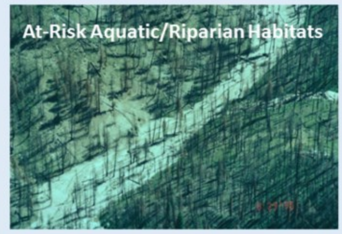
Post Fire Decision Support

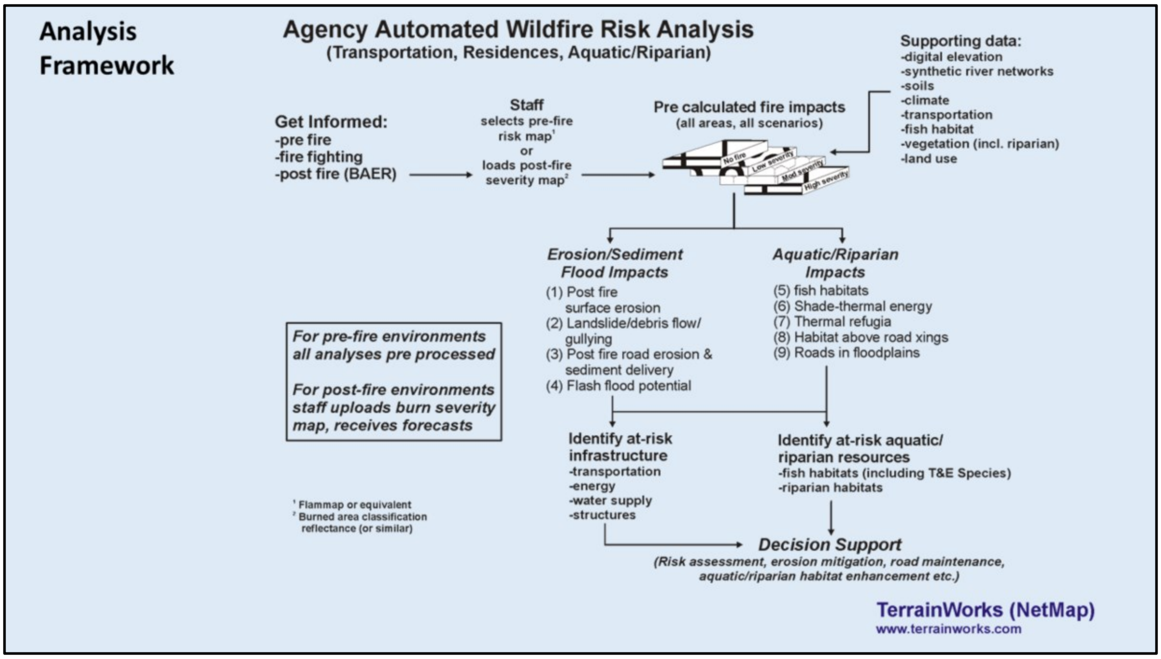
Identifying At-Risk Infrastructure and Aquatic/Riparian Habitats to Inform Post Fire Restoration

(Pilot Project, Canyon Creek Complex Wildfire, 2015, Malheur National Forest, Eastern Oregon)



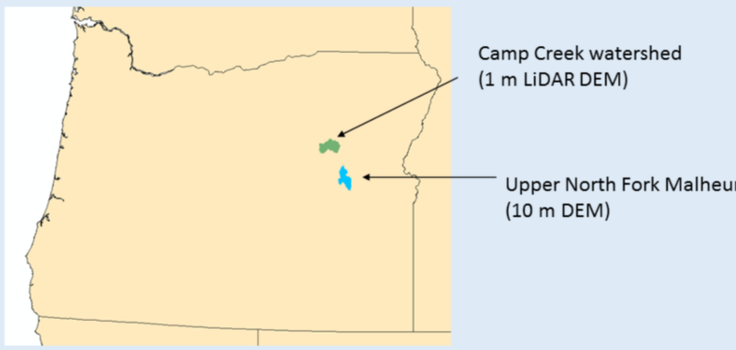
TerrainWorks (NetMap), in Collaboration with US Forest Service, PNW Corvallis and Malheur National Forest
Summer, 2015

This Powerpoint presentation summarizes the use of NetMap for a Fire and Fish Decision Support System. Created on July 24, 2015 by Dr. Lee Benda and Kevin Andras (TerrainWorks).



The general approach strategy: wildfire is evaluated in terms of potential impacts to at-risk infrastructure (roads, structures, water supply, energy) and aquatic/riparian habitats via (1) erosion processes and sediment delivery to streams (surface erosion, gullying, shallow landsliding and post fire road erosion) and (2) riparian processes, specifically impacts on shade, thermal loading and thermal refugia. The approach is designed to provide decision support for (i) pre fire management (vegetation and roads) and (ii) firefighting (including retardant drops). See companion PPT-PDF describing the use of pre fire severity maps in a similar analysis.

For the Pre-fire analysis in two pilot areas in the Malheur National Forest, go to:
http://www.netmaptools.org/Pages/FireFish/NetMap_Fire&Fish.pdf **and for video, go to:**
www.netmaptools.org/Pages/FireFish/NetMap_Fire&Fish2.pptx

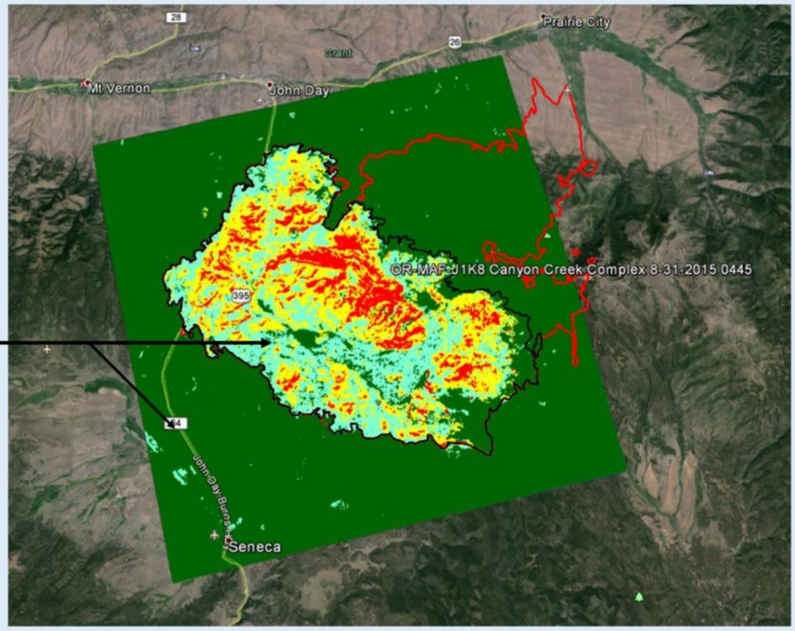


Continue with post fire (BAER) analysis, next slide…..

Post fire BAER Analysis

Canyon Creek Complex Wildfire, as of August 31, 2015

Canyon Creek BAER-NetMap analysis area (colored)



Models and Sources

(1) DEMs – 10 m
(2) Synthetic River Networks (stream layers) NetMap (www.terrainworks.com)
(3) Fire severity (BARC map, Canyon Creek Complex)
(4) Post fire surface erosion (WEPP – Disturbed)
(5) Post fire gully potential (Parker et al. 2010)
(6) Post fire landsliding/gullying (Miller and Burnett 2007, 2008, NetMap)
(7) Post fire road surface erosion and sediment delivery (GRAIP-Lite w/ modified sediment delivery)
(8) Flash Flood Index (Smith 2010, NOAA-NWS)
(9) Salmon habitat (FS habitat distribution/Intrinsic Potential Model, Burnett et al. 2007)
(10) Shade/thermal loading/thermal refugia (NetMap and Groom et al. 2011)
(11) Road – stability (NetMap)
(12) Cumulative habitat length above roads (NetMap)

Refer to NetMap's online technical help manuals for additional information

Here is a list of the various models and data sources there were used in the BAER analysis.

Data Deliverables

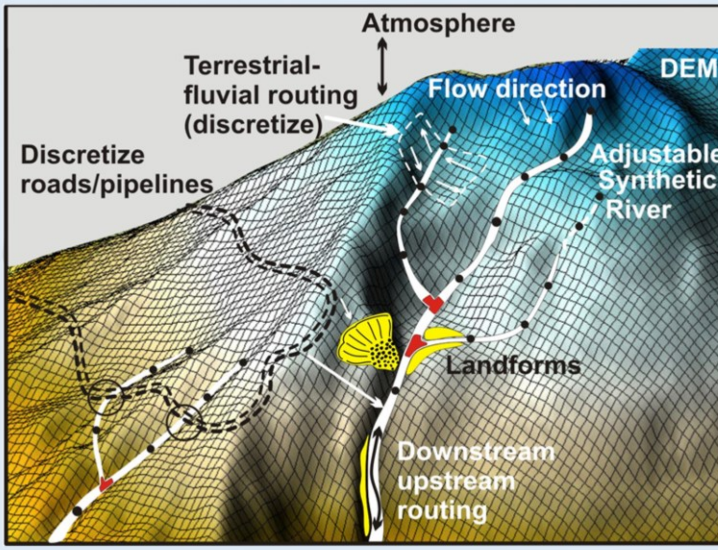
Data Type	Raster	Road	Polygon	Reach Segment	Reach, routed	Aggregated HUC 6th Polygon
1) Burned Area Reflectance Classification (BARC)	x			x	x	x
2) Salmon intrinsic potential (variable, e.g., steelhead, coho, Chinook)				x	x	x
3) Post fire surface erosion (WEPP-Disturbed)	x			x	x	x
4) Landslide potential	x			x	x	x
5) Gully potential						
6) Flash Flood Index, Fire Impacted	x			x	x	x
7) Current shade-thermal energy/thermal refugia (LEMMA)				x	x	x
8) Post fire shade-thermal energy/thermal refugia (LEMMA reduced)				x	x	x
9) Thermal difference (sensitivity) map				x	x	x
10) Road Sediment production		x		x	x	x
11) Road sediment delivery (no fire)		x		x	x	x
12) Post fire road sediment delivery (e.g., reduced soil infiltration capacity)						
13) Road sediment delivery difference (no fire-fire)		x		x	x	x
14) Cumulative habitat length above road crossings				x		
15) Road – landslide/gully potential		x				

These are the general data deliverables and their formats within ArcMap shapefiles.

The analysis uses NetMap's synthetic river network and virtual watersheds

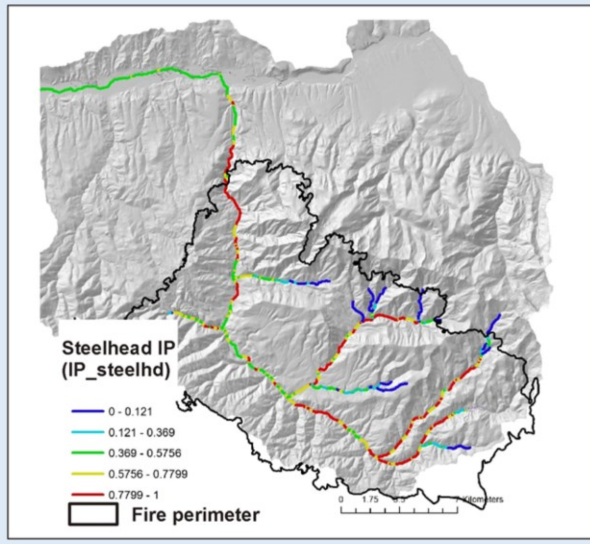
Go to www.terrainworks.com to learn about how synthetic river networks and virtual watersheds are built, and their capabilities

For additional details see slides towards the end of this presentation



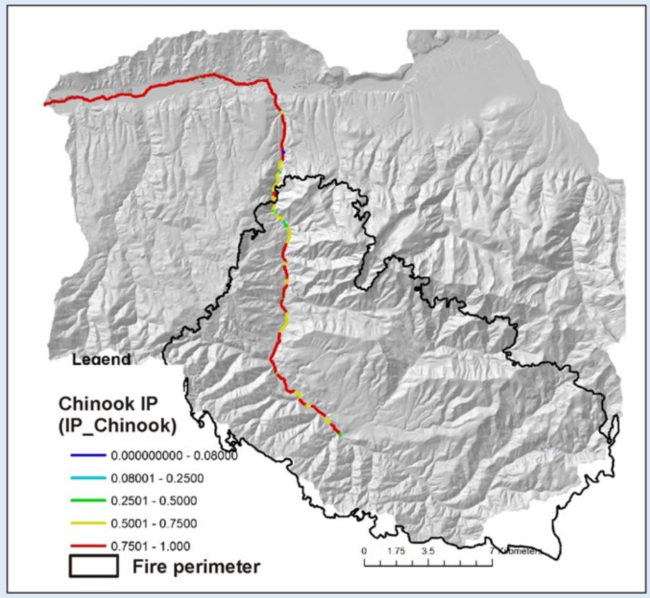
The analytical foundation for the Fire Analysis is NetMap's synthetic stream network and virtual watersheds. For brevity, this important topic is left for the viewers to explore as they need to; see www.terrainworks.com for additional background information or NetMap's online Technical Help materials.

Data Deliverables:
Fish Habitat: steelhead Trout (*Oncorhynchus mykiss*)



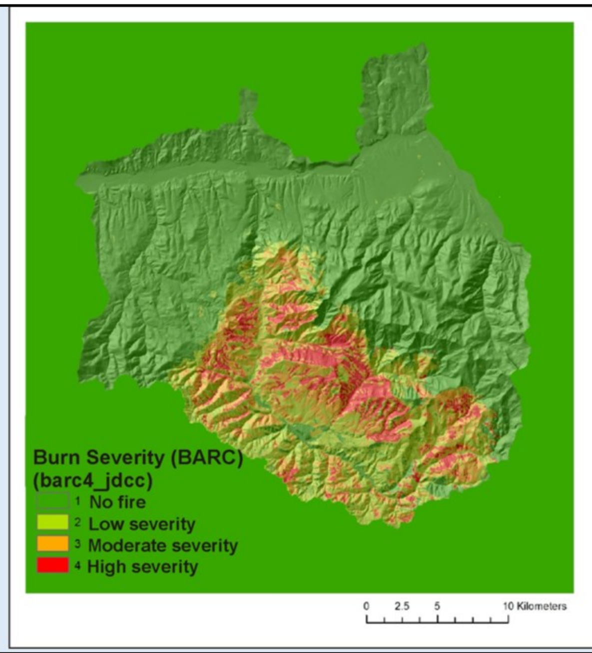
Based on intrinsic potential habitat modeling (Burnett et al. 2007).

Fish Habitat: Chinook salmon (*Oncorhynchus tshawytscha*)



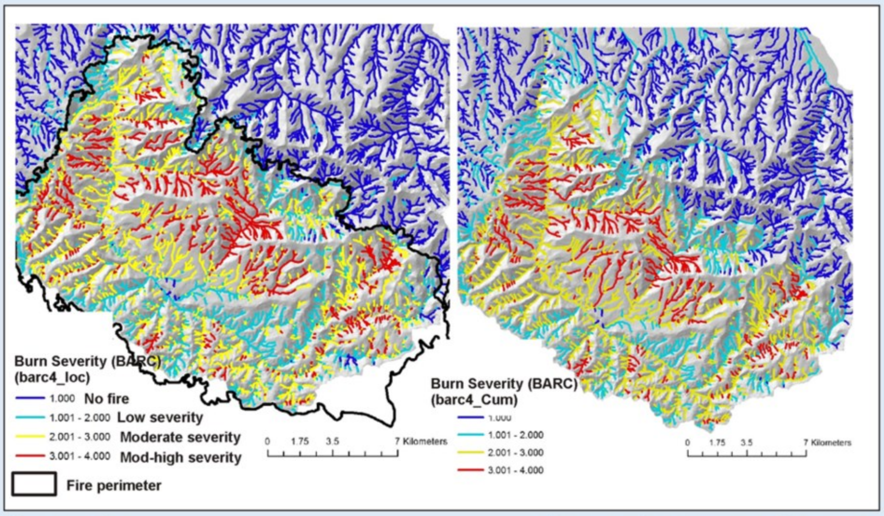
Based on intrinsic potential habitat modeling (Burnett et al. 2007).

Fire Severity (hillside, Burned Area Reflectance Classification [BARC] Map)



Fire severity as reported in the Burned Area Reflectance Classification [BARC] map.

Fire severity mapped to channels



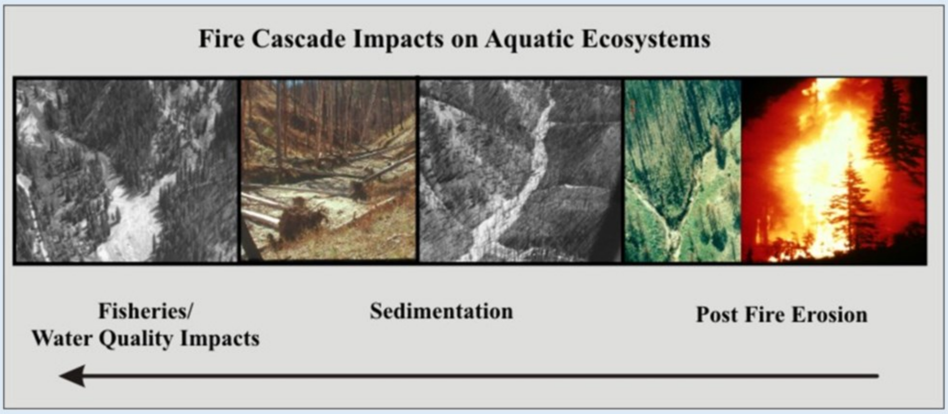
Why are hillslope attributes reported to channels, via drainage wings?

This facilitates comparing hillslope related stressors (fire severity, erosion, roads etc.) to fish habitats, a channel attribute.

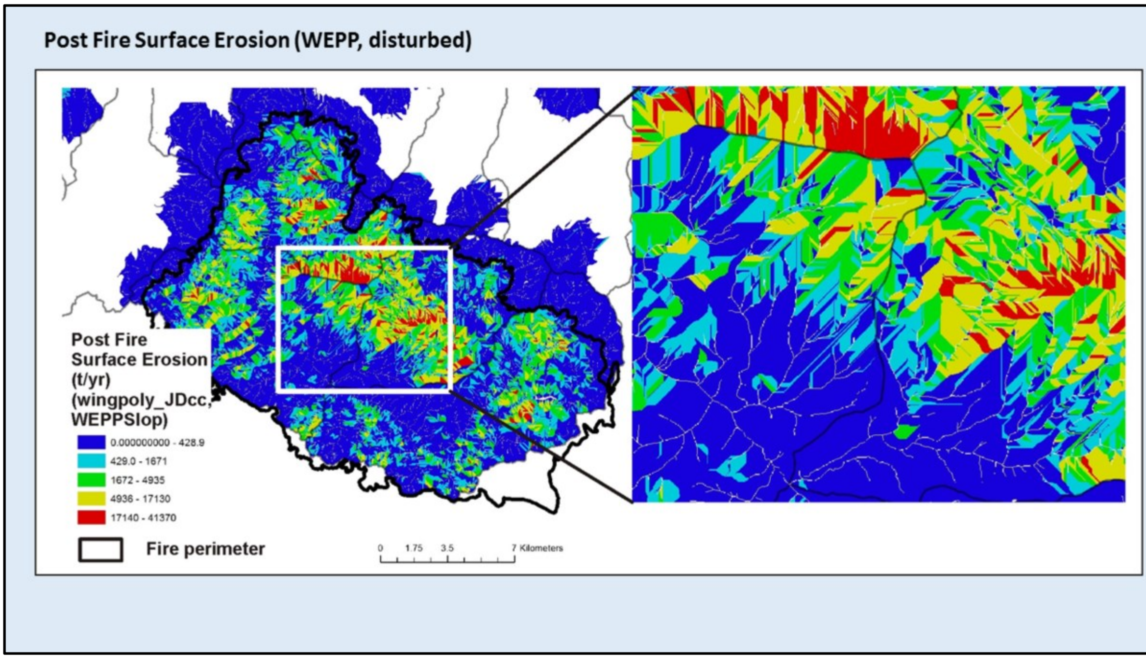
Fire Severity (channel, fish eye)

Fire Severity, Aggregated Downstream (tributary scale patterns)

Fire severity is reported to individual channel segments (left), via drainage wings, and aggregated downstream.

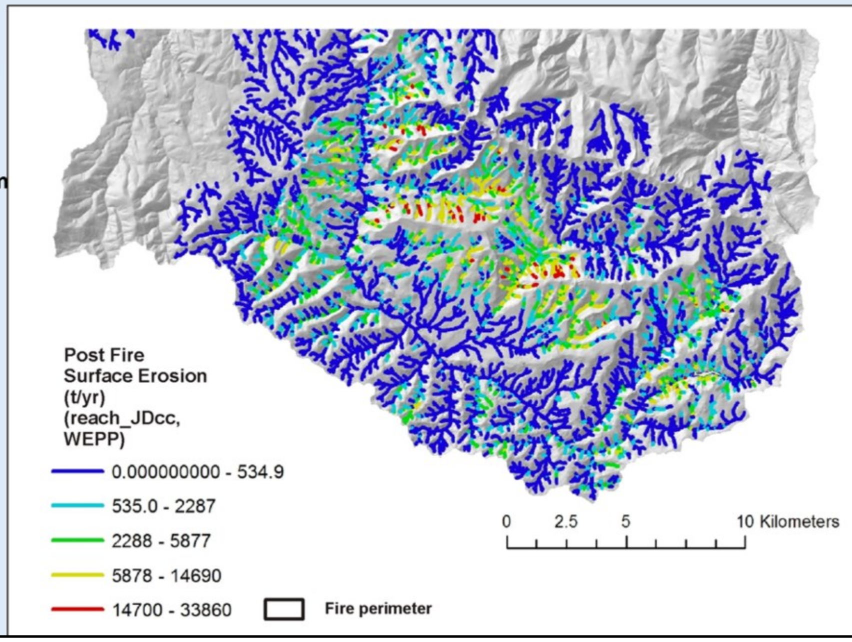


Post fire erosion and channel sedimentation are predicted for surface erosion, gullying and shallow landsliding.



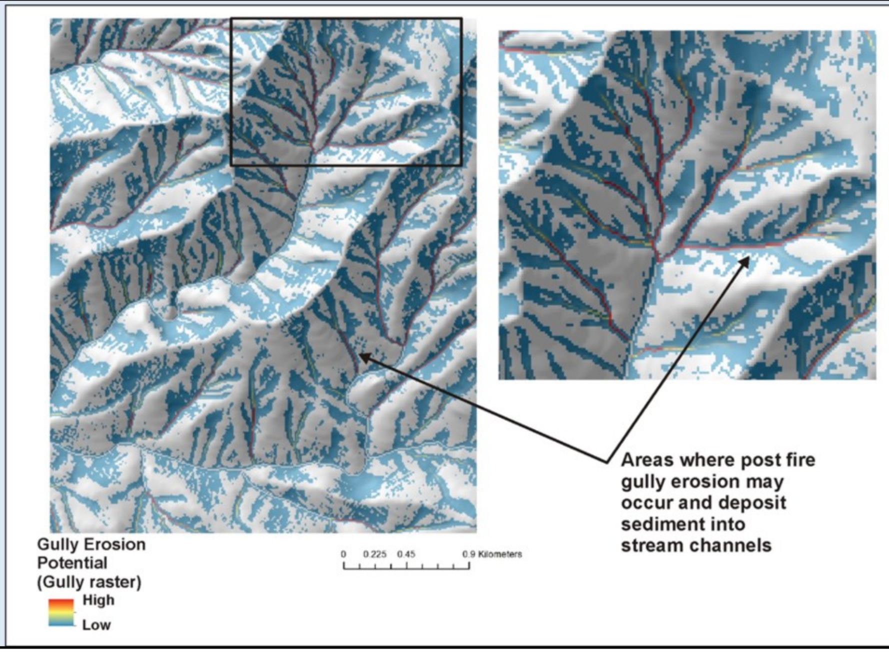
Post fire surface erosion was predicted using the WEPP-disturbed model. The color patterns indicating variable surface erosion illustrate the variable sizes and shapes of local contributing areas or drainage wings. See NetMap's online technical help materials for additional information:
http://www.netmaptools.org/Pages/NetMapHelp/5_5_surface_erosion_veg_fire.htm

Post Fire Surface Erosion (WEPP, disturbed, e.g., function of fire severity) reported to stream channels (aggregated downstream also available)



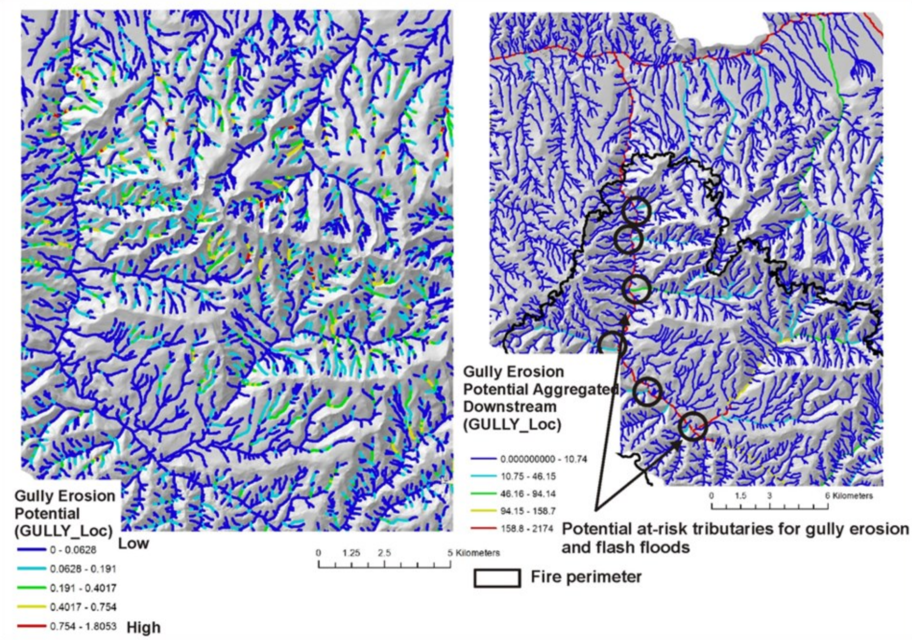
Predicted surface erosion is transferred to individual stream segments (left) and aggregated downstream (right), the latter revealing erosion patterns at the tributary and subbasin scale.

Post Fire Gully Potential

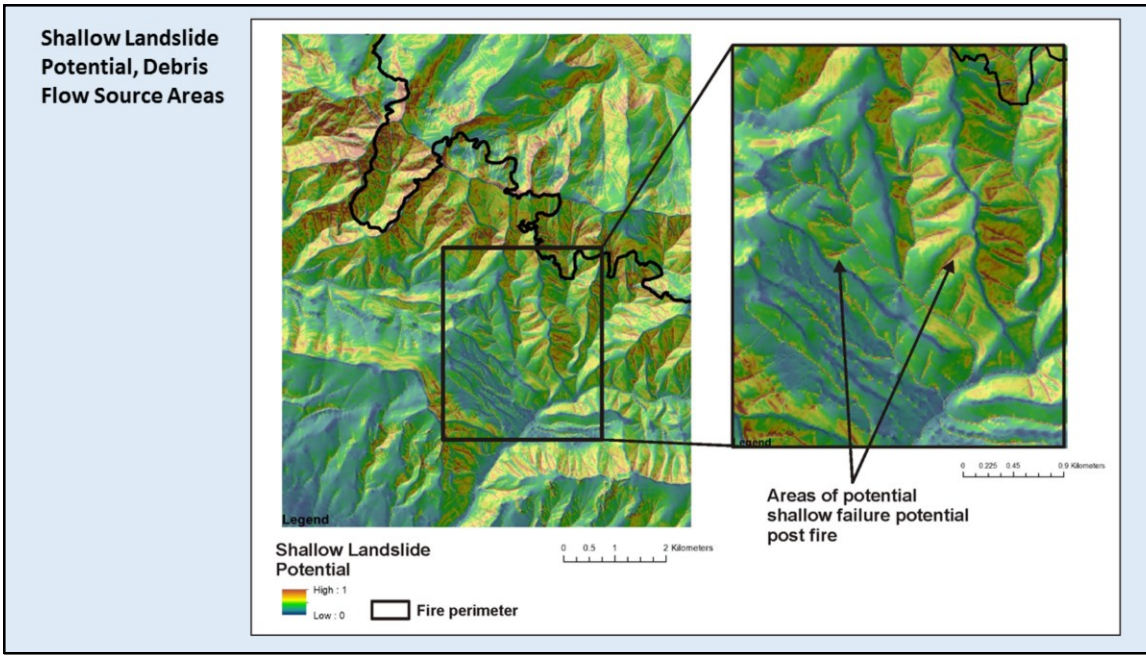


An gully erosion model was used in the analysis (Parker et al. 2010). See NetMap's online technical help materials for additional information. http://www.netmaptools.org/Pages/NetMapHelp/gullying.htm

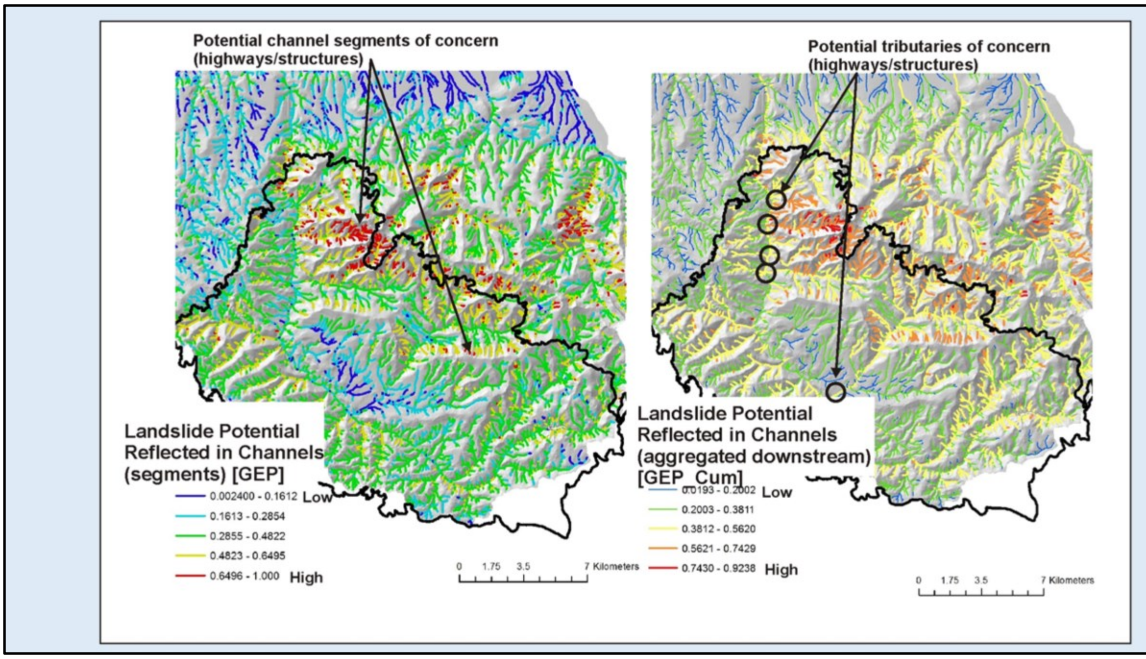
Post Fire Gully Potential (fish eye view)



Gully erosion results reported to stream channels, via drainage wings or local contributing areas.



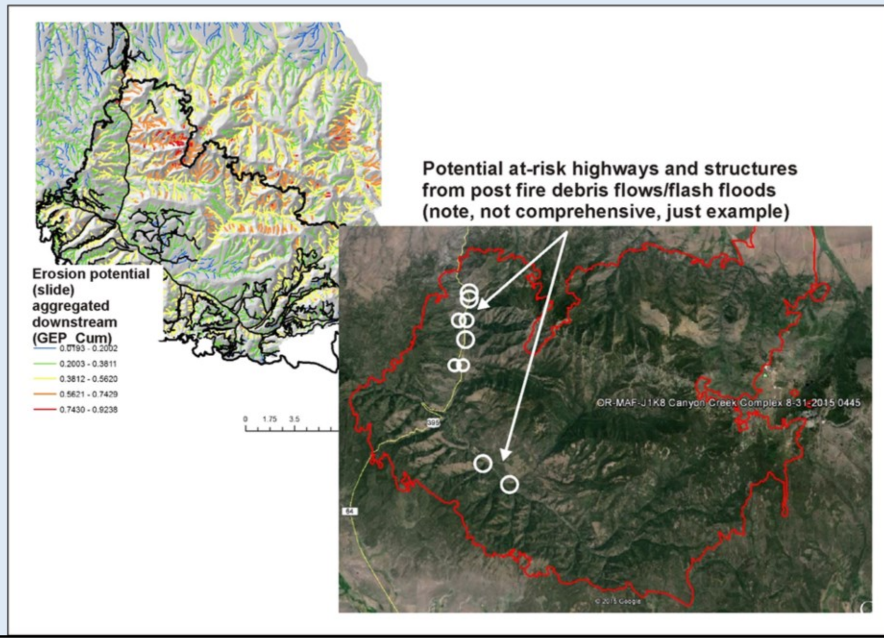
A shallow landslide model (Miller and Burnett 2007) based on hillslope gradient and curvature was used in the analysis. See NetMap's online technical help materials for additional information:
http://www.netmaptools.org/Pages/NetMapHelp/hillside_1.htm



Shallow failure potential as represented in individual channel segments and aggregated downstream.

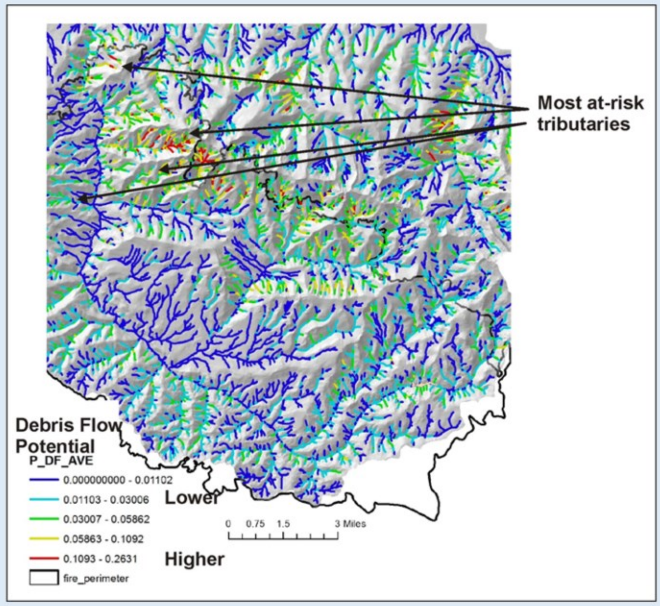
Example of a risk assessment

you can combine post fire surface erosion with gullying and shallow failure



Here is an example of a risk assessment that overlays predicted erosion potential (aggregated downstream, and thus tributary scale) and the locations of vulnerable highways and residences.

Consider tributary debris flow risk



Although the model employed (Miller and Burnett 2007) is based on data from another mountainous landscape, it provides an approximation of at-risk tributaries using universal attributes related to debris flows including number of source areas, tributary channel gradients, valley confinement and tributary junctions. Also predicted is gully erosion, shallow failure potential and flash flood potential.

FLASH FLOOD Potential

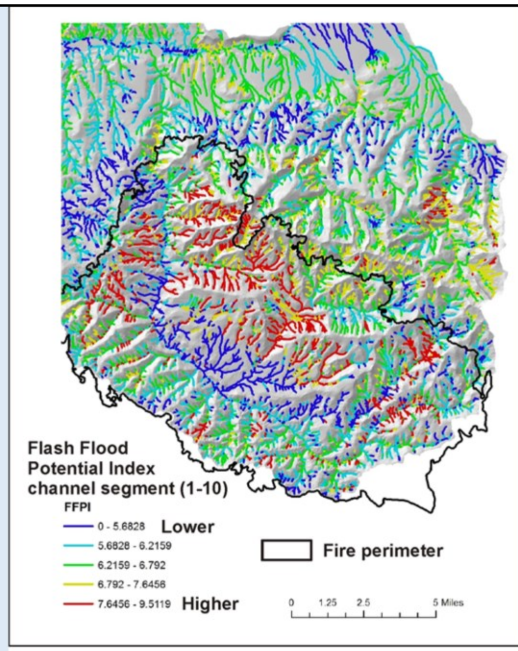
A dimensionless index developed by the National Weather Service. The Flash Flood Potential Index (FFPI) consists of four factors:

1) hillslope gradient
2) soils (percent silt, clay and sand)
3) vegetation density (forest, shrubs, grasses)
4) fire impacts on soils and vegetation.

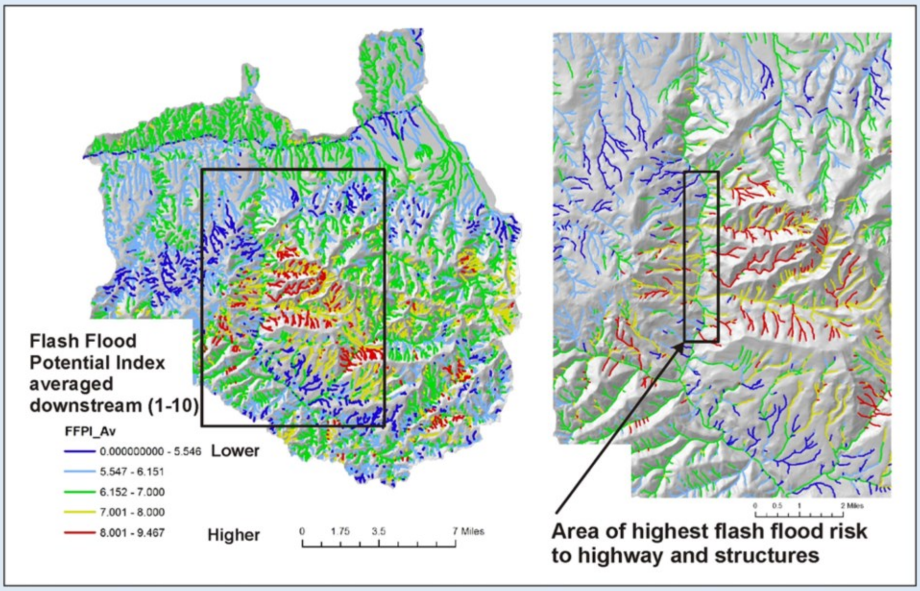
See NetMap's online technical help manual for additional details.

A flash flood potential index will be applied to the study area (second week of Sept).

Flash Flood Potential Index
(individual channel segment scale)

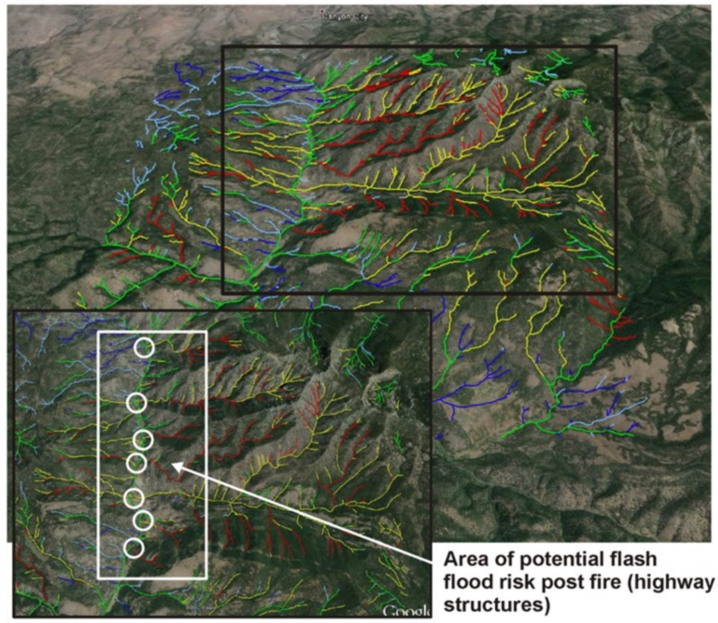


Flash Flood Potential Index (tributary scale, most relevant from risk assessment)

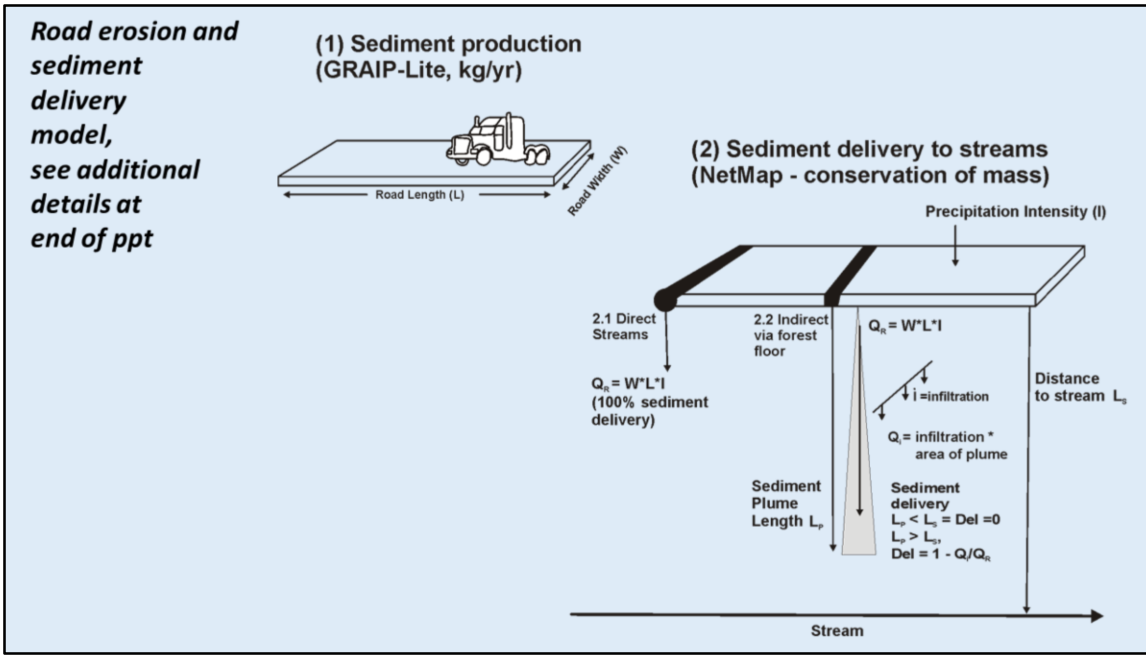


Flash Flood Potential Index (tributary scale, most relevant from risk assessment)

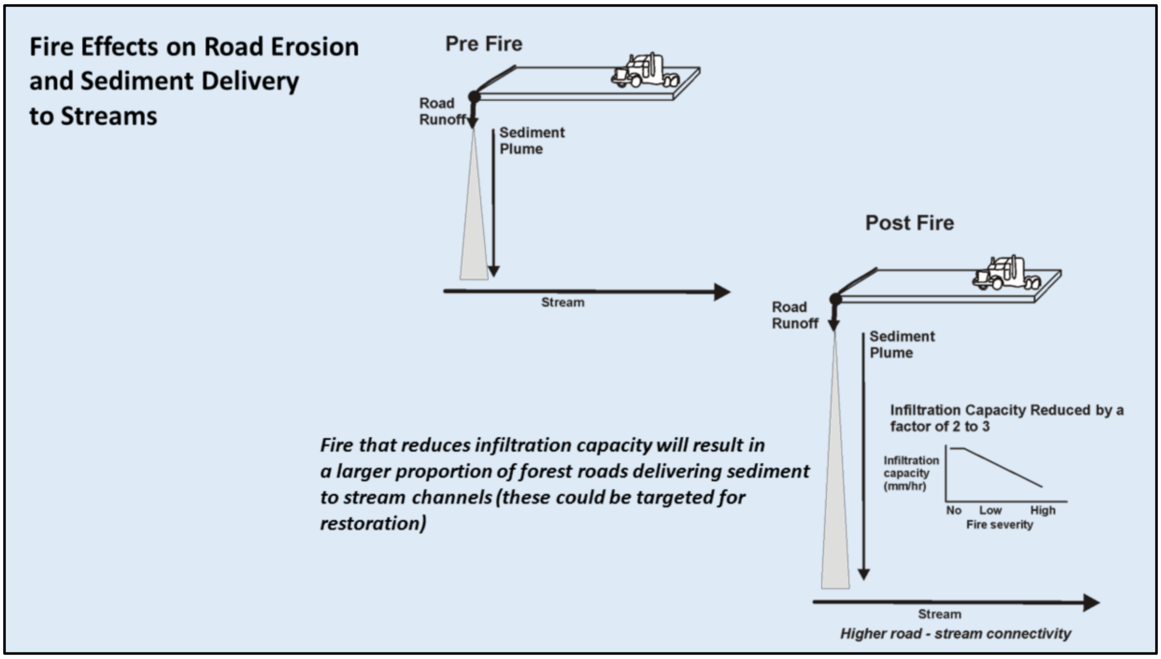
mapped to Google Earth



Roads can be significant sources of flooding, erosion and sediment delivery to streams, post fire.

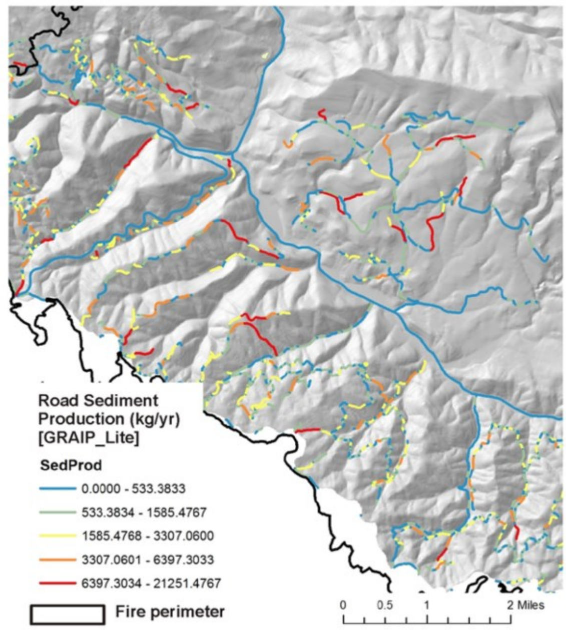


The model GRAIP-Lite for sediment production was coupled to NetMap's conservation of mass sediment delivery model (see end of pptx for additional details).



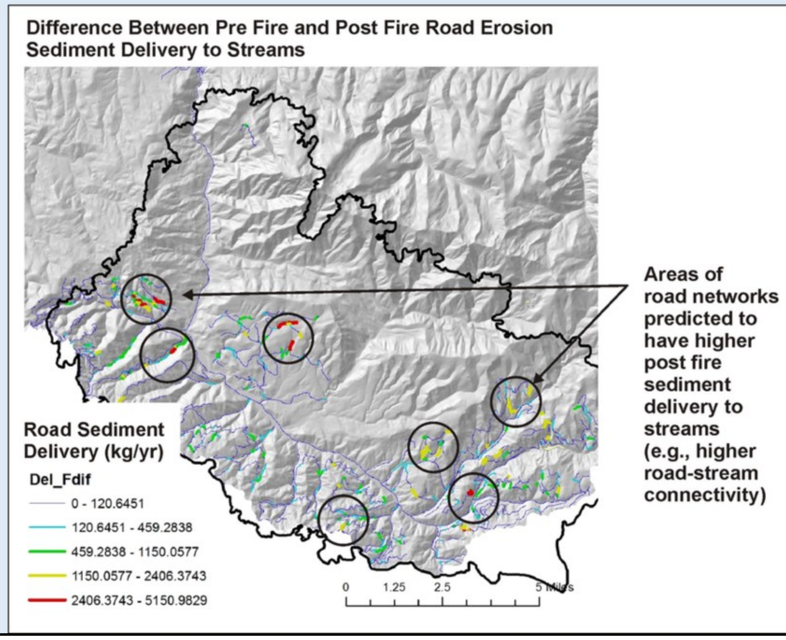
Fire reduces infiltration capacity and thus allows greater sediment travel distances from roads to streams and hence greater road-stream connectivity.

First, start with road sediment production



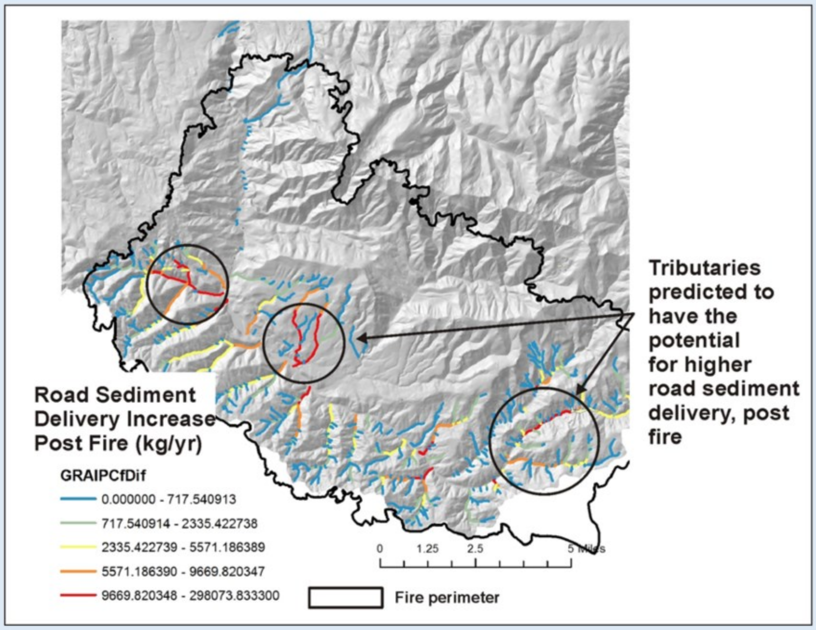
Sediment production as predicted by GRAIP-Lite; a base erosion rate of 1.5 kg/yr was used.

Next, calculate sediment delivery pre fire and compare that to sediment delivery post fire, and identify areas of predicted increases

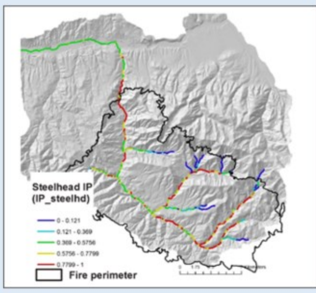


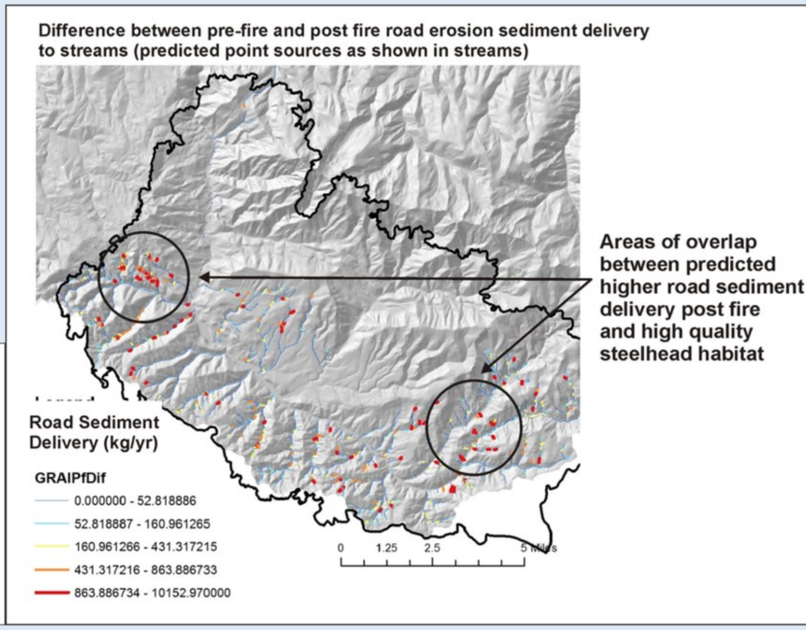
A difference map of road sediment delivery reveals that some road segments are more sensitive to fire reductions in infiltration capacity compared to others.

Identify tributary scale increases in delivery of road sediment



Then compare it to locations of high quality and sensitive aquatic habitats

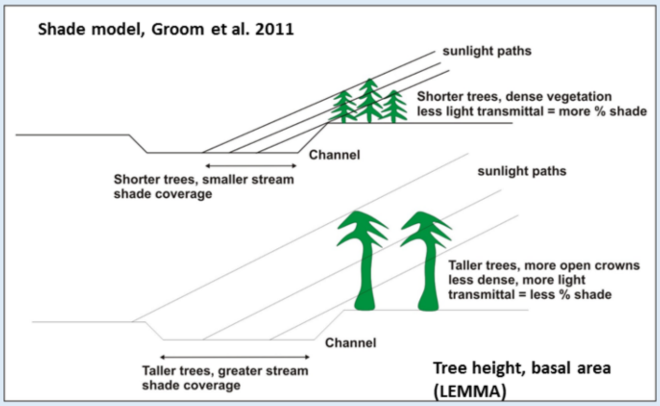


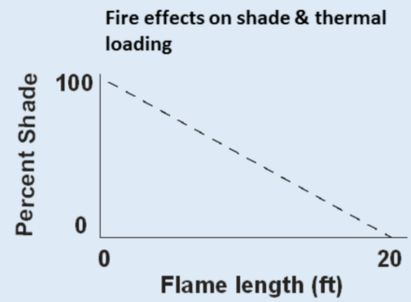


Stream reaches where post fire road sediment delivery is predicted to increase; some of these reaches overlap sensitive fish habitats.

Riparian Zones: Impacts from Fire, Loss of Shade, Increases in Thermal Loading and Loss of Cool Water Refugia

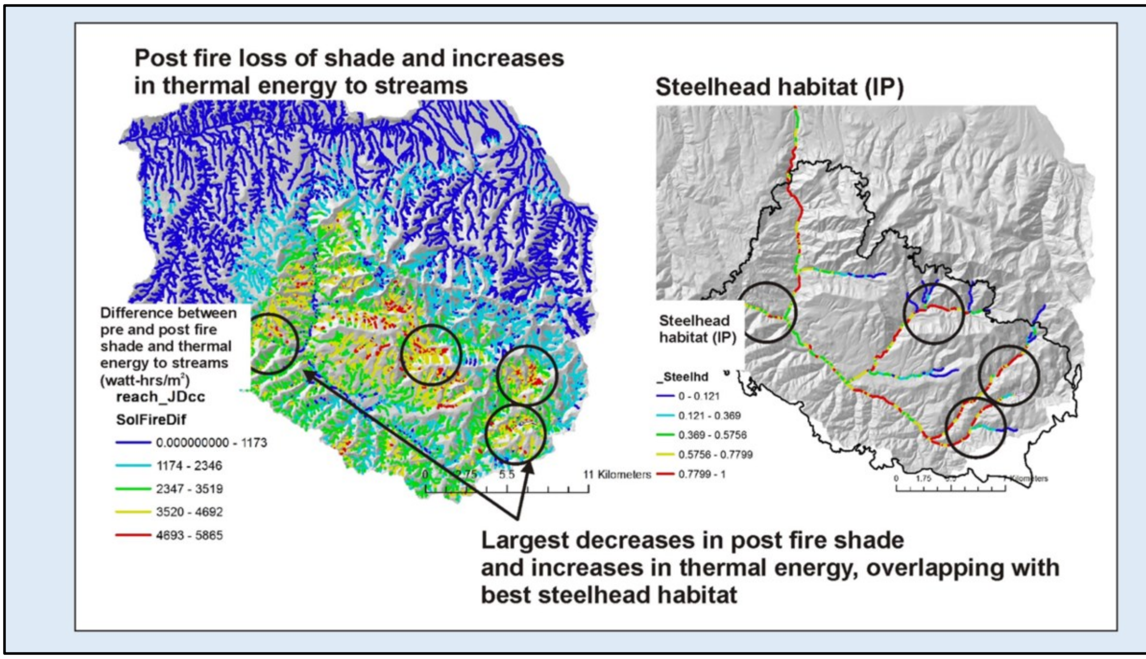
Riparian – Current Shade/Thermal Energy



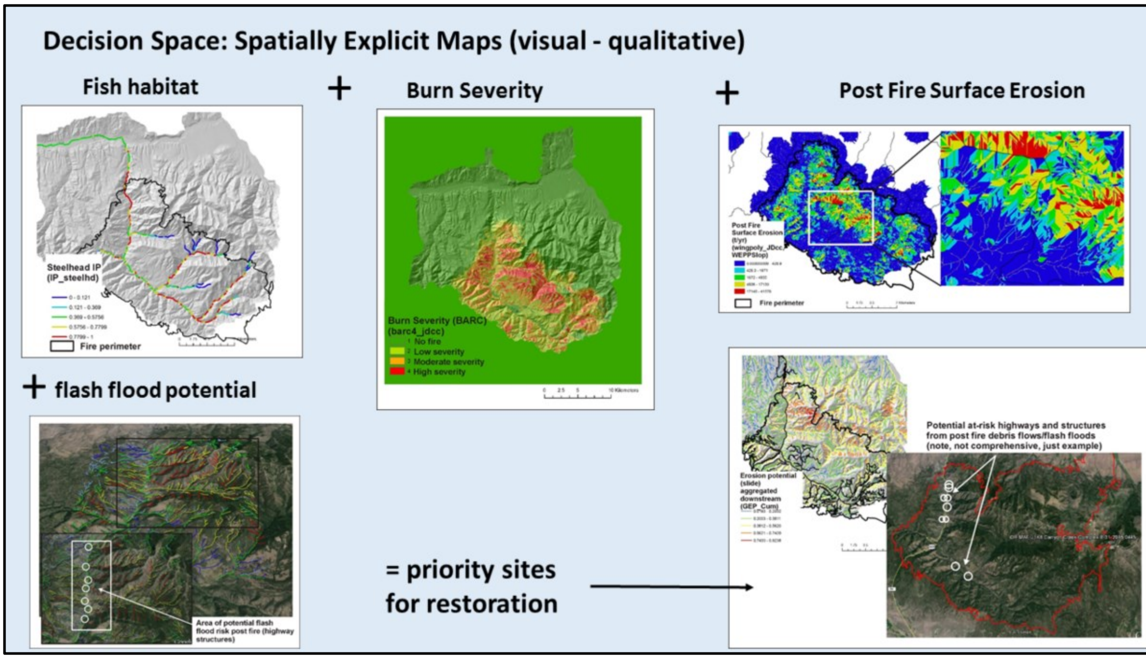


(where fire would have the largest impacts on the thermal regime, including loss of thermal refugia)

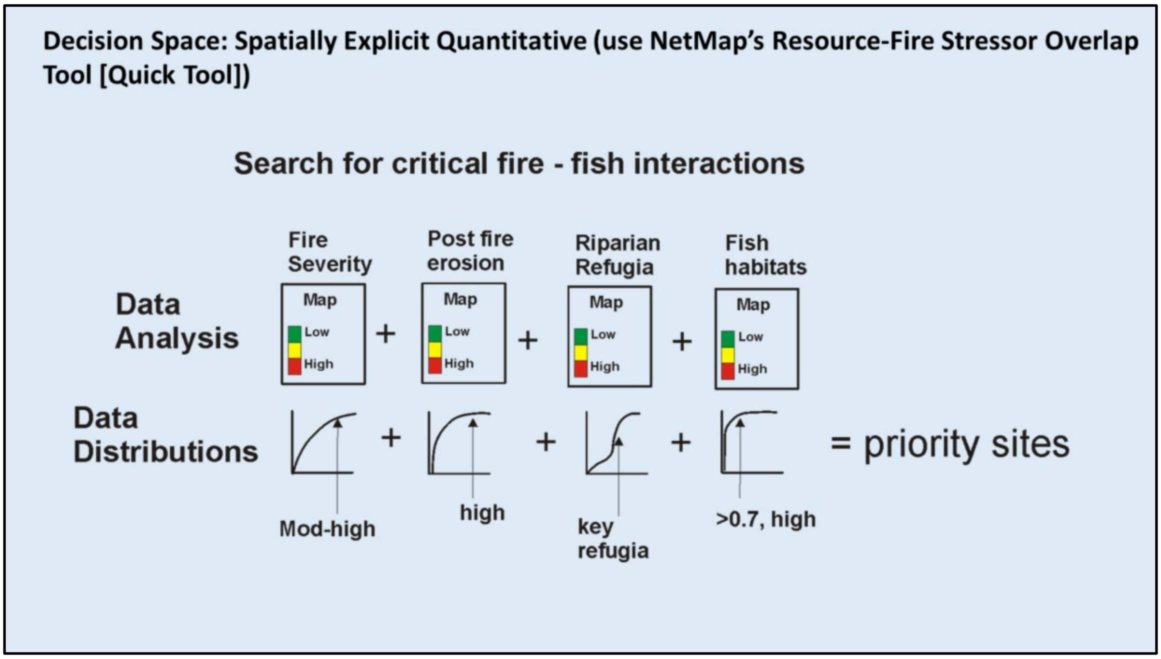
A shade model was used to estimate the effects of vegetation on reducing thermal energy to streams. Shorter, denser vegetation provides more shade, but the shadow length is smaller. Taller older trees have less dense vegetation mid crown that can reduce the shade, but they have a longer shadow length. We used a simple linear relationship between percent shade and predicted flame length. To learn more about this modeling approach, go to NetMap’s online technical help materials: http://www.netmaptools.org/Pages/NetMapHelp/current_shade_thermal_energy.htm



The difference between thermal energy to streams under no fire shade conditions (using LEMMA vegetation data (http://lemma.forestry.oregonstate.edu/) and fire-reduced shade. Many channel segments receive higher thermal loading, post fire.



Information provided in the BAER analysis (previous slides, among other data) can be used visually and qualitatively to search for intersections or overlaps between various fire related stressors (fire severity, post fire surface erosion, gully erosion) and sensitive aquatic habitats, as illustrated above. Or one of NetMap's tools (Resource – Fire Stressor Overlap Tool) can be used quantitatively to locate overlaps and intersections (see next slide).



NetMap's Quick Tool that contains the Resource – Fire Stressor overlap capability can be used to locate intersections between fire related impacts and sensitive fish habitats. The tool calculates, on the fly, the full frequency distribution of values (shown as the cumulative distribution of values in this slide), and the analyst, using the tool, selects from the distributions to search for overlaps. For example, an analyst can quickly search for intersections among the highest 10% of fire severity, highest 5% of post fire surface erosion (or landsliding or gullying), highest 10% of fire related increases in thermal loading, and fish habitats (either presence of habitat or some numeric value of habitat quality [used in IP]).

For additional information, see NetMap's online technical help that describes the overlap tool:
http://www.netmaptools.org/Pages/NetMapHelp/overlap_tool___reaches.htm

And the Quick Tool, which is provided as part of this analysis:
http://www.netmaptools.org/Pages/NetMapHelp/netmap_quick_tool.htm

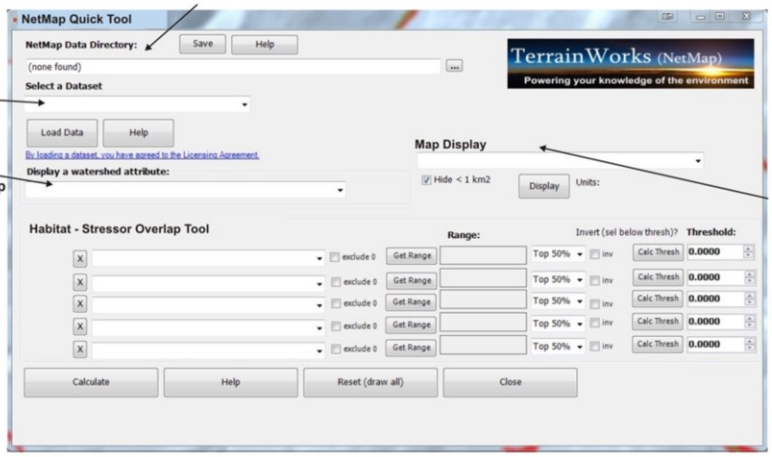
NetMap's Resource-Fire Stressor Overlap Tool

Locate the directory where your NetMap datasets are stored

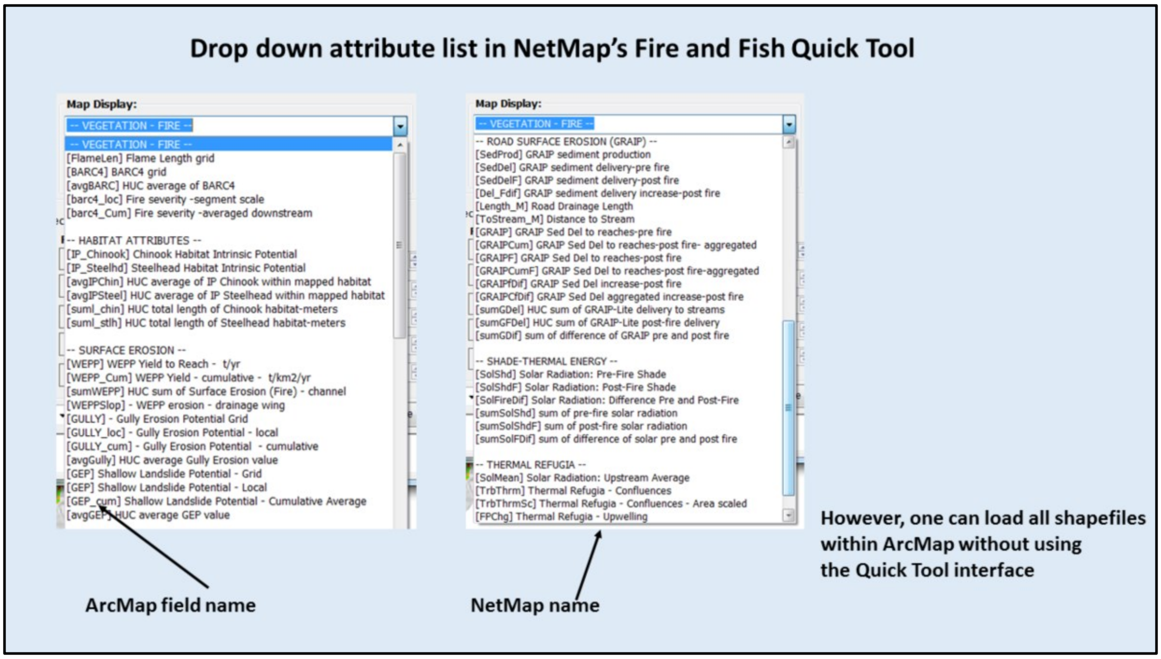
Select and load a NetMap dataset

Display an attribute on the map that contains the results from the habitat-stressor analysis

Select individual maps from a drop down organized by topic

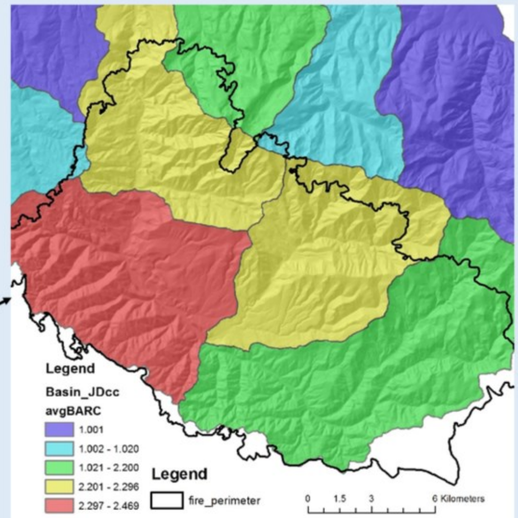


Conduct Habitat - Stressor Analyses, choose up to five individual reach attributes (habitat quality, floodplains, thermal refugia, effects of current shade on thermal energy, current in-stream wood recruitment potential, shallow landslide and debris flow risk etc.). For example, where does the highest 10% of coho salmon habitat potential overlap with the lowest 10% of in-stream wood recruitment (highlighting sites for in-channel restoration). Or where does the highest 10% of coho salmon habitat overlap the highest 10% of debris flow risk (to identify sites for additional slope stability protection). See examples below.



The drop down list of analysis results in the Quick Tool (previous slide) shows all of the analysis results.

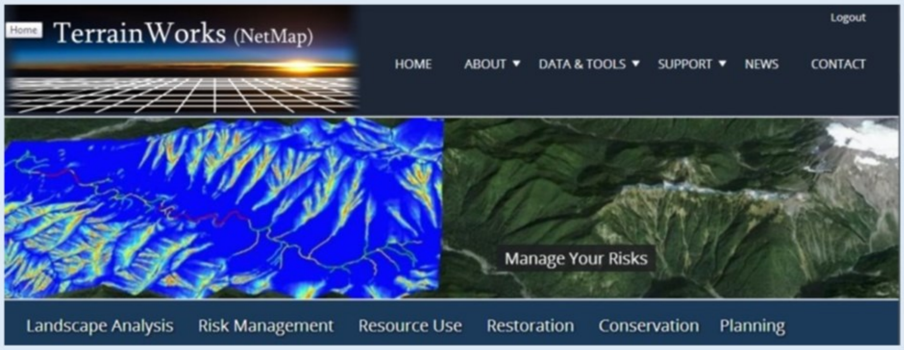
All analysis results are summarized at the scale of HUC 6th field



For example, burn severity (BARC) per 6th field subbasin

All analysis results are summarized to the HUC 6th subbasin scale. This can be used to examine subbasin scale patterns of fire related attributes and stressors and the locations of aquatic habitats. Subbasin scale data summaries may be most useful at the scale of larger watersheds or entire national forests.

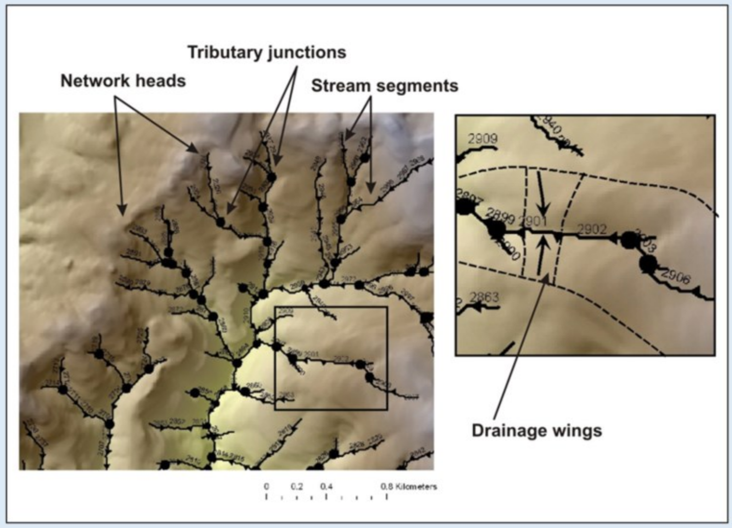
Presentation Complete



TerrainWorks designs and builds the most advanced watershed and landscape analysis system in the world. Learn more about NetMap virtual watersheds, watershed analysis tools, online technical help and tools at: www.terrainworks.com. Contact us with questions, we are here to help.

The next four slides contain additional details about NetMap capabilities as applied to the BAER analysis

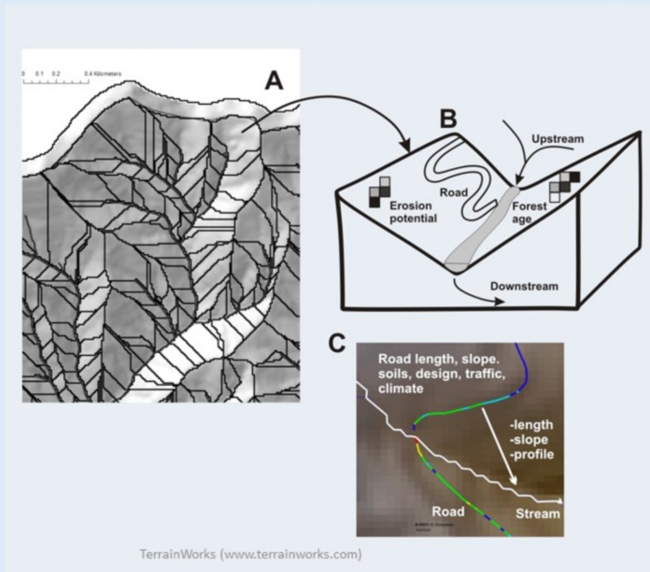
The BAER-NetMap analysis requires that terrestrial information (on hillsides) be transferred to channel networks, so that fire related stressors (erosion, roads) can be directly linked to structures and fish habitats, at the scale of individual channel segments.



TerrainWorks (www.terrainworks.com)

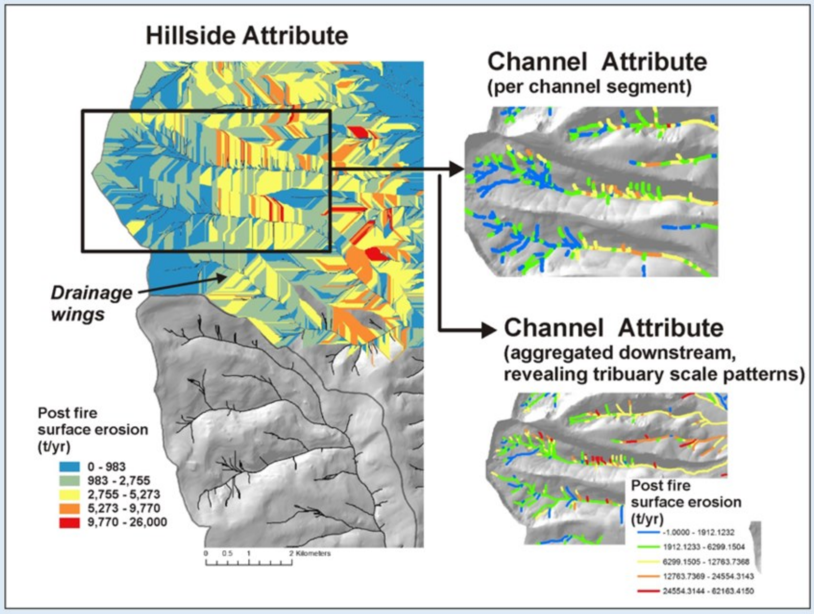
The data structure of the virtual watershed includes a synthetic river network (derived from DEMs and the NHD) and drainage wings, local contributing areas located on both sides of 100 m channel segments. Each channel segment has a corresponding set of local contributing areas or drainage wings.

Drainage wings (discretize landscapes and land uses)

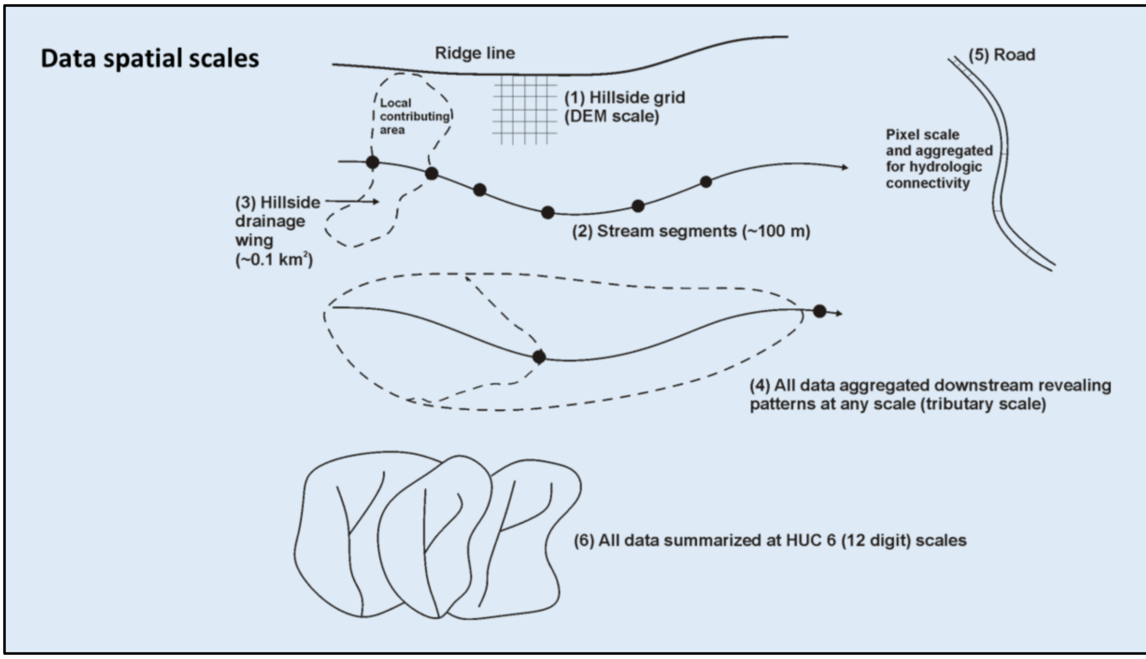


The drainage wings discretize the watershed terrestrial environment into small areas (approx. 0.1 km^2 in area) and all information on hillsides is then summarized to channels. This supports analysis of aquatic habitat-terrestrial stressor intersections.

An example about how a hillside attribute (post fire erosion) is transferred to individual channel segments, and aggregated downstream



Here is an example of how a terrestrial (hillside) attribute is transferred to the channel network and aggregated downstream. These types of channel attributes can then be compared to other channel attributes such as fish habitat or other watershed characteristics, like thermal refugia.



The data deliverables come at a range of scales including (1) hillside raters or grids (at the scale of the DEM), (2) individual stream segments (~100 m), (3) hillside drainage wings (local contributing areas, ~ 0.1 km2), (4) stream segment data aggregated downstream, (5) road segments broken a pixel boundaries and re-aggregated for various purposes, including hydrologic connectivity and (6) data summarized at the scale of HUC 6 subbasins.

The next seven slides contain additional details about the road analysis

Road Model Details (7 slides)

GRAIP-Lite model of road surface erosion (in NetMap)
(USFS, Rocky Mountain Research Station, Boise ID)

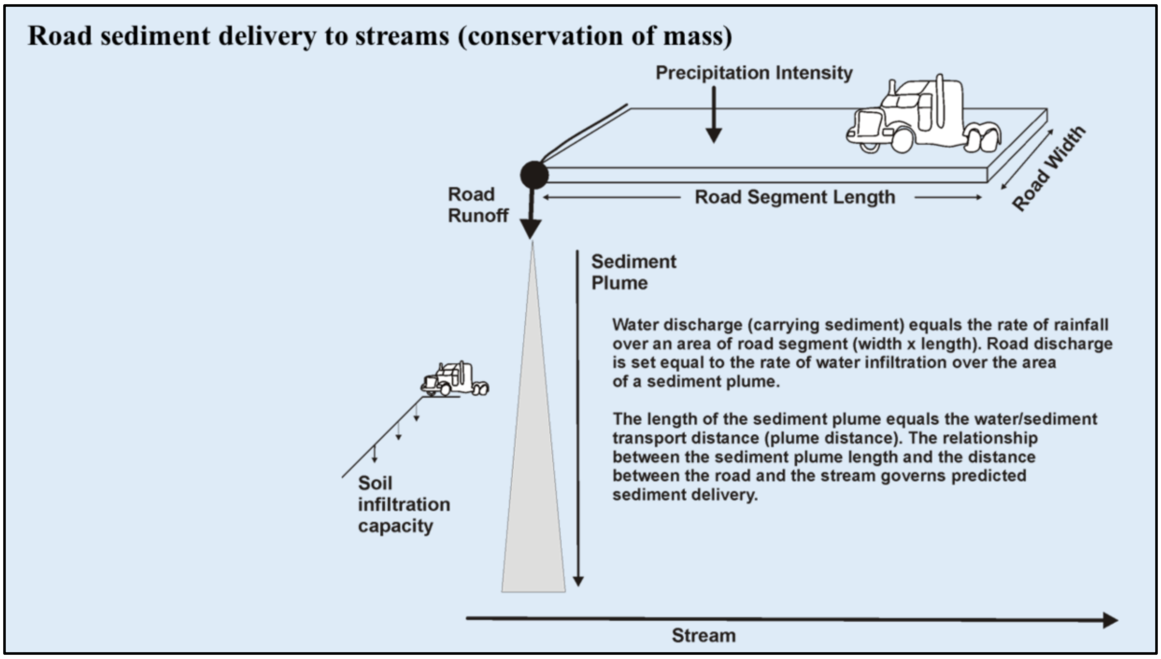
E = B * R * S * V

where E is road sediment production to streams (kg/yr), B is the "base" surface erosion rate (empirical), R is the elevation difference between the road segment end points (length), S is the road surface factor and V is the vegetation factor.

V = 1 – 0.86x, where x is the fraction of the road length where flow path vegetation (ditch) is greater than 25%; R (elev. diff) is slope x road segment (hydrologic) length.

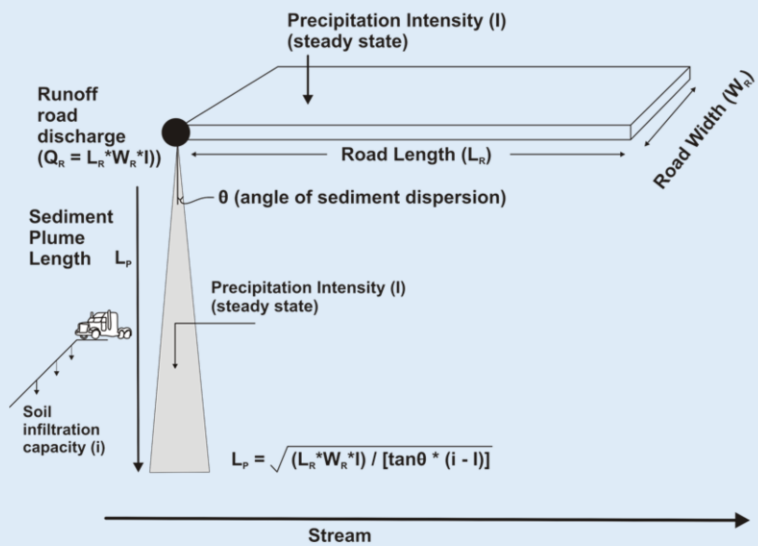
- Example base rates:
- Oregon Coast Range = 79 kg/yr
- Idaho Batholith = 33 kg/yr
- Montana (Belt sedimentary) = 7 kg/yr
- Eastern Oregon (Umatilla, Basalt) = 1.5 kg/kg
- Eastern Sierra (SPI) = 11 kg/yr

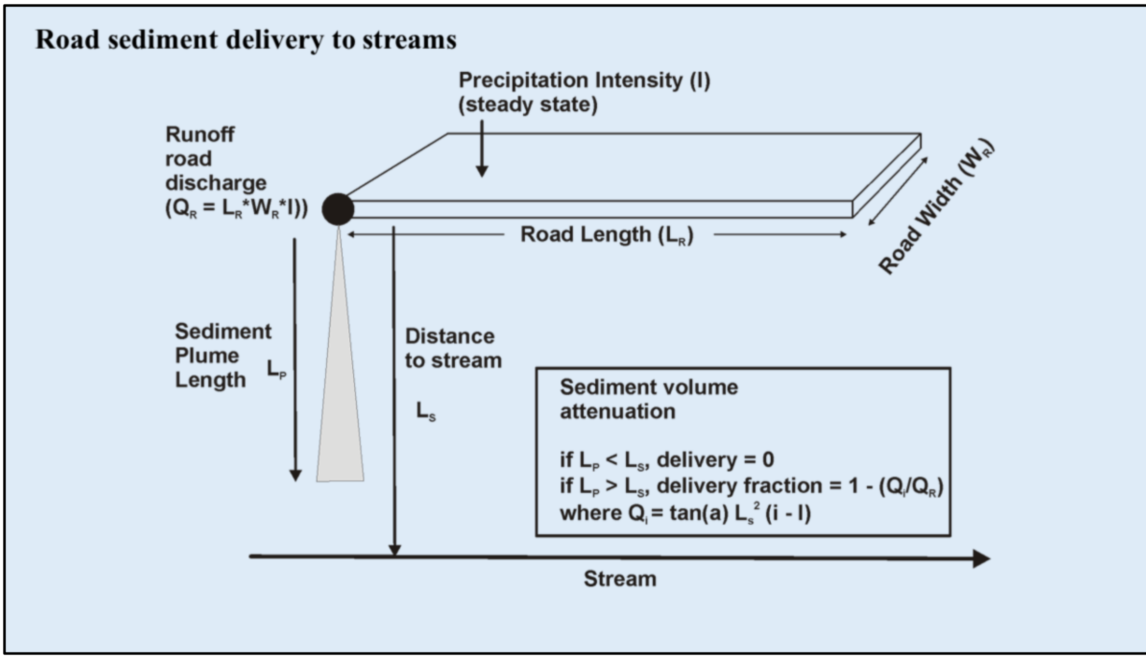
The GRAIP-Lite model (RMRS, Luce, Black and Nelson) was used in the analysis. See NetMap's online technical help materials for additional information: http://www.netmaptools.org/Pages/NetMapHelp/graip_lite.htm



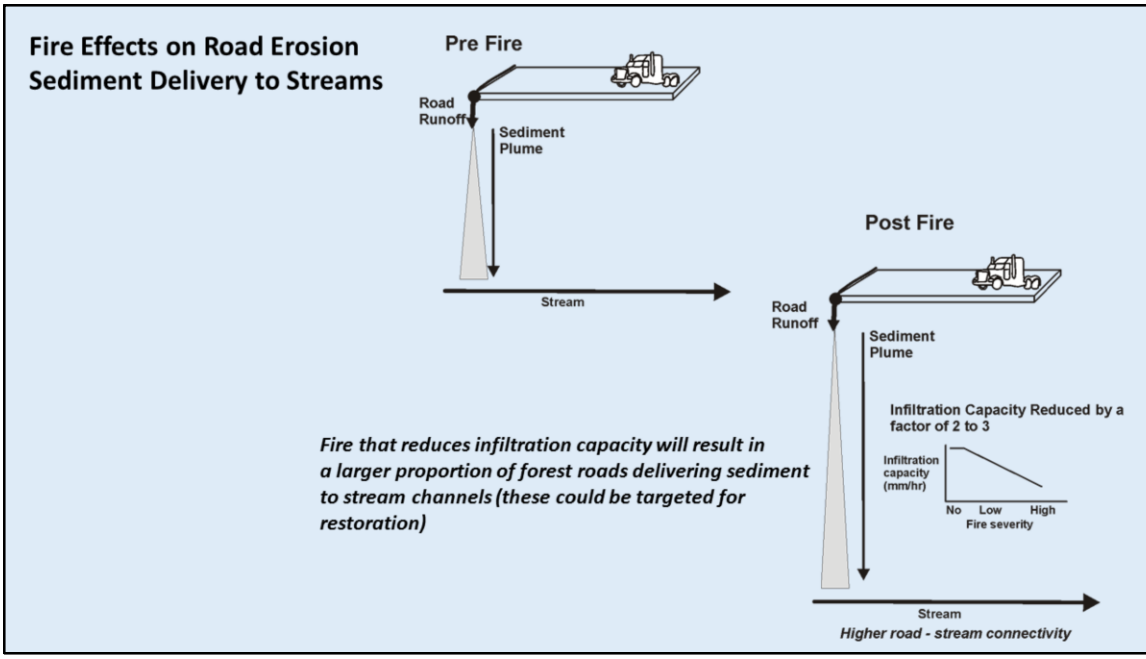
The GRAIP-Lite sediment delivery component was modified in NetMap, using a steady state, conservation of mass approach. For additional information, see NetMap's online technical help:
http://www.netmaptools.org/Pages/NetMapHelp/netmap_sediment_delivery_2.htm

Road sediment delivery to streams





Road sediment delivery to streams
Precipitation Intensity (I)
(steady state)
Runoff
road
discharge
($Q_R = L_R*W_R*I$))
Road Length (L_R)
Road Width (W_R)
Sediment
Plume
Length
L_P
Distance
to stream
L_S
Sediment volume
attenuation
if $L_P < L_S$, delivery = 0
if $L_P > L_S$, delivery fraction = 1 - (Q_i/Q_R)
where Q_i = tan(a) L_s^2 (i - I)
Stream



Fire can impact road erosion sediment delivery by reducing the infiltration capacity of the forest floor (if burned). Lower infiltration capacity can lead to longer sediment plume lengths and greater connectivity between forest roads and stream channels.

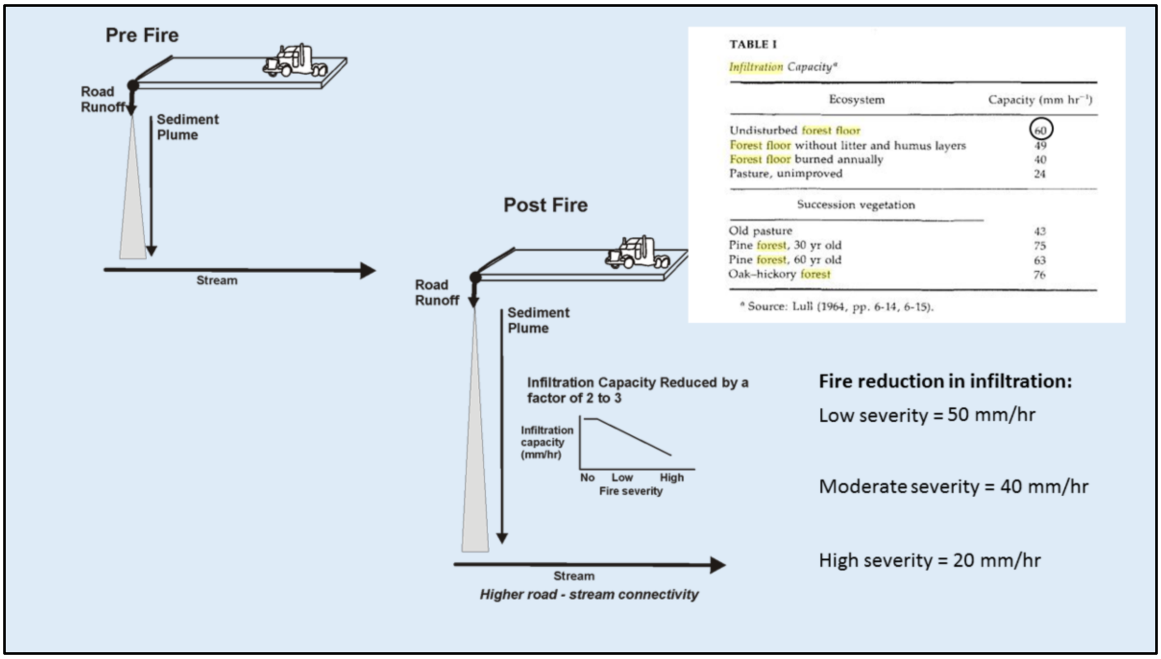


TABLE I

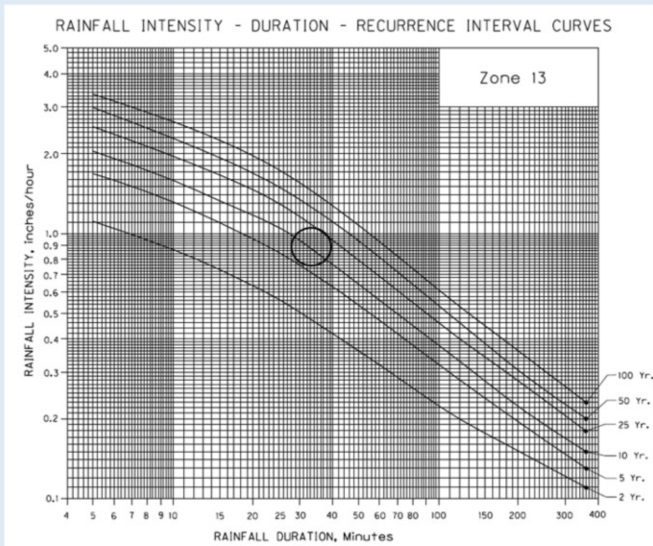
Infiltration Capacity[a]

Ecosystem	Capacity (mm hr^{-1})
Undisturbed forest floor	60
Forest floor without litter and humus layers	49
Forest floor burned annually	40
Pasture, unimproved	24
Succession vegetation	
Old pasture	43
Pine forest, 30 yr old	75
Pine forest, 60 yr old	63
Oak–hickory forest	76

[a] Source: Lull (1964, pp. 6-14, 6-15).

We selected a non fire forest floor infiltration rate of 60 mm/hr; this was reduced based on predicted fire severity as indicated above.

Design storm (short duration, high intensity)



0.92 in/hr (23 mm/hr)

ftp://ftp.odot.state.or.us/techserv/Geo-Environmental/Hydraulics/Hydraulics%20Manual/Chapter_07/Chapter_07_appendix_A/CHAPTER_07_APPENDIX_A.pdf

A design storm is needed in NetMap's sediment delivery model. We choose a short duration 10-year storm to mimic thunderstorm activity, post fire.