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Riparian Zone Estimator Tool (RipZET)
Documentation of Tool Demonstration in Marin County

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Introduction

The San Francisco Estuary Institute and Aquatic Science Center (SFEI-ASC) has developed the Riparian Zone Estimation Tool (RipZET) to help the California community of riparian interests visualize and characterize riparian areas as habitat unto themselves as well as their capacity to function as buffers for protecting the ecosystem services of the state's streams, lakes and wetlands. RipZET is a tool used with Geographic Information System (GIS) and spreadsheet software to estimate "functional riparian width," or the width associated with different riparian functions (e.g., large woody debris input, shading, floodwater storage), which varies with channel type and watershed location. The concept of functional riparian width is central to the riparian definition recommended by the National Research Council (NRC 2002) and is integral in many recently developed riparian design and management guidelines around the country.

To demonstrate the tool's capabilities, SFEI-ASC coordinated with the Marin County Department of Planning on running RipZET for a watershed where functional width estimates could be helpful for future planning. The County selected the San Geronimo Creek watershed in western Marin County for the tool demonstration. This document provides an overview of how the tool works, information on the data sources used to run the tool for the San Geronimo Creek watershed, key parameter values, and tool output maps showing the resulting riparian functional width estimates along the tributaries and mainstem San Geronimo Creek.

General RipZET Description

RipZET produces estimates of functional riparian width along streams, lakes, and wetlands using three separate modules:

1. Hillslope Processes module (or Hillslope module)
    - Appropriate for steep, low order channels and upper watershed lakes and wetlands.
    - Targeted riparian functions include large woody debris (LWD) and coarse sediment supply.
    - Estimates functional riparian width for large watershed areas based on the hillslope angle adjacent to the channel. For every 1% increase above a threshold angle value, the module provides 1 m of functional riparian width.

2. Vegetation Processes module (or Vegetation module)
    - Appropriate for steep, low order channels to lower gradient, mid-watershed channels, as well as mid-watershed lakes and wetlands.
    - Targeted riparian functions include shading, bank stabilization, and runoff filtration.
    - Estimates functional riparian width for large watershed areas based on adjacent floodplain or hillslope angle and vegetation height. The module estimates functional riparian width using the equation:

      $w = Ah \times \cos(B)$

      where w is the functional width, h is the mature tree height, A is the tree height adjustment factor (greater than 1), and B is the floodplain or hillslope angle. Essentially, the functional riparian width for a flat floodplain is at least 1 tree height and the width decreases as the floodplain or hillslope angle becomes steeper. For vegetation types other than trees, the module uses a standard functional width estimate.

3. Hydrologic Connectivity module (or HyCon module)
    - Appropriate for low gradient alluvial channels with established floodplains.
    - Targeted riparian functions include floodwater storage, fine sediment trapping, and groundwater recharge.
    - Estimates functional riparian width for several cross-sections within discrete channel reaches based on an estimate of the inundation extent for large floods. The module estimates functional width using peak flood discharge estimates with a simple hydraulic equation (Manning's equation):

      $Q = (1.49/n)(A)(R^{2/3})(S^{1/2})$

      where Q is flow discharge, A is flow area within the channel, n is a surface roughness factor, R is hydraulic radius (similar to average flow depth), and S is local channel slope. The module uses this equation to determine flow stage for large floods, which is then used to estimate the maximum local flood elevation and the associated local inundation extent.

The output of each module is a unique visual display (GIS coverage) of the estimated functional riparian area. The displays are not regarded as riparian maps *per se* because they do not depict areas with definite boundaries based on field indicators. Instead, they depict areas where the riparian functions represented by the individual modules are likely to be supported. The modules can be run separately or together, and the outputs from different modules can be conflated to estimate the maximum likely riparian extent for all the functions represented by all the modules. More information about the science behind RipZET can be found in *RipZET: The Riparian Zone Estimation Tool* (SFEI 2015a) and more information regarding the computations within each module can be found in *Riparian Zone Estimation Tool (RipZET): User's Manual v1* (SFEI 2015b).

Tool Input and Parameterization

RipZET was run for the entire San Geronimo Creek watershed, from the headwater channels in Woodacre Creek to the confluence with Lagunitas Creek. The Hillslope and Vegetation modules were run along all channels in the channel network while the HyCon module was run at three discrete mainstem San Geronimo Creek reaches: Site 1 was between the Willis Evans Creek confluence and Roy's Pools; Site 2 was between the Larsen Creek and Clear Creek confluences; and Site 3 was near the Lagunitas Rd. bridge just upstream of the Cintura Creek confluence. Each reach was 20 "bankfull widths" in length, with bankfull width estimates derived from a regional curve relating bankfull width and contributing drainage area (see Collins and Leventhal 2013 for more detail). Within each reach, the HyCon module calculated flooding extents at three primary cross-sections (upstream end of the reach, middle of the reach, and downstream end of the reach) and in the areas adjacent to the cross-sections.

The data inputs and key parameter values for all three modules were as follows:

1. Hillslope module
   - Channel network: Bay Area Aquatic Resource Inventory (BAARI, unpublished)
   - Topography: Marin County 1-m LIDAR (provided by B. Quinn, County of Marin)
   - Threshold adjacent hillslope angle: 20% (based on information in Swift 1986, Trimble and Sartz 1957, and Wegner 1999)

2. Vegetation module
   - Channel network: Bay Area Aquatic Resource Inventory (BAARI, unpublished)
   - Topography: Marin County 1-m LIDAR (provided by B. Quinn, County of Marin)
   - Vegetation data: CALVEG with updated data where available (provided by L. Williams, County of Marin)
   - Tree heights and standard width estimates: Multiple sources (documentation can be provided as needed, see Table 1 for values)
   - Tree height adjustment factor: 2 (based on information in Reid and Hilton 1998)

3. HyCon module
   - Channel network: Bay Area Aquatic Resource Inventory (BAARI, unpublished)
   - Topography: Marin County 1-m LIDAR (provided by B. Quinn, County of Marin)
   - Estimated flooding extent: 10- and 50-year floods (based on information in Ilhardt et al. 2000)

- 10- and 50-year peak flood discharges: For the most downstream mainstem San Geronimo Creek site (Site 3), the discharge values were calculated using annual maximum discharge data from the Marin Municipal Water District (MMWD) flow gage at the Lagunitas Rd. bridge. For Sites 1 and 2, the discharge values were obtained using North Coast regional equations that estimate peak discharge values from mean annual precipitation and drainage area (Gotvald et al. 2012) and North Bay correctors. The correctors were determined by comparing peak discharge values from several USGS gages around the North Bay with the regional equation values at the gage sites. See Table 2 for values.

- Mean annual precipitation: PRISM dataset (PRISM Climate Group, Oregon State University). See Table 2 for values.

- Drainage area: HUC12 watershed area (USGS). See Table 2 for values.

- Channel roughness: Estimated using the Strickler (1923) roughness equation and local median bed particle size values from the San Geronimo Valley Salmonid Enhancement Plan Existing Conditions Report (Stillwater Sciences 2009). See Table 2 for values.

- Floodplain roughness: Estimated by first identifying floodplain land use from recent aerial photographs using Google Earth and then assigning roughness values by land use from the tables in Chow (1959). See Table 2 for values.

Results

The results from running all three RipZET modules in the San Geronimo Creek watershed are shown in Figures 1 to 4. Some key findings from the tool demonstration include the following:

- The majority of channel reaches within the watershed currently have some estimated functional riparian width. The reaches without width estimates have adjacent hillslope or floodplain angles that are less than 20% and are located in developed areas (e.g., the town of Woodacre and the San Geronimo Golf Course) or managed pasturelands devoid of tall trees. In general, the Hillslope module output is wider for the steep, lower order channels and the Vegetation module output is wider for the lower gradient, higher order channels with established floodplains. Most of the steep, lower order channels where the Vegetation module output is wider are lined with large stands of Redwoods (e.g., around the Woodacre Creek confluence, in Roy's Redwoods along Larsen Creek, near the town of Lagunitas, and near the confluence of San Geronimo Creek with Lagunitas Creek). These areas are also characterized by lower gradient, higher order channel reaches with some of the widest Vegetation module output in the entire watershed. The relatively great height of these redwoods allows them to be relatively far from the channel and still provision it with LWD.

- The HyCon module provided similar results at all three mainstem San Geronimo Creek sites. The estimated Q_{10} (10-year flood event) and Q_{50} (50-year flood event) inundation extent are essentially the same at most locations and typically less than 50 ft from the channel thalweg, indicating a high degree of incision that allows larger floods to remain in the channel (which matches field observations). The estimated riparian functional width from the HyCon module at most cross-sections within the three sites is therefore very low to negligible.

- It's instructive to examine the maximum functional riparian width estimated by each of the three modules where they have been applied together. For the three mainstem San Geronimo sites, estimated total width ranged from very low to negligible at the most incised reaches with developed floodplains and sparse vegetation to over 500 ft where the development density is relatively low and the floodplain is dominated by large trees (e.g., Redwoods and other tall trees).

Interpretation

The results generated from this demonstration of the RipZET tool should be regarded as preliminary. A more rigorous estimation of riparian functional width would involve adjustments in the module's parameters to account for the effects of local geology (i.e., the threshold of slope that triggers the Hillslope module and the rate at which the riparian width increases for increasing slope that match local mass wasting processes), actual site-specific tree heights (i.e., the table of tree heights can be adjusted for local observations); and actual site-specific channel and floodplain roughness (i.e., the roughness factor used in the Manning's n equation can also be adjusted for local conditions).

Once calibrated for local conditions, the modules should be re-applied. The revised output can then be summarized as the percent of the riparian area within continuous width classes relating to high, medium, and low levels of the riparian functions represented by the modules. A matrix of these relationships must be constructed based on the state-of-the-science and local or regional expertise. In general, studies from around the world show that the riparian widths needed to stabilize banks and shade the channel are usually narrower than widths needed to filter adjacent overland runoff, which in turn are usually narrower than widths needed to provide LWD to the channel, which in turn are usually narrower than widths needed to provide coarse sediment and other materials from hillslope processes. Wildlife support is typically the riparian function that requires the widest width.

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Table 1. Mature tree heights and standard width estimates used in the Vegetation module.

Vegetation Class	Mature Tree Height (m)	Standard Width Estimate (m)
Serpentine Grassland	1	--
Serpentine Leather-Oak Chaparral	3	--
Serpentine Scrub	3	--
Serpentine Hardwoods	6	--
Serpentine Conifer	15	--
Douglas-Fir - Pine	21	--
Montane Mixed Hardwood	22	--
California Bay	30	--
Central Coast Riparian Forests	50	--
Redwood	70	--
Annual Grasses and Forbs	--	1
Coastal Lupine	--	1
Non-Native/Ornamental Grass	--	1
Urban/Developed (General)	--	1
Lower Montane Mixed Chaparral	--	3
MacNab Cypress	--	6

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Table 2. Site physical data used in the HyCon module.

HyCon Module Variable	**Site 1**			**Site 2**			**Site 3**		
	Upstream	*Middle*	*Downstream*	*Upstream*	*Middle*	*Downstream*	*Upstream*	*Middle*	*Downstream*
Mean Annual Precipiation (in)	42.6			40.0			41.3		
Drainage Area (mi^2)	3.7			5.8			8.7		
Q_{10} estimate (cfs)	975			1388			2859		
Q_{50} estimate (cfs)	1341			1915			4000		
Local channel slope	0.0130	0.0150	0.0040	0.0130	0.0030	0.0070	0.0030	0.0030	0.0050
Channel roughness	0.037	0.037	0.037	0.037	0.037	0.037	0.042	0.042	0.042
Left floodplain roughness	0.03 to 0.07	0.03 to 0.07	0.03 to 0.07	0.03 to 0.07	0.03 to 0.07	0.03 to 0.07	0.07	0.07	0.07
Right floodplain roughness	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

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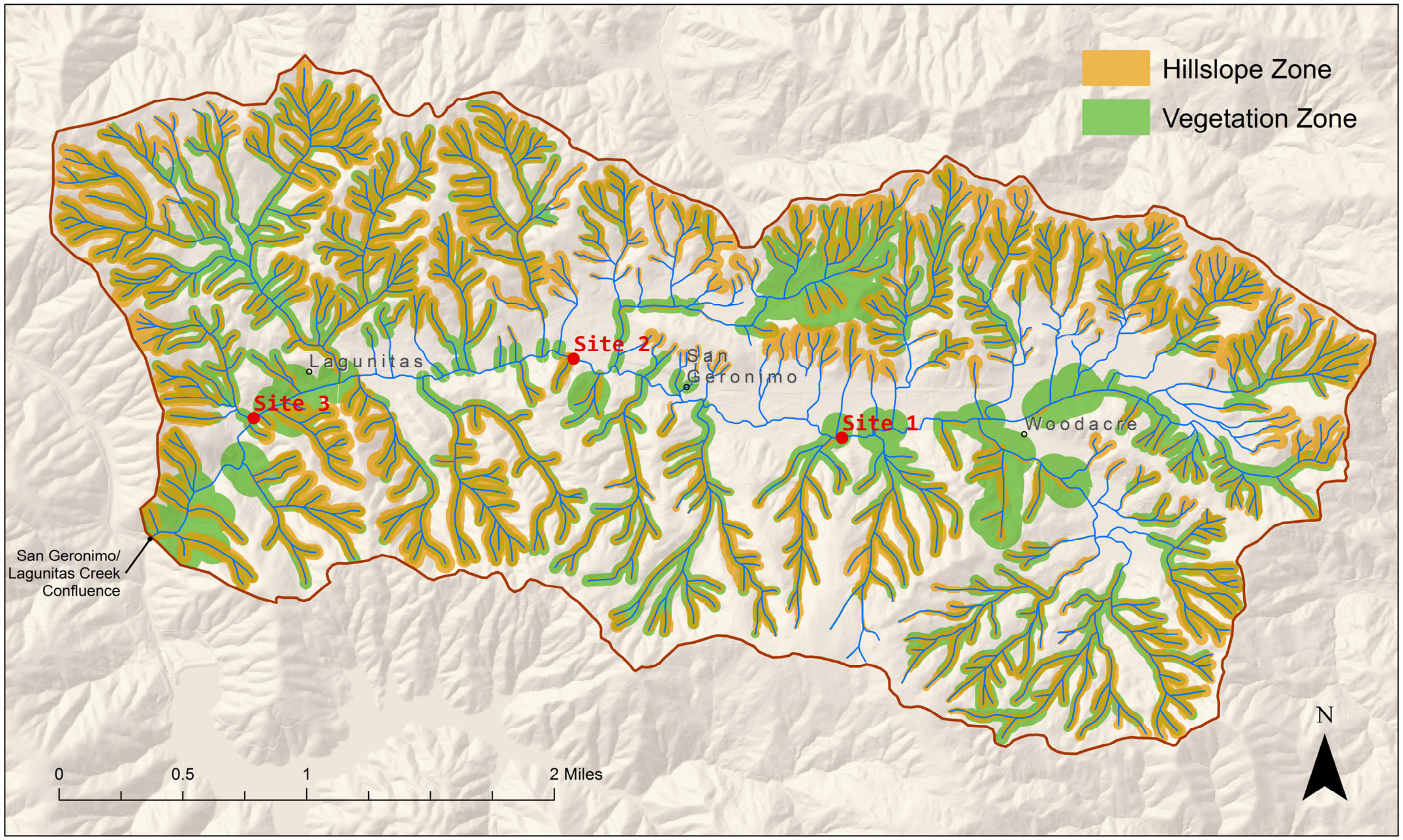

Figure 1. Output from the Vegetation and Hillslope modules for the San Geronimo Creek watershed (HyCon module sites shown in red).

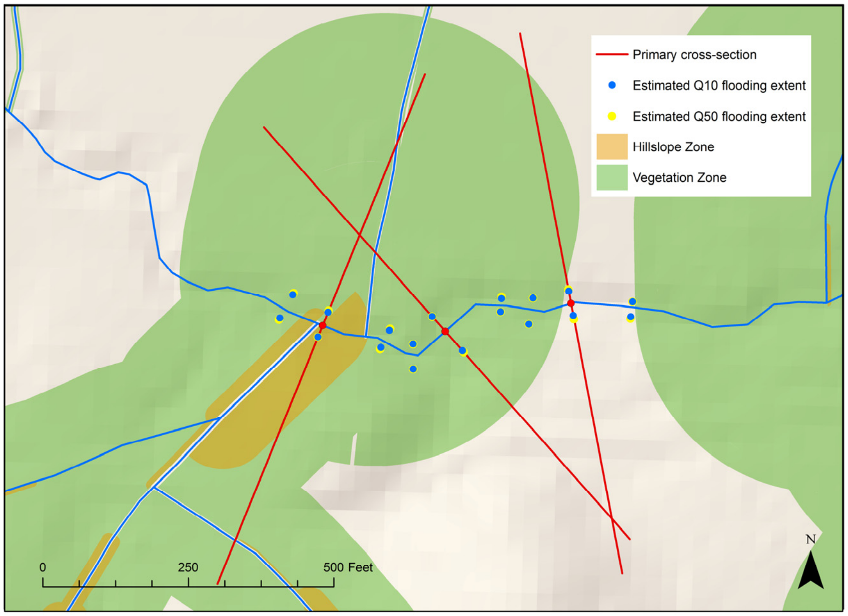

Figure 2. Output from all three modules at Site 1 (flow is from right to left).

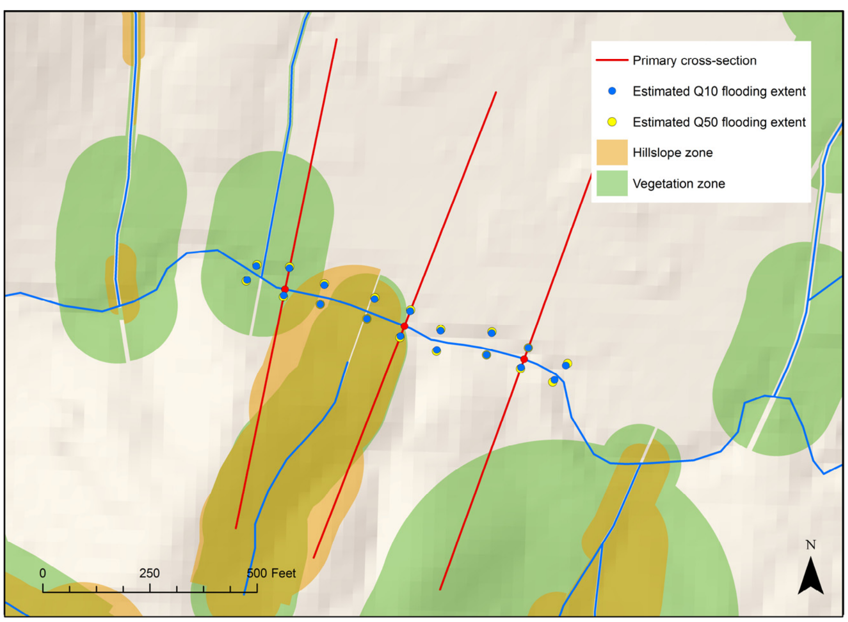

Figure 3. Output from all three modules at Site 2 (flow is from right to left).

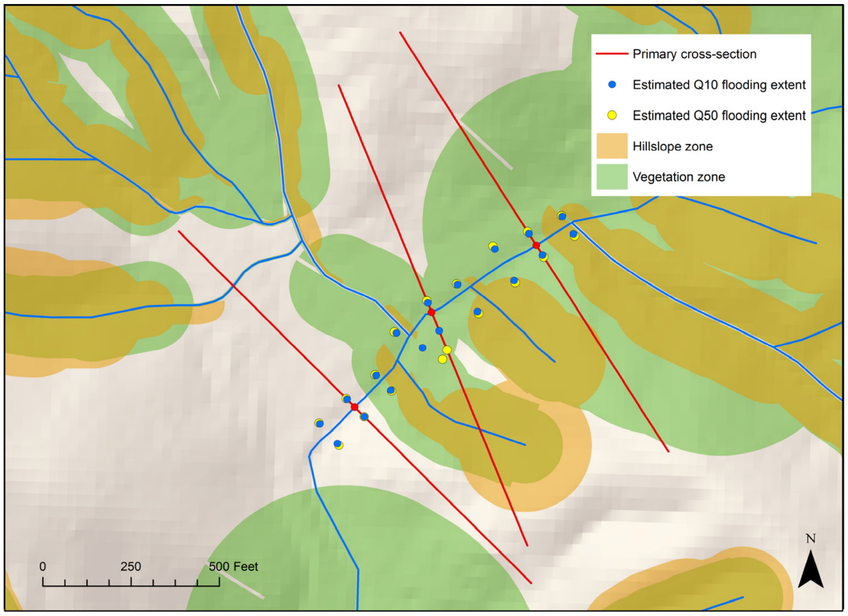

Figure 4. Output from all three modules at Site 3 (flow is from right to left).