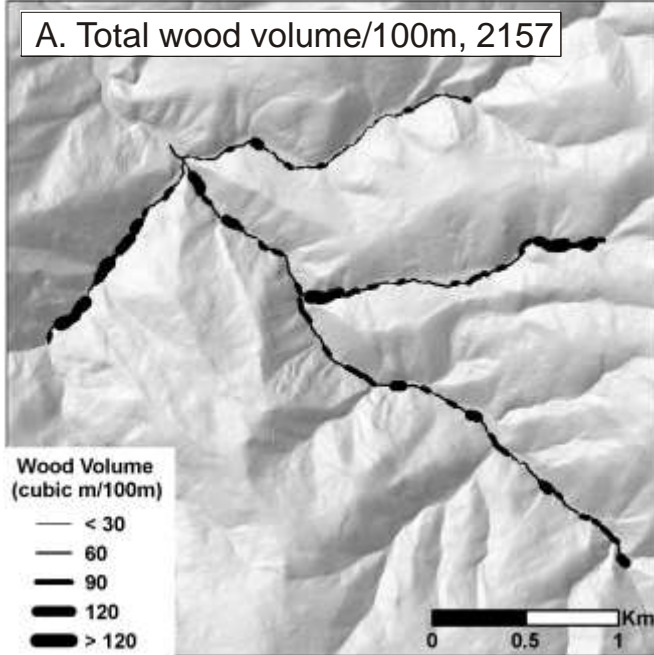
**Effect of piece length on habitat function**



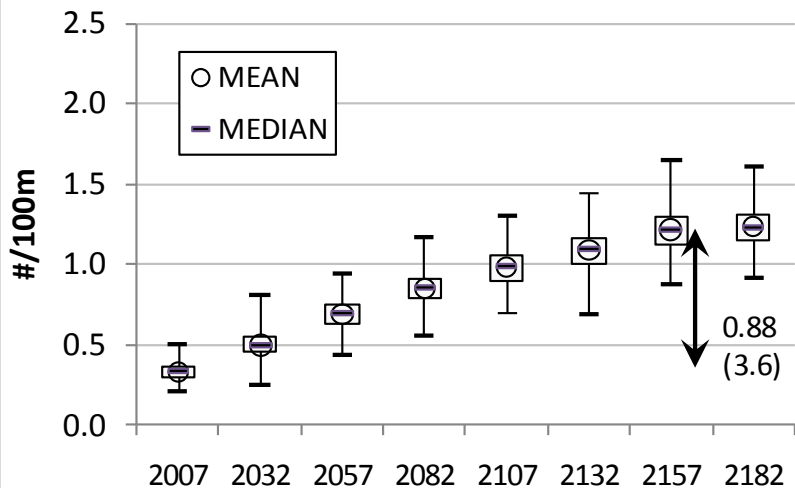
Controls on wood habitat function, based on multinomial logistic regression to inventory of pieces and associated function from field survey. Habitat function classes are as follows: NONE=no function, AS=Accumulates Sediment, FP = Forces Pool, HC = Provides Habitat Cover.

Wood volume and wood-formed pools per reach (normalized to 100-m reach lengths) from two Monte Carlo iterations for year 2157 in Evans Creek.

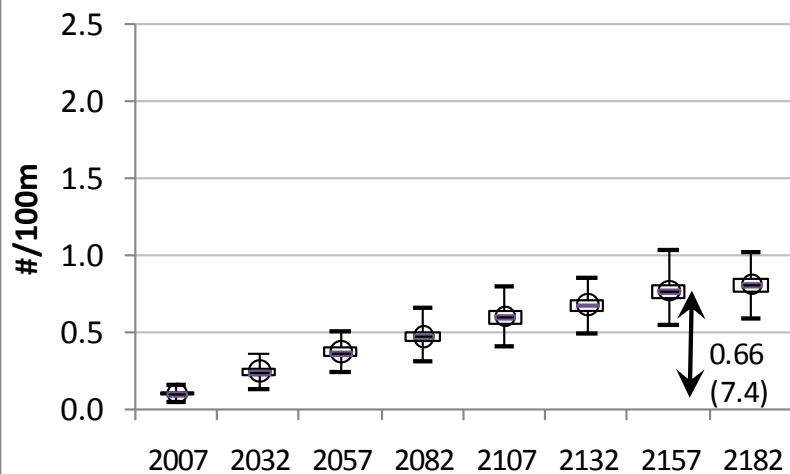
Stand growth and mortality deterministically with FVS; recruitment, position, and function modeled stochastically based on empirically calibrated probabilities.



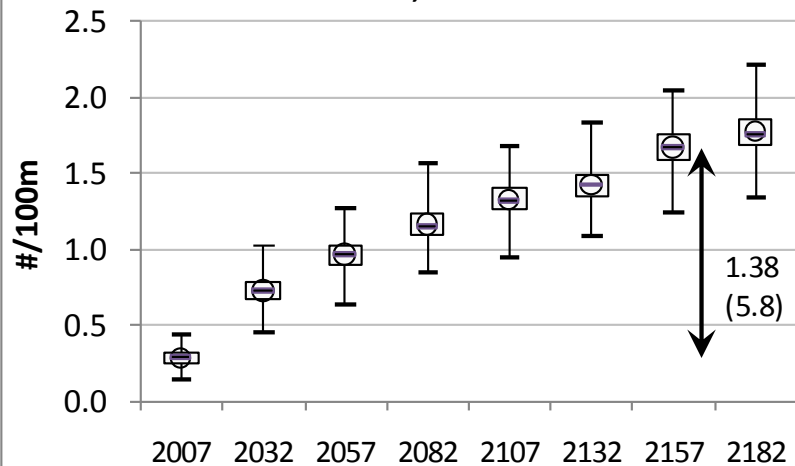
**Evans Creek, Basin-Average,  
Wood-Formed Pools, All Pieces**



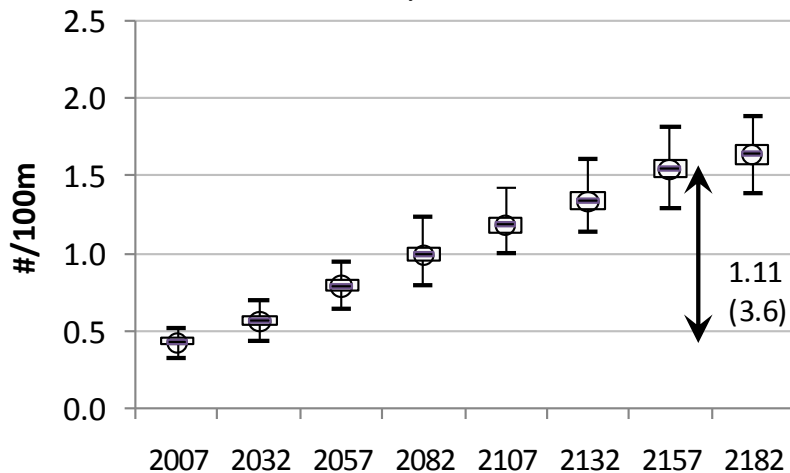
**Lake Creek, Basin-Average,  
Wood-Formed Pools, All Pieces**



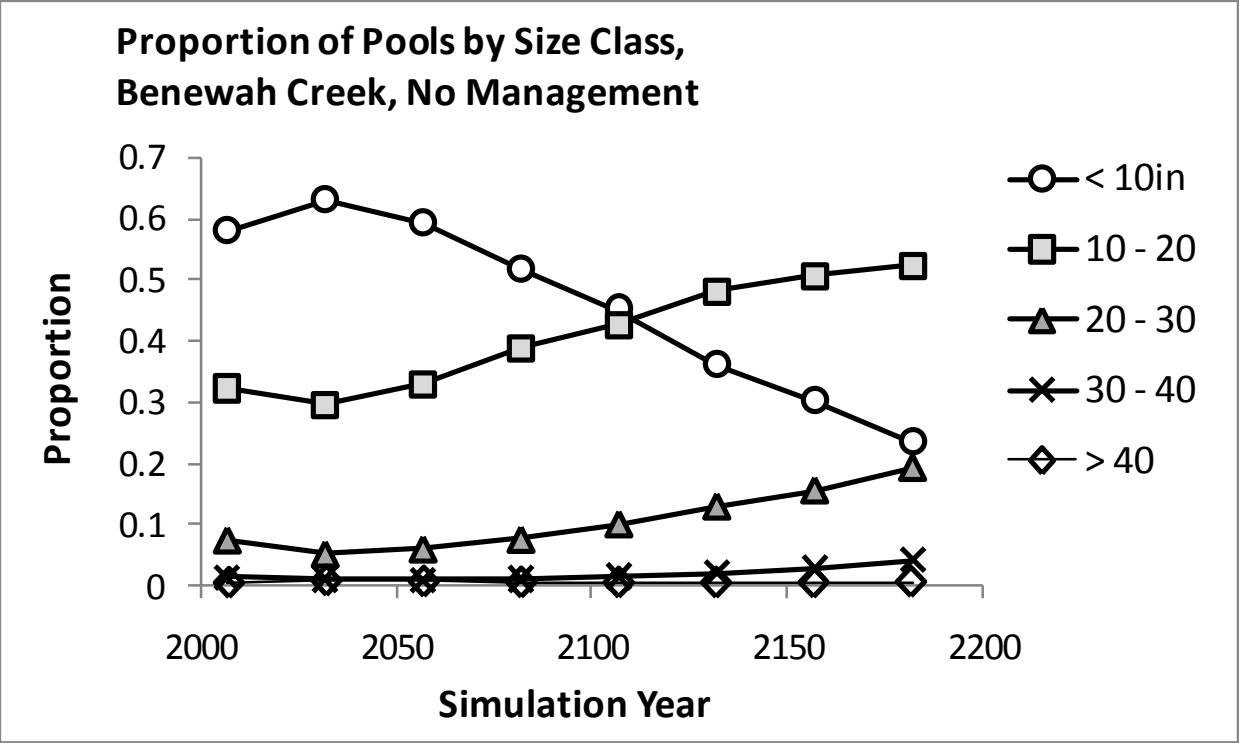
**Alder Creeks, Basin-Average,  
Wood-Formed Pools, All Pieces**



**Benawah Creek, Basin-Average,  
Wood-Formed Pools, All Pieces**

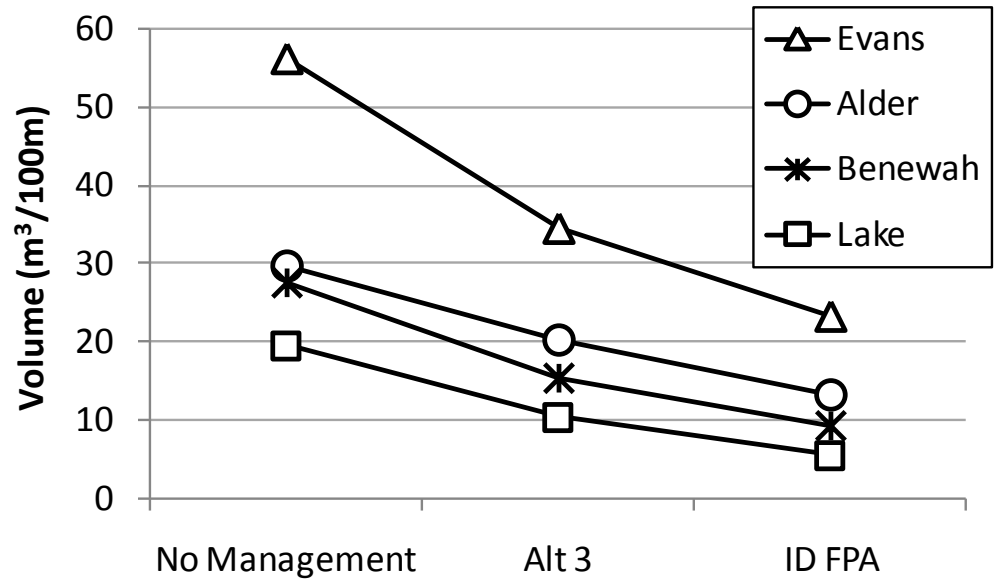


**Figure 3.2.2-8.** Box plots for basin-averaged number of wood-formed pools for each of the four study basins under the no-management scenario, based on 1000 Monte Carlo iterations. Arrows indicate the change in between 2007 and 2157 (150 years); the numbers to the right of the arrow indicate the absolute change over this time period, the value in parenthesis indicates the proportional change over this time

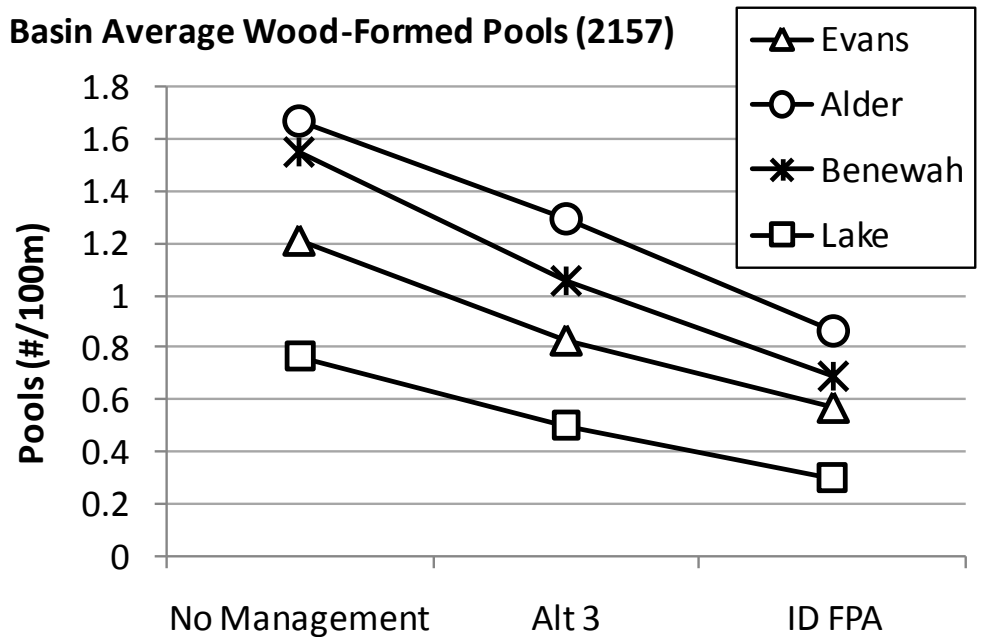


Compare management alternatives across basins.

**Basin Average Wood Volume by alternative (2157)**



**Basin Average Wood-Formed Pools (2157)**



## Debris Flows

- Identify debris flow source areas
- Identify debris flow travel path from each source DEM cell
- Find conditional probability that each DEM cell was traversed by a debris flow from upslope

For each DEM cell, this gives a mean annual probability of being traversed by a debris flow

Starting from each debris-flow source DEM cell, accumulate potential wood cell by cell along each debris-flow source track

The proportion of wood taken from each pixel is determined by:

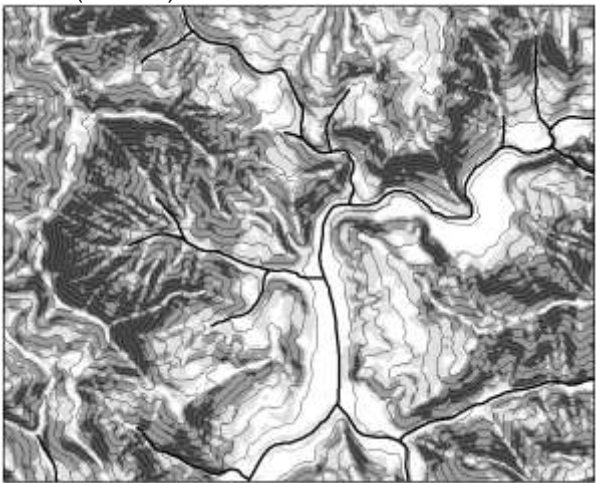
- Mean debris flow track width (from ODF data)
- The probability of no debris-flow deposition in the pixel

The proportion of accumulated wood deposited in each pixel is determined by the relative downslope decrease in debris-flow traversal probability (e.g., if traversal probability decreases by 20%, 20% of the accumulated wood is deposited)

# Landslide-delivered wood, focusing on debris-flows:

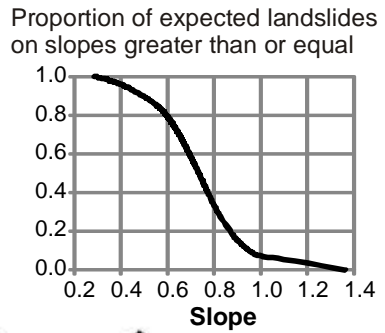
## Spatially distributed landslide susceptibility (Miller and Burnett, 2007, Water Resources Res. 43: W03433)

30-m (86-feet) contours

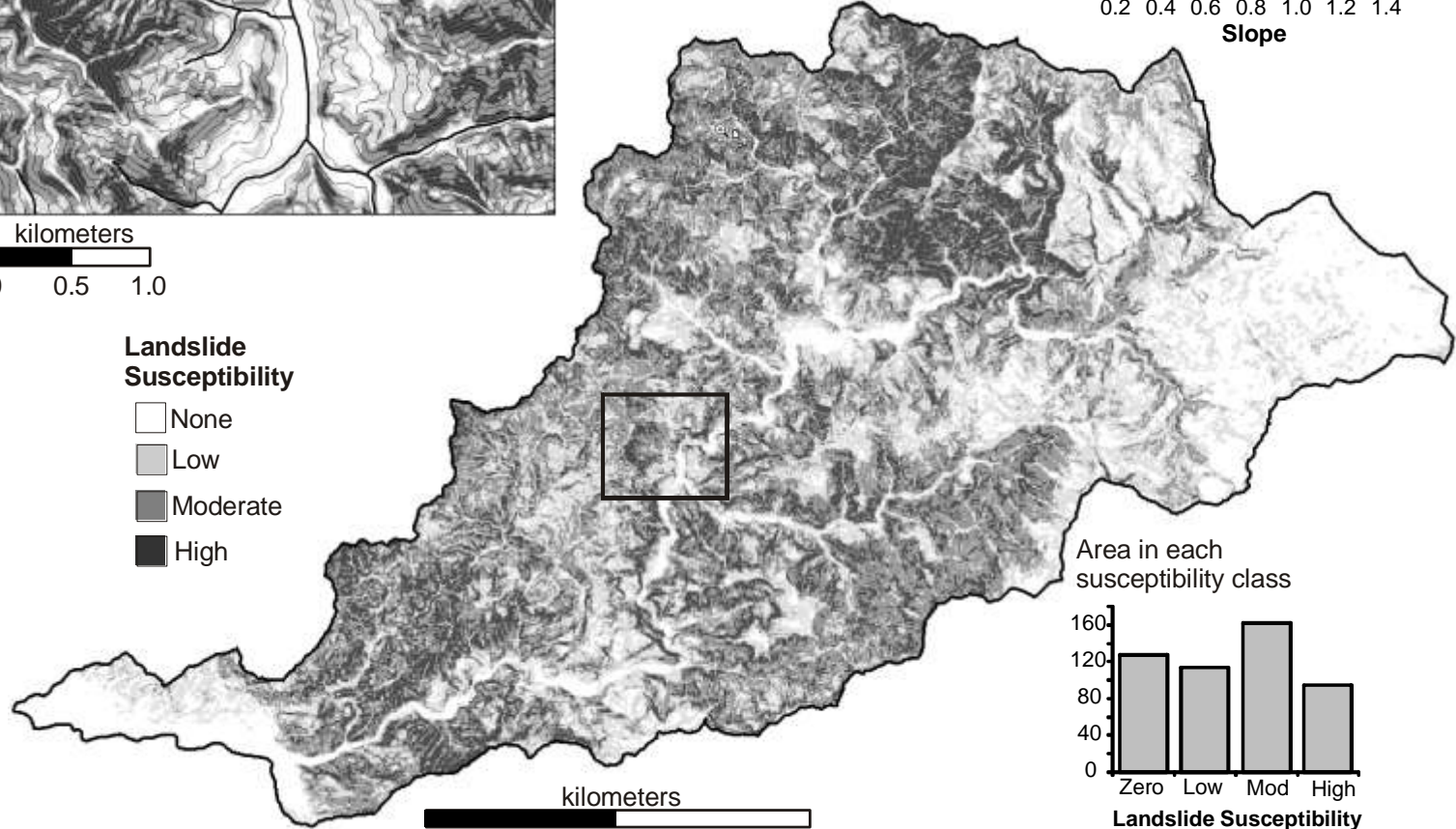


kilometers  
0 0.5 1.0

**Wilson River Basin  
Landslide Susceptibility**  
based on proportion of  
expected landslides as  
a function of slope

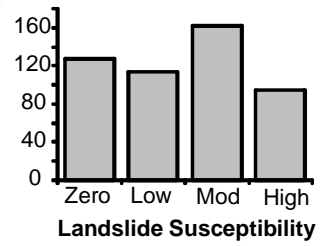


**Landslide  
Susceptibility**  
None  
Low  
Moderate  
High



kilometers  
0 5 10

Area in each  
susceptibility class



# Probability for landslide (debris-flow) delivery to a channel from each DEM cell (Miller and Burnett, 2008, *Geomorphology*, **94**: 184-205)

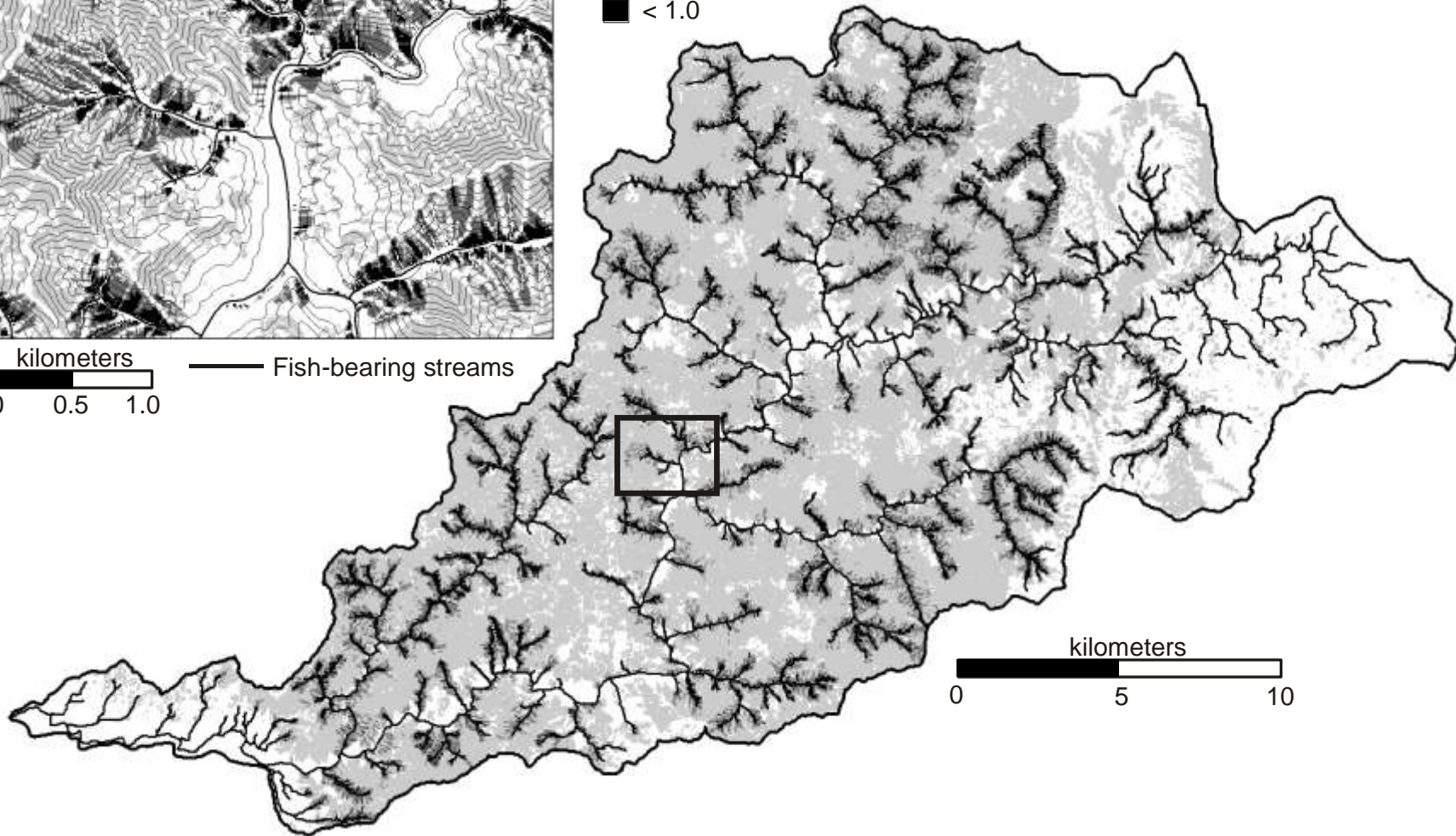
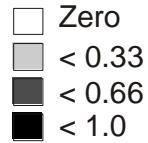
30-m (86-feet) contours



kilometers  
0 0.5 1.0

— Fish-bearing streams

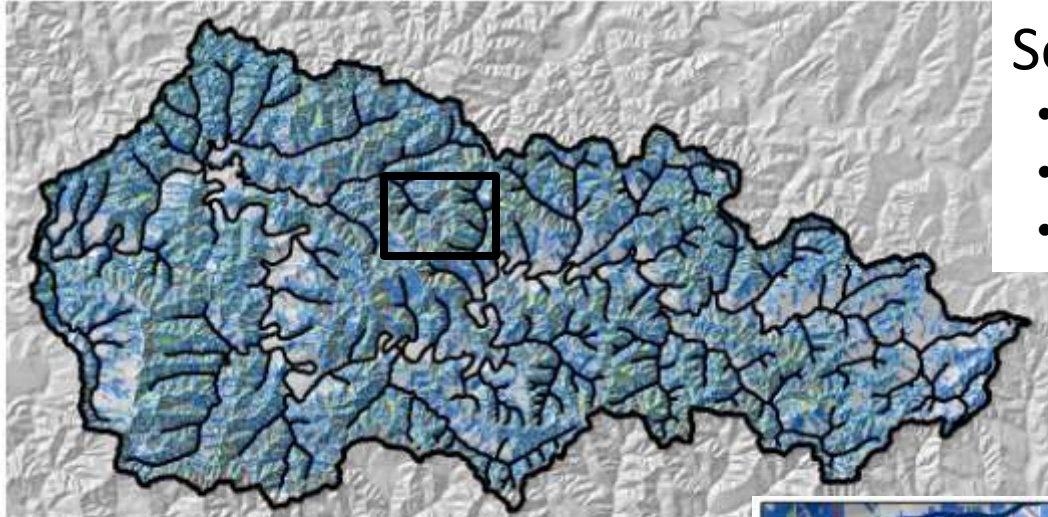
## Delivery Probability



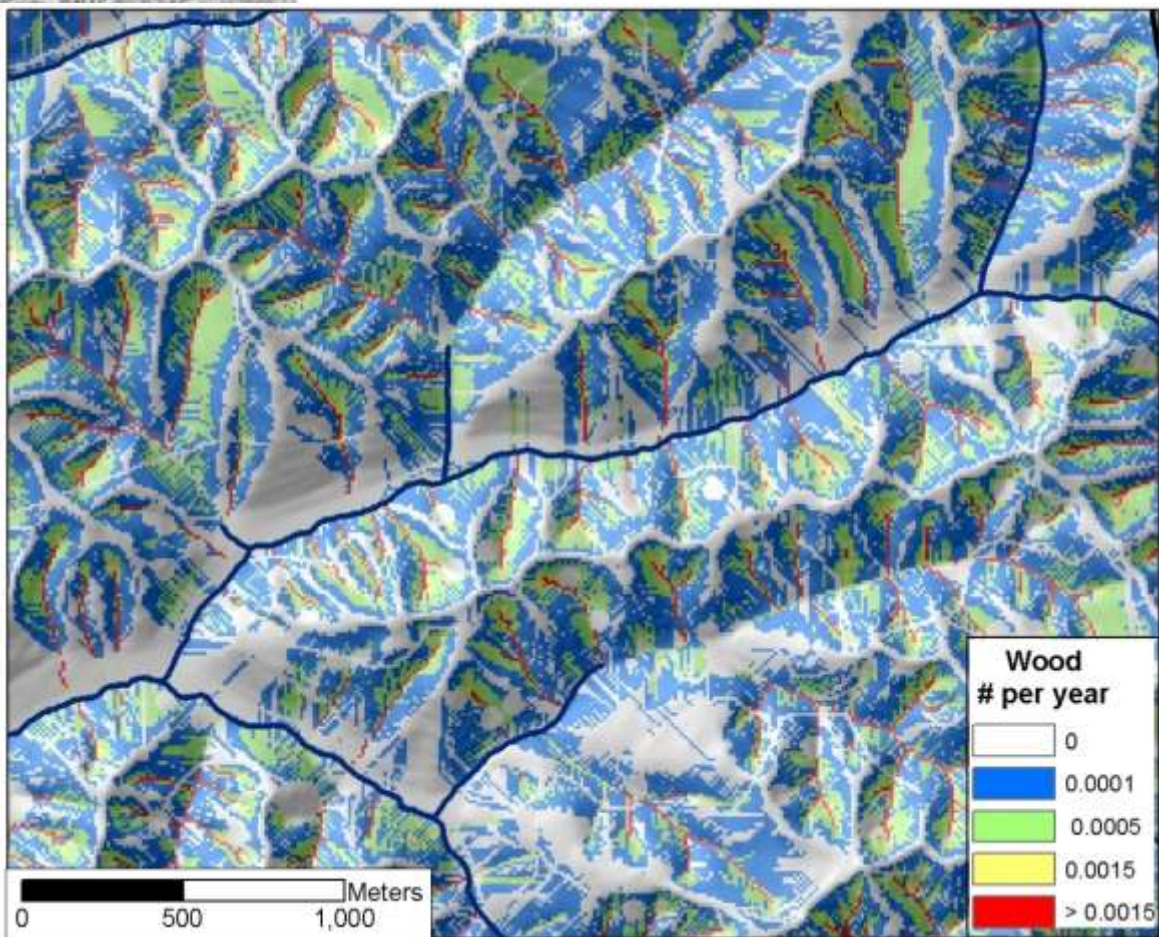
kilometers  
0 5 10

## Sources for debris flow wood:

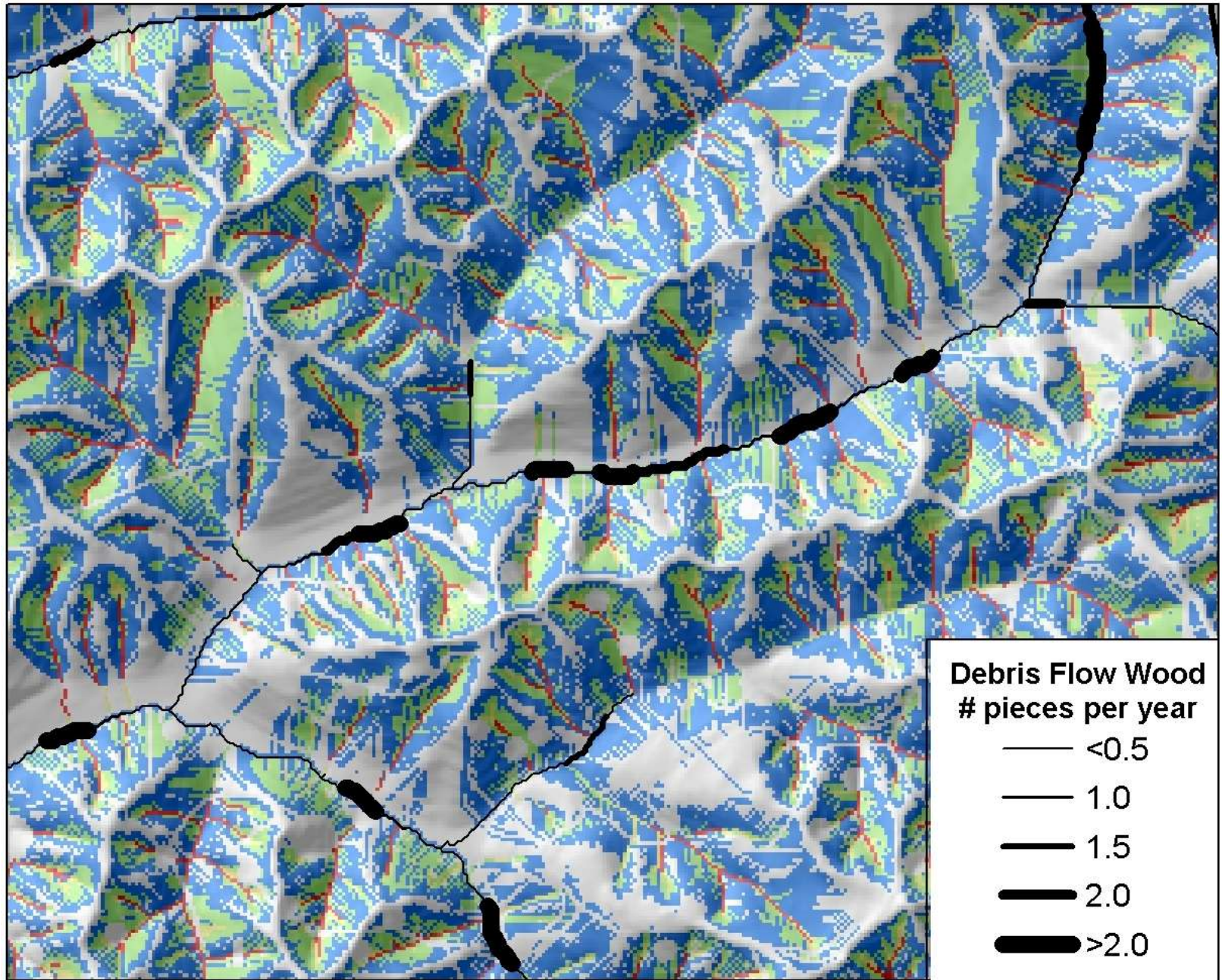
- Standing trees (from stand tables)
- Down wood (calculated as per riparian)
- Wood deposited by previous debris flows



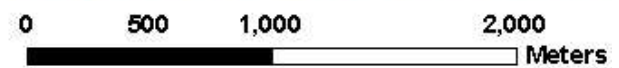
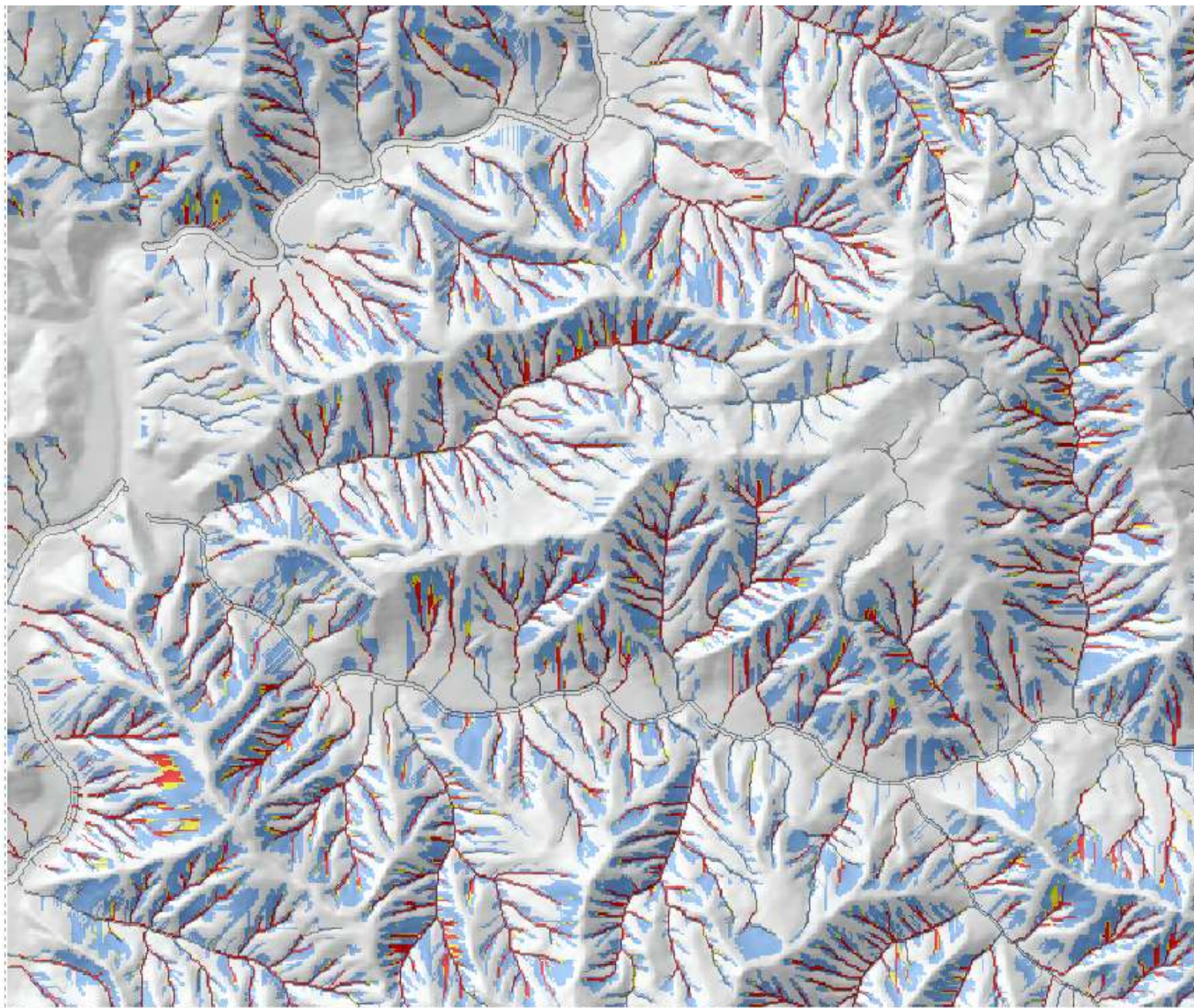
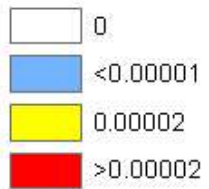
0 5,000 10,000 Meters



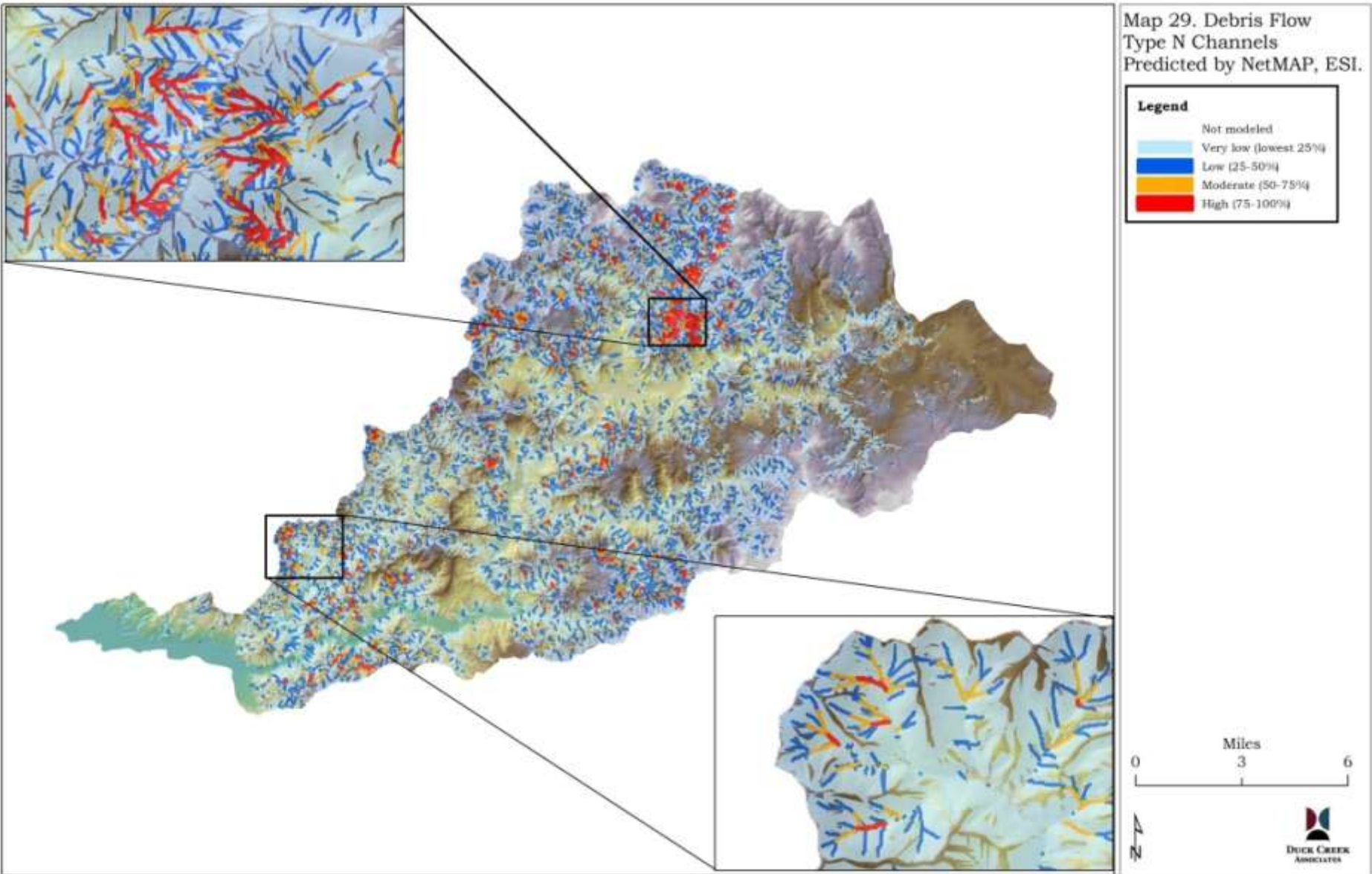
Debris flow inputs to fish-bearing streams occur at low-order channel junctions.



Debris-flow inputs,  
0.2-0.5 m diameter  
pieces/yr



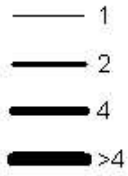
These models suggest that the areas most likely to provide debris-flow-carried wood to fish-bearing streams are the low-order channels that serve as debris-flow corridors. We can identify those most likely to serve as future sources of debris-flow wood (Burnett and Miller, 2007, Forest Science, 53: 239-253)



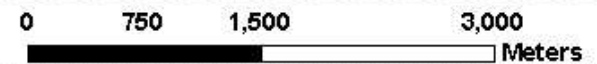
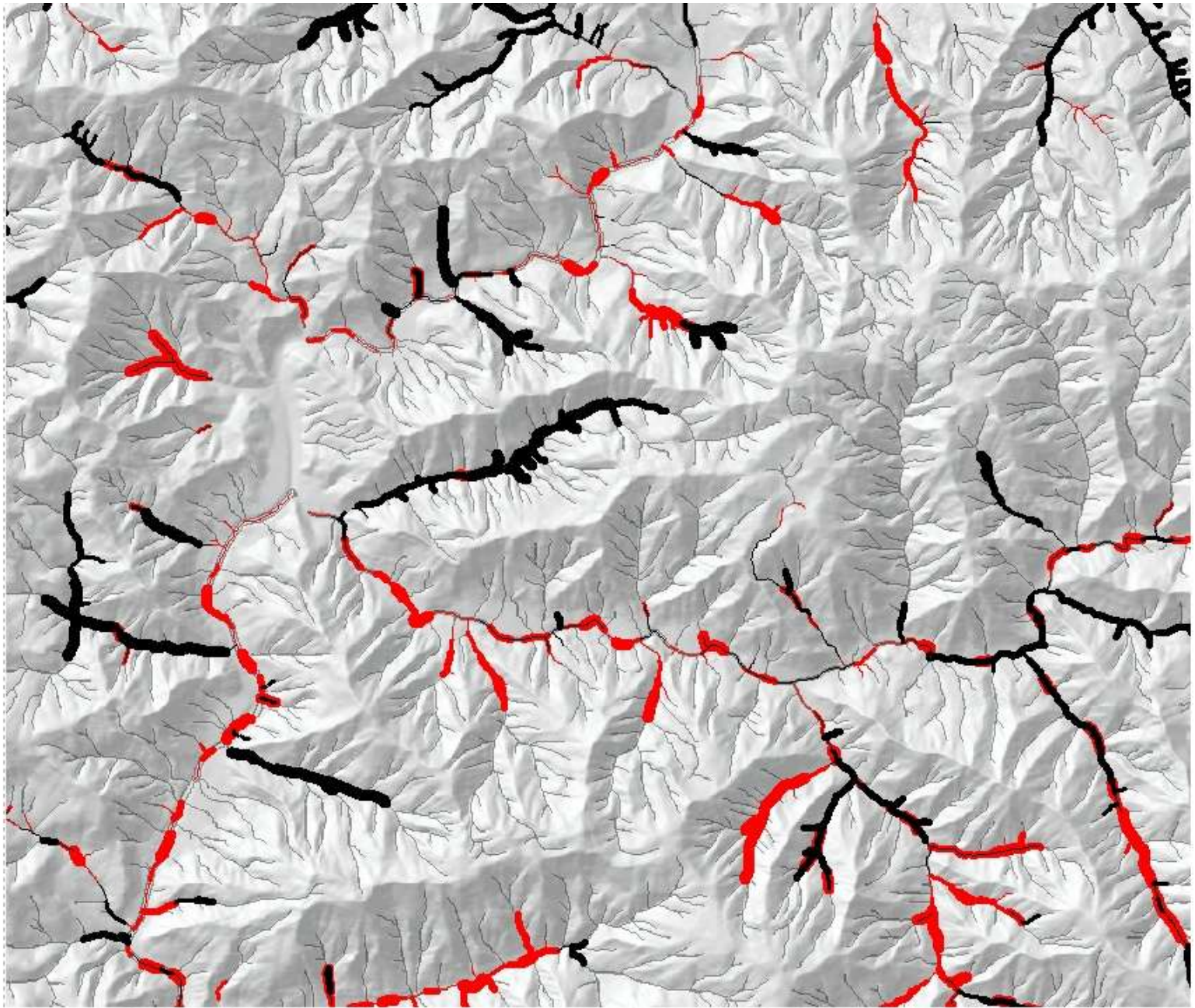
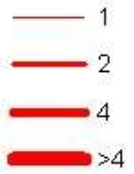
We can compare processes

0.2-0.5 m diameter  
pieces/mile/yr

RIPARIAN\_1



DEBRIS\_F\_1



0.5-0.8 m diameter

Pieces/mile/yr

RIPARIAN\_2

— 0.005

— 0.01

— 0.02

— >0.02

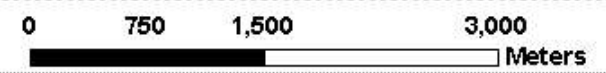
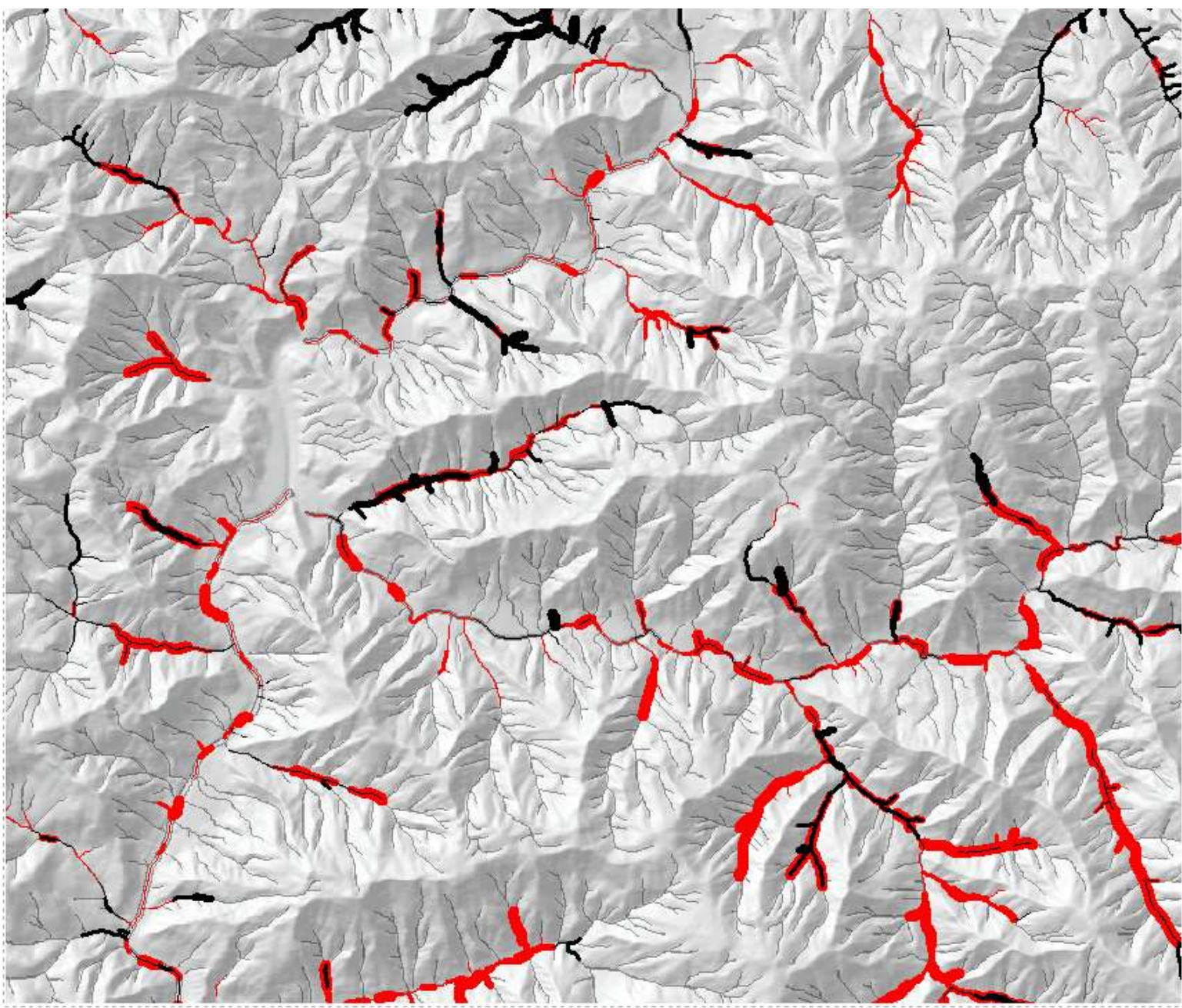
DEBRIS\_F\_2

— 0.005

— 0.01

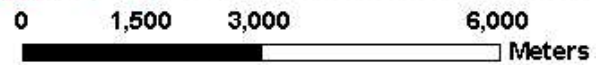
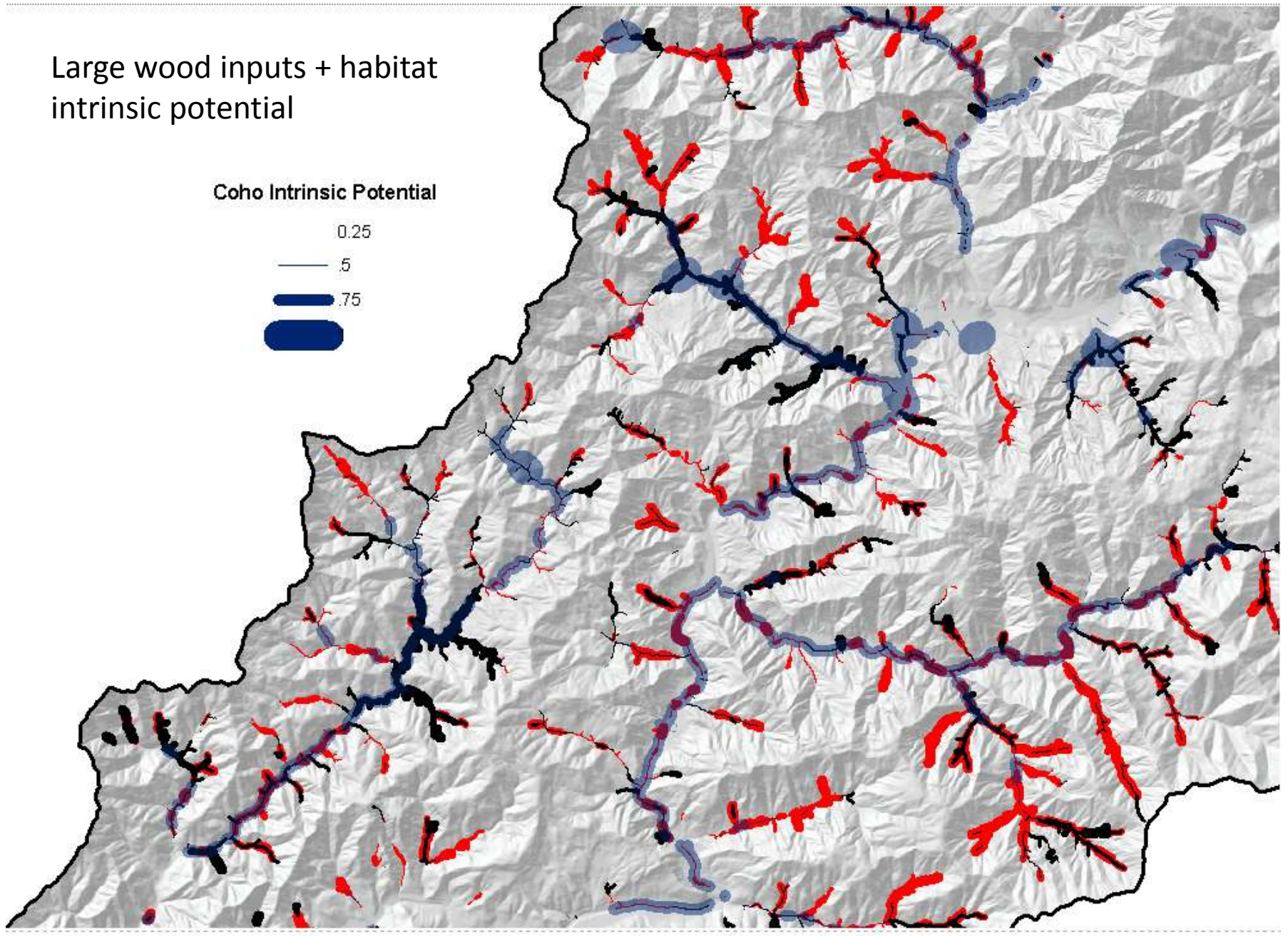
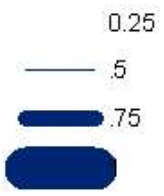
— 0.02

— >0.02



# Large wood inputs + habitat intrinsic potential

## Coho Intrinsic Potential



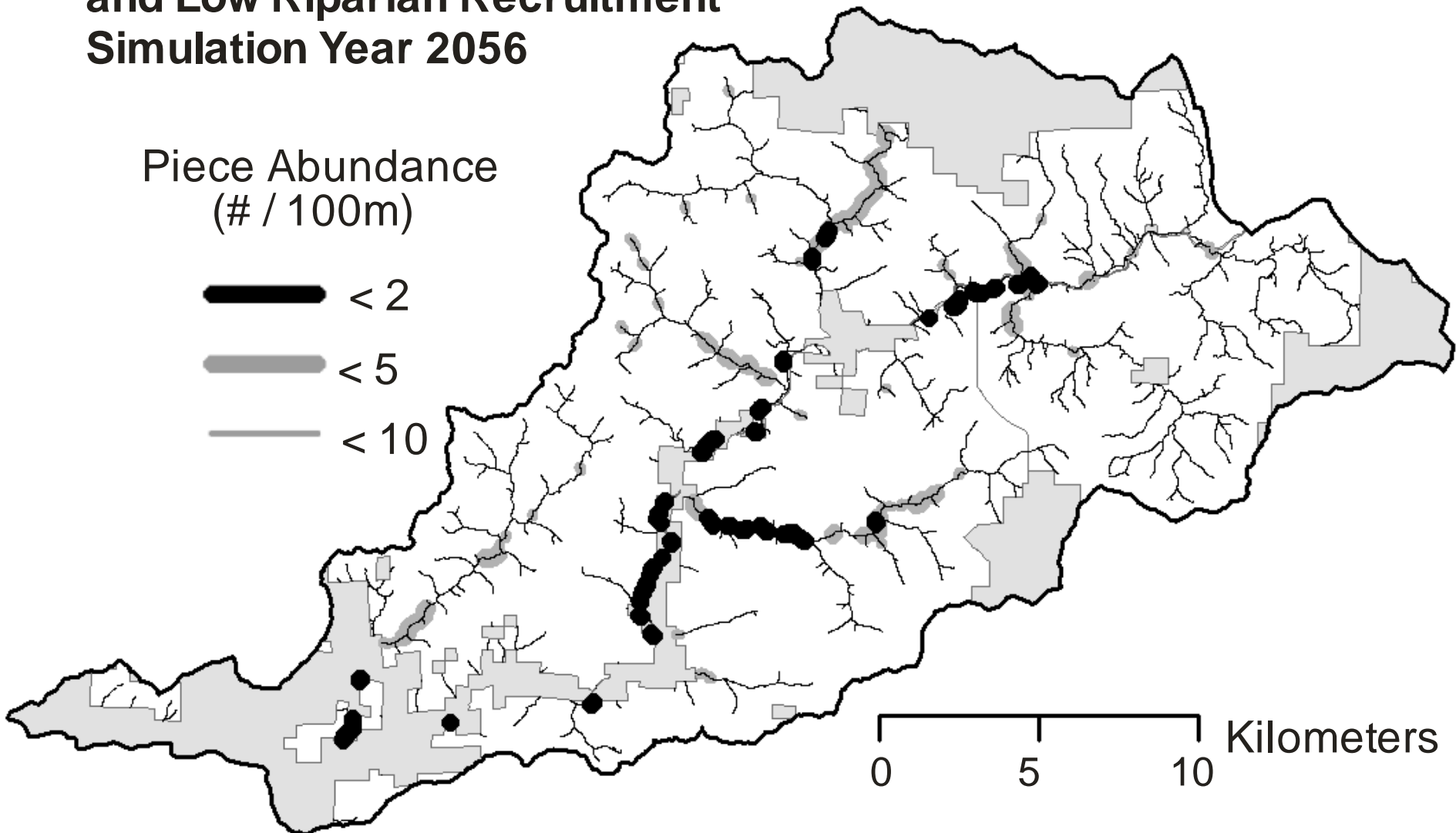
# Reaches with High to Moderate Debris Flow Susceptibility and Low Riparian Recruitment Simulation Year 2056

Piece Abundance  
(# / 100m)

 < 2

 < 5

 < 10



## High Priority Reaches

### Area Encompassing % of Expected Landslides that Deliver

 Low (10% of Expected Landslides)

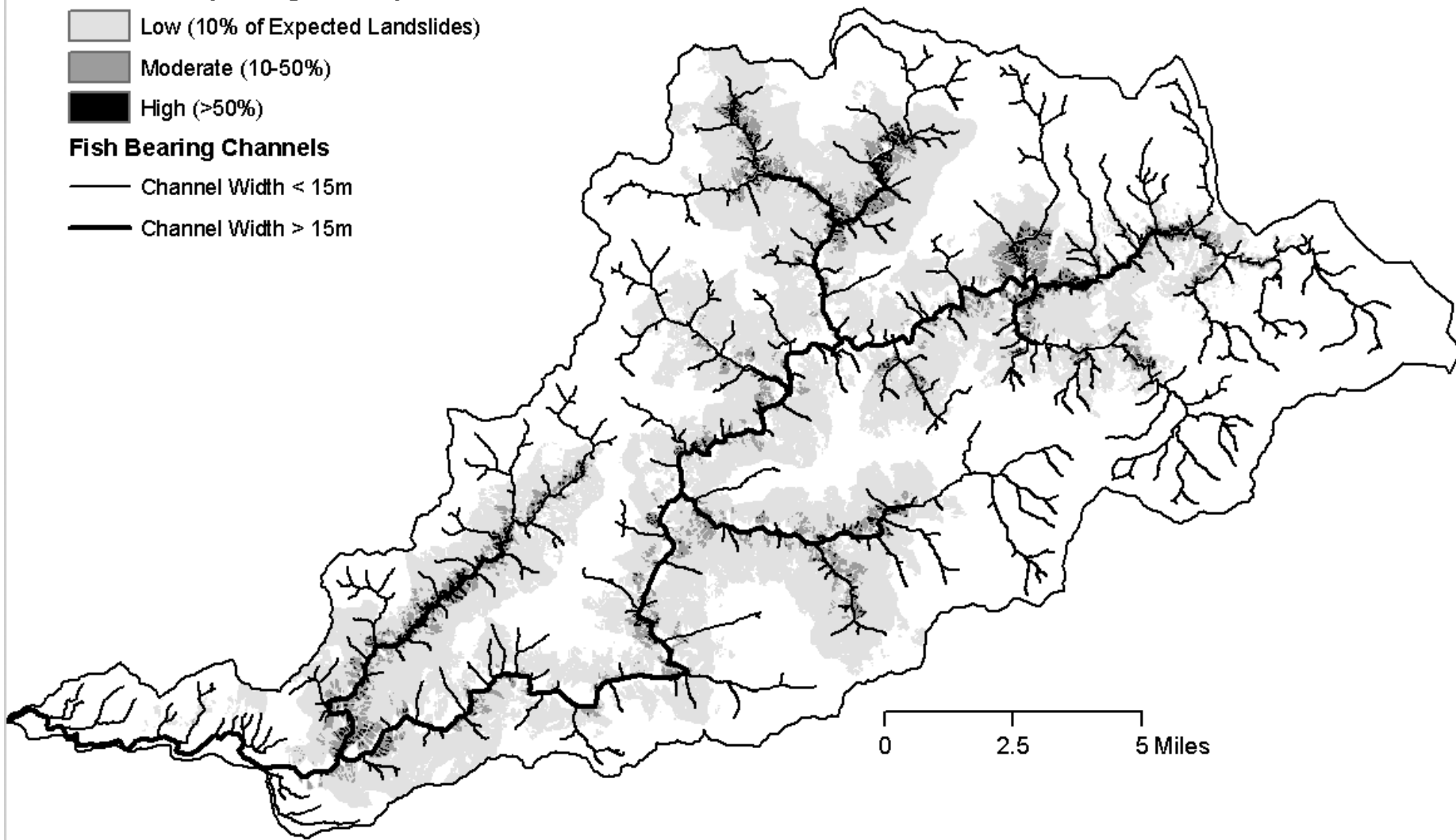
 Moderate (10-50%)

 High (>50%)

### Fish Bearing Channels

 Channel Width < 15m

 Channel Width > 15m



# What's next?

These models can be coupled with stochastic fire and storm simulations to create spatially distributed time series of wood loading and associated habitat function. We are using such models to explore effects of altered disturbance regimes on habitat abundance and spatial distribution.

