TUCANNON RIVER STYLES PRELIMINARY ASSESSMENT STAGES 1 AND 2

Elijah Portugal, Wally MacFarlane, Jordan Gilbert, and Josh Gilbert

CONTENTS

GEOMORPHIC ANALYSIS USING A RIVER STYLES FRAMEWORK

We are progressing through a geomorphic assessment of the Tucannon watershed using a modified version of the River Styles framework. The River Styles framework is a hydrologic and geomorphic classification system which provides tools for interpreting river character, behavior, geomorphic condition, and recovery potential (Brierley and Fryirs, 2005). It consists of a series of four stages that includes 1) an identification of the unique suite of River Styles (i.e., reach types) within the watershed, 2) an assessment of the current condition of the watershed, given the historical context, 3) predictions about the recovery potential and finally 4) implications for watershed management and restoration planning. This framework is widely used by watershed managers in Australia and New Zealand and is gaining traction in the Columbia River Basin. Our geomorphic assessment of the Tucannon River Watershed does not strictly adhere to the River Styles framework in that we do not explicitly incorporate all elements of Stages 2 – 4 (e.g., measured cross sections) and we bolster the condition assessment with spatially explicit network based models of riparian and floodplain condition.

Geomorphic classification of rivers is based on the systematic categorization of physical features of a river flowing through its channel while interacting with structural elements (e.g., LWD, boulders, beaver dams), the valley setting, and the unique suite of geomorphic units of the channel, floodplain and confining features (Brierley and Fryirs, 2005; Buffington and Montgomery, 2013). River form is ultimately an expression of the balance between sediment supply and the waters ability to transport that supply (i.e., transport capacity) but is complicated by a variety of other parameters like valley setting, the caliber of sediment supplied, vegetation, and structural elements in the channel. The River Styles framework provides a means to assess the rivers character and behavior in a spatially hierarchical classification scheme. A rivers character (i.e., form) can be regarded as its specific morphology that is comprised of valley, channel and floodplain geomorphic features. River behavior (i.e., function) is the tendency and capacity for adjustment within its given valley setting and floodplain (Brierley and Fryirs, 2005). River behavior can be revealed by the specific suite of geomorphic units within the channel and floodplain, where their form is reflective of the processes that shaped them. For example, a fresh point bar deposit on the inside of a meander bend with an adjoining freshly cut bank opposite the point bar are the features (i.e., form) that reveals the behavior (i.e., process) of the rivers lateral adjustment.

The River Styles Framework provides a method for understanding why rivers look and behave the way they do given the imposed sediment and water flux and how they might look in the future, given specific management actions. The nested hierarchical classification system embraces the relationship between large-scale processes of sediment and water flow that directly influence smaller scales. As such, the large-scale features within the watershed are characterized and explained.

STAGE ONE: LANDSCAPE UNITS

Landscape units (LUs) are identifiable topographic features within a watershed that have a distinct pattern of landforms (Figure 1). The pattern of landforms are controlled by the boundary conditions of underlying bedrock, channel slope, elevation, aspect and relief interacting with vegetation cover, soils and precipitation. Ultimately channel form, drainage density and the type and distribution of River Styles are dictated by this relationship. Landscape units were delineated based on regional geology, vegetation cover, soils and hydrologic data. Much of this information is compiled into level IV Ecoregions published by the Western Ecology Center of the US Environmental Protection Agency (Thorson et al., 2003) and informed the landscape units delineated in the Tucannon Watershed (Figure 1). The Tucannon watershed is composed of four distinct Landscape Units. The four units are Mesic Forest Headwaters, Dissected Highlands, Dissected Loess Uplands and Deep Loess Foothills.

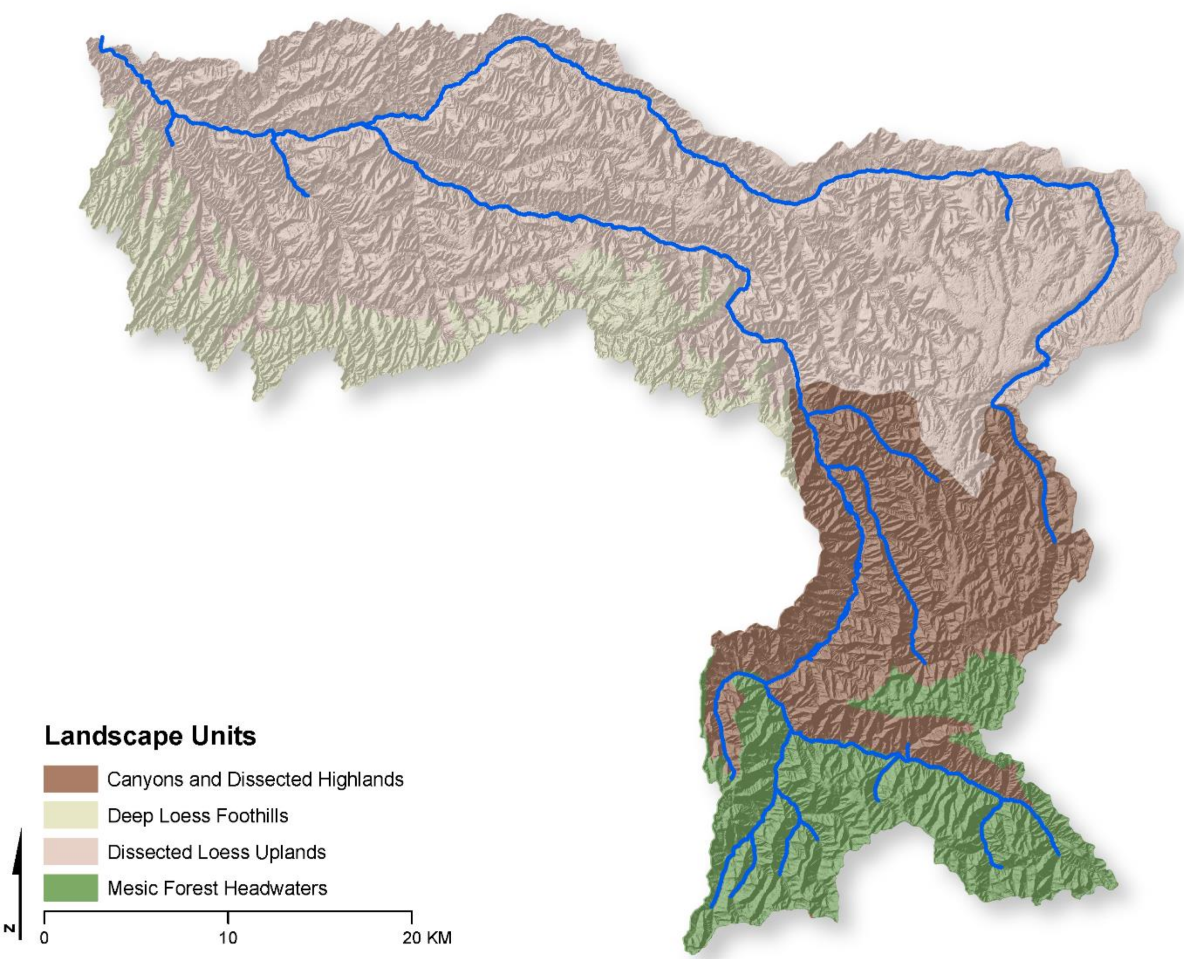


Figure 1 – Landscape Units of the Tucannon Watershed

Table 1 - Parameters used to differentiate and classify Landscape Units in the Tucannon River Watershed

Parameter/ Landscape Unit	Mesic Forest Headwaters	Dissected Highlands	Dissected Loess Uplands	Deep Loess Foothills
Level 4 Ecoregion	Mesic Forest Zone	Canyons and Dissected Highlands	Dissected Loess Uplands	Deep Loess Foothills
Physiographic Character or Landscape Morphology	Dissected volcanic plateau composed of rounded to moderately steep mid-elevation, forested mountains	Dissected volcanic plateau composed of steeply sloping upper slopes. Forested north- facing slopes otherwise grassland or shrubland	Flat plateau top with rolling hills separated by low angle swales. Plateau edge maintains steeper slopes. Heavy agriculture on plateau top.	Flat plateau top with broad low angle swales. Deepest loess deposits in watershed. Heavy agriculture.
Landscape Position	Uppermost catchment area, draining the Blue Mountains	Transition from Mesic Headwaters to Loess dominated Landscape Units	Majority of mid to lower watershed	Southern portion of mid to lower watershed
Geology	A series of basalt flows	A series of basalt flows	Loess deposits covering basalt flows	Deep loess deposits covering basalt flows
Relief	100 – 300 m	100 - 400 m	100-200 m	10-100 m
Elevation	1000-1800 m	660 – 1650 m	190 – 1300 m	250 – 1000 m
Valley Width	Up to 50 m	Up to 150 m	Up to 650 m	Up to 75 m

The mesic forest headwater landscape unit comprises the uppermost portions of the Tucannon watershed, and drains the higher elevation Blue Mountains to the south. It is underlain by Tertiary basalt flows with no loess deposits present. Basalt outcrops act as local controls on river behavior and character and structures valley width and slope. The streams within this LU are primarily fed by snowmelt and provide enough moisture to support an extensive conifer dominated forest. Where intact, the dense conifer forest provides a good source for LWD recruitment to the larger streams in this LU. The high levels of LWD provide sufficient instream structural elements to force a complex channel planform with high levels of geomorphic complexity. The dissected highlands LU occurs directly below the mesic forest headwater LU and represents a transition into the loess dominated LUs in the lower watershed. The dissected highlands also represent a transition from conifer dominated slopes of the headwaters to the grass-dominated, loess mantled lower watershed. Basalt is dominate in this LU forcing narrow, steep canyons in the smaller streams. This LU transitions into the loess dominated lower LUs of the deep loess foothills, and the dissected loess uplands. Both the loess dominated LUs are characterized by flat plateaus that support extensive agriculture. The deep loess foothills only occurs on the loess mantled plateau top and supports low gradient unconfined uplands swales. In contrast, the dissected loess uplands encompasses the plateau tops as well as the dissected edges of the plateau and wide alluvial valleys. On the plateau top the dissected loess uplands is also heavily farmed and supports laterally unconfined, low gradient uplands swales. As streams drain the edges of the loess mantled plateau they interact occasionally with the basalt bedrock base underlying the loess deposits. This allows for increased slope and stream power. The highly erosive nature of loess provides a source of sediment to develop large alluvial valleys which attain there largest size within the lower reaches of this LU.

STAGE ONE: RIVER STYLES

River Styles (RS) are determined through five primary physical parameters: valley setting, channel planform, floodplain and in-stream geomorphic units, the caliber of bed material, and instream structural elements (Brierley and Fryirs, 2005). A River Style represents a specific assemblage of the five primary parameters which are consistent over the reach scale (typically on the scale of kilometers). The 5 River Styles present in the Tucannon watershed were initially distinguished using the following procedural trees (Figure 2, Figure 3 and Figure 4) informed by desktop GIS and aerial imagery analysis. Google Earth imagery and 10m and 1m cell resolution Digital Elevation Model (DEM) were the primary tools used for the desktop delineation. Additionally, we used network based models (Appendix B: Description of Network Models) to identify the level of valley confinement, and the extent of the valley bottom. Delineations were then verified with field observation and detailed mapping at representative locations within each RS.

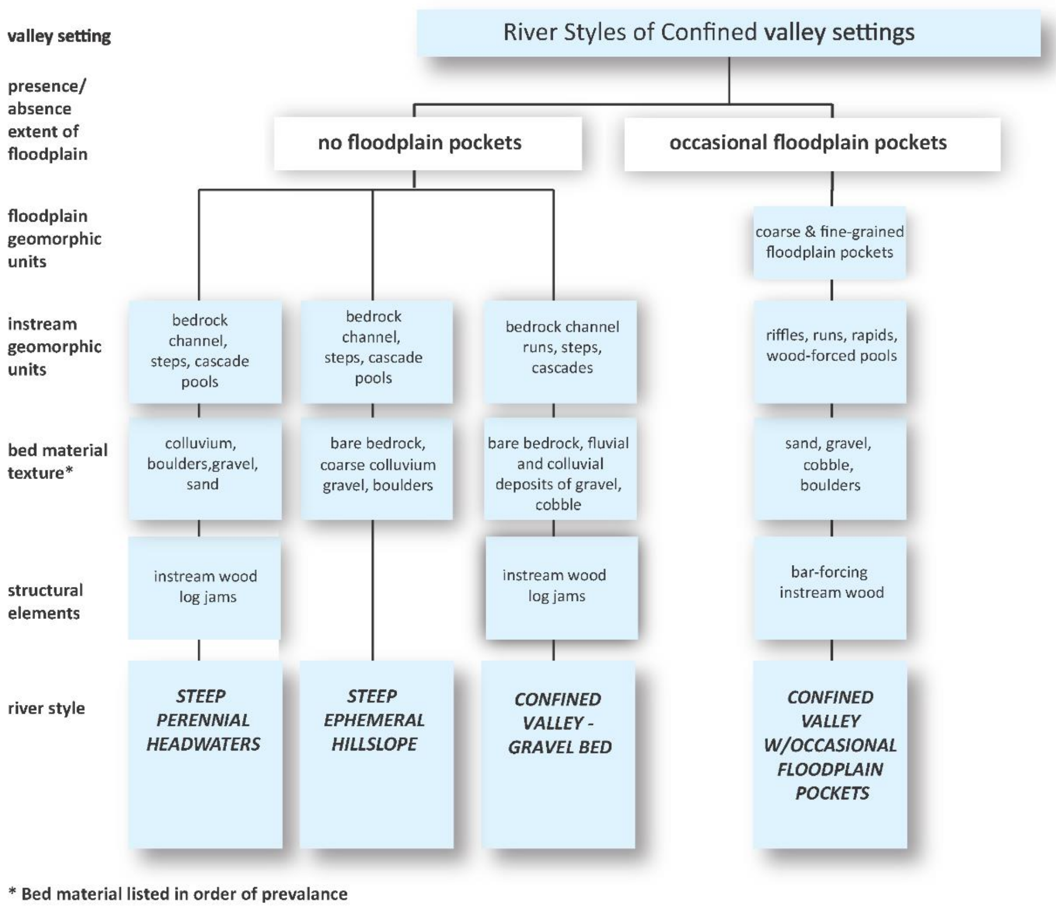


Figure 2 – River Style tree for confined valley settings in the Tucannon Watershed.

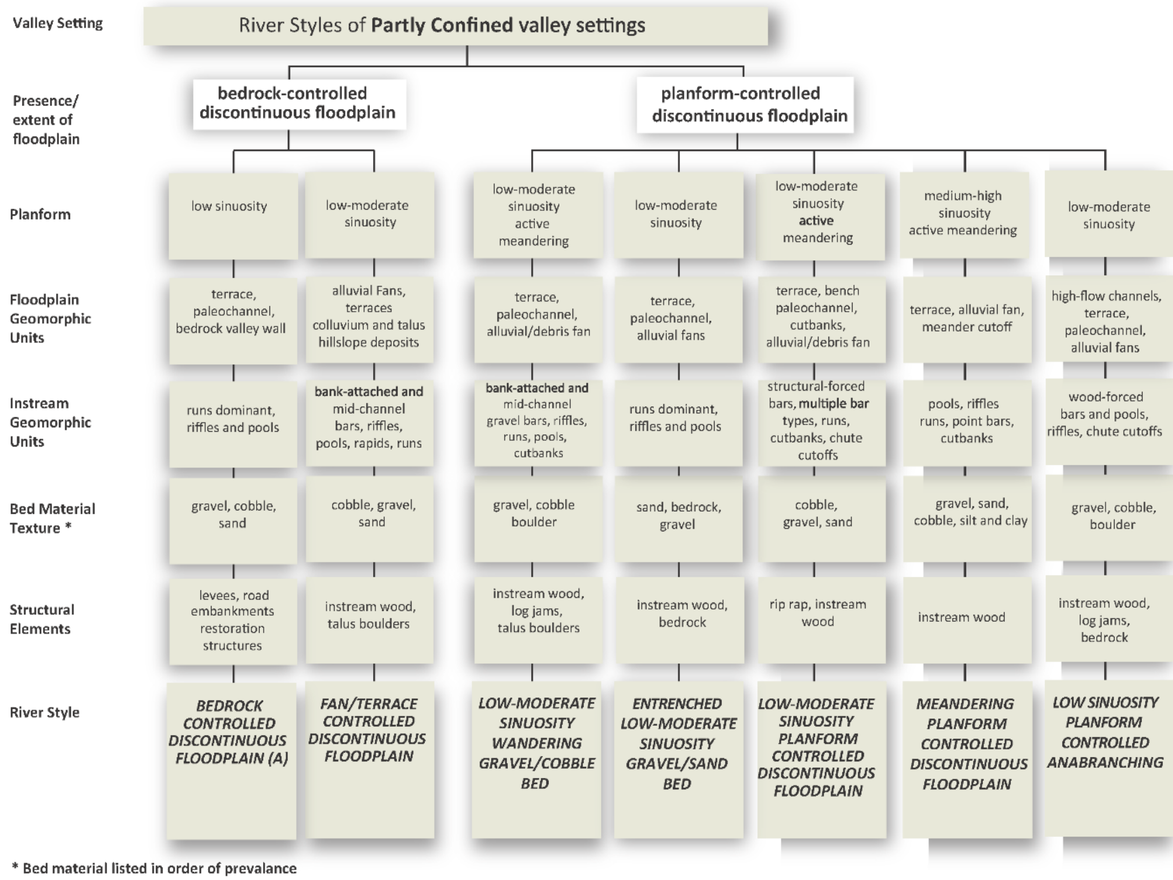


Figure 3 - River Styles tree for partly confined valley settings in the Tucannon Watershed.

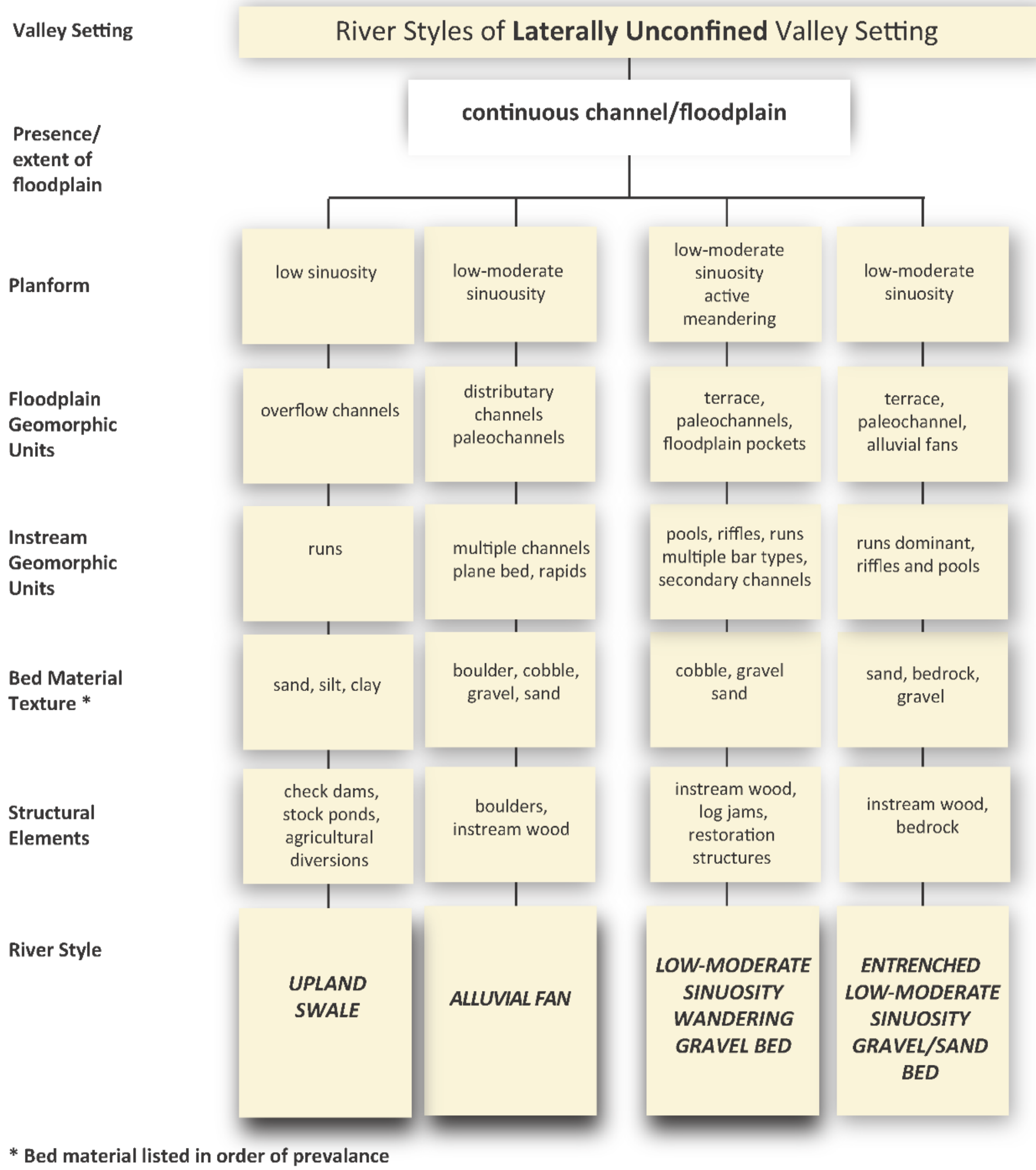


Figure 4 – River Styles tree for laterally unconfined valley settings in the Tucannon watershed.

Table 2 – Summary of attributes of River Styles within a confined valley setting in the Tucannon watershed.

River Styles Confined Valley Setting	Landscape Unit	River Character Channel Planform	Geomorphic Units	Bed Material Texture	River Behavior
CV-Gravel Bed	Primarily Loess dominated LUs	Single channel, low sinuosity	Bare bedrock, runs, cascades	Bedrock, colluvium, gravel	Steep, often ephemeral, adjustment potential low as this RS is laterally confined by hillslopes. Occurs primarily at transition from loess covered flat plateau top (upland swale RS) to the lower gradient COFP RS.
Confined Occ. Floodplain Pockets	Found throughout LUs but more common in basalt dominated upper LUs	Primarily single-threaded but LWD forces multi-threaded planform, locally. Low to mod. sinuosity largely controlled by valley sinuosity	Discontinuous pockets of coarse and fine grained floodplain, bedrock outcrops, pool-riffle, rapids, bars	Bedrock, boulders, colluvium, gravel, sand and silt more common in lower watershed	Steep channel, often intermittent at high elevations, with alternating assemblage of bedrock forced pools and pool-riffle-rapid sequences. Floodplain is formed by both lateral migration, typically forced by LWD inputs, and fine grained accretion in lower gradient areas. Typically this RS is coarser bedded and steeper, higher in the watershed and lower gradient and finer bedded in the loess dominated LUs.
Steep Ephemeral Hillslope	Only occurs within the loess dominated LUs	Primarily single channel, low – mod sinuosity	Bare bedrock, runs, rapids, no floodplain	Coarse colluvium, bedrock, gravel, boulders	Ephemeral, steep, aligned to the valley, and confined by adjoining hillslopes. Coarse bed material texture with highly angular colluvium eroded and transported downstream from adjacent hillslopes. Rarely, localized high-intensity thunderstorms transport bed material and the planform may become anabranching if space allows.
Steep Perennial Headwaters	Occurs primarily in upper watershed in Mesic Forested Headwaters and Canyons and Dissected Highlands LU	Primarily single channel, low sinuosity aligned to valley sinuosity	No floodplain present, bedrock, rapids, runs, wood-forced step-pools	Coarse colluvium, bedrock, gravel, boulders	Snowmelt fed perennial first and second order steep tributary streams dominated by bedrock and hillslope deposits. LWD forced channel anabranching during highflow. Channel forming flows occur during spring runoff.

Table 3 - Summary of attributes of River Styles within a partly confined valley setting in the Tucannon watershed.

		River Character			
River Styles Partly-Confined Valley Setting	**Landscape Unit**	**Channel Planform**	**Geomorphic Units**	**Bed Material Texture**	**River Behavior**
Bedrock Controlled DF (A)	Occurs throughout mainstem Tucannon but not in the Mesic Forested Headwaters LU	Single-threaded, low sinuosity. Pinned against valley wall on one side by levees and berms. Planform created by channelization and artificial confining features.	Floodplain inaccessible due to human infrastructure, runs dominate, minimal bar features and pools. Restoration structures force pools locally.	Gravel, cobble dominate, some sand present, direct coupling to hillslope provides some inputs of coarse colluvium	Anthropogenically created RS. Only found in middle and lower watershed within the mainstem Tucannon adjacent to agricultural fields. Levees and berms force the channel against one side of the alluvial valley to allow for more room for agriculture. The historic floodplain is largely inaccessible except during very rare flood events. LWD and other structural elements removed to convey high-flows.
PC Low-Mod. Sin Wandering Gravel/Cobble Bed	Occurs throughout mainstem Tucannon but not in the Mesic Forested Headwaters LU	Wandering planform (2-3 active channels on average). Low to moderate sinuosity.	Floodplain accessible, and reflects formation by both lateral migration and vertical accretion, wood forced pool and bar features common	Gravel dominate particularly in lower mainstem reaches, cobble dominate in upstream reaches, sand	Dynamic, low gradient alluvial RS with high natural capacity for adjustment. Where natural recruitment of LWD is present instream and floodplain geomorphic complexity is high. High flow events force lateral adjustments, access floodplain and form new side channels.
PC Entrenched Low-Mod. Sin. Gravel/Sand Bed	Dissected Loess Uplands	Incised, single-threaded, low – moderate sinuosity. Contemp. planform largely controlled by pre-incision planform which was often more sinuous.	Small discontinuous contemporary floodplain within boundaries of incision trench. Runs dominant within active channel.	Gravel and sand dominate, bedrock present in some locations.	Incised, contemporary stream is confined within boundaries of incision trench. High flows not capable of reaching past floodplain (terrace). High flow events capable of accessing the walls of incision trench and remobilizing fine-grained loess deposits.
Low-Mod. Sin. Planform Controlled DF	Occurs in every LU, common in Dissected Loess Uplands	Primarily single-threaded but wood forcing can cause multi-threaded planform. Low –mod. sinuosity	Discontinuous floodplain formed by a mix of lateral and vertical accretion, paleochannels and high flow channels on FP. Runs, pools, bar features present.	Cobble, gravel, sand	Channel exhibits low-moderate sinuosity, but can be restricted on occasion by bedrock. Found in wider but still partly confining valleys. Multiple channels may develop in some areas, but one channel will always contain the majority of flow. Larger than bankfull floods will often force sudden alterations to the primary channel. Floodplain is well developed, although discontinuous. Sediment cycles between transport and storage zones, creating complex bars in some areas.
Meandering Planform Controlled DF	Dissected Loess Uplands	Single-threaded moderate to high sinuosity	Discontinuous fine-grained floodplain, pools, riffles, runs, cutbanks	Gravel, sand and silt dominate, cobbles present	Actively meandering throughout a fine-grained discontinuous floodplain. Moderately to highly sinuous. Only occurs within the upper mainstem of Pataha Creek. Not incised.

Fan/Terrace Controlled DF	Canyons and Dissected Highlands	Single-threaded, low to moderate sinuosity largely imposed by alluvial fan inputs	Discontinuous coarse floodplain, runs, rapids, step-pools, some bar features present in lower gradient reaches	Colluvium, gravel, cobble, sand, bedrock	Occurs in relatively narrow but partly-confined valleys where coarse alluvial fan inputs largely impose the sinuosity and channel planform. Downstream terminus of individual fans may be steep with rapids and cascades.
Low Sin. Planform Controlled Anabranching	Mesic Forest Headwaters	Multi-threaded with low to moderate sinuosity. The amount of active channels is determined by the local supply of LWD.	Floodplain a mix of coarse and fine-grained deposits. Wood forced bar and pool features abundant, riffles and runs	Cobble and gravel dominate but sand and finer material present	Highly dynamic. Characterized by high rates of natural wood-loading which forces the planform, amount of side channels, and most instream geomorphic complexity. In some location bedrock walls interact with the channel and here the planform is typically single-threaded and less complex.

Table 4 - Summary of attributes of River Styles within a laterally unconfined valley setting in the Tucannon watershed.

River Styles Laterally-Unconfined Valley Setting	Landscape Unit	River Character: Channel Planform	River Character: Geomorphic Units	River Character: Bed Material Texture	River Behavior
Alluvial Fan	Occurs throughout the watershed but most common in the Canyons and Dissected Highlands LU.	One to multiple channels (flow dependent), low to moderate sinuosity	Continuous floodplain, Forced pools, Runs, Side channels, Dammed pools	Sand, gravel, cobble	Behavior dependent on the bed material and flow regime of individual alluvial fans. Fine grained, low angle fans found in lower watershed which are often incised. Coarser, higher angle fans are found in the upper watershed and can exert a strong control on mainstem river behavior in narrow valley settings. LWD from upper river sections tends to accumulate within fans, leading to forced pools, dammed pools, and long deep runs.
Entrenched Low-Mod. Sin. Gravel/Sand Bed	Dissected Loess Uplands	Incised, single-threaded, low – moderate sinuosity. Contemporary planform is largely controlled by the pre-incision planform which was often more sinuous.	Small discontinuous contemporary floodplain within boundaries of incision trench. Runs dominant within active channel.	Gravel and sand dominate, bedrock present in some locations.	Incised, contemporary stream is confined within boundaries of incision trench. High flows not capable of reaching paleo- floodplain (terrace). High flow events capable of accessing fine-grained sediment from the walls of the incision trench which are reworked and redeposited within the small contemporary floodplain.
Low-Mod. Sin. Wandering Gravel Bed	Dissected Loess Uplands	Wandering planform (2-3 active channels on average). Low to moderate sinuosity.	Floodplain accessible, and reflects formation by both lateral migration and vertical accretion, wood forced pool and bar features common	Gravel dominate, cobble, sand and silt	Dynamic, low gradient alluvial RS with high natural capacity for adjustment. Where natural recruitment of LWD is present instream and floodplain geomorphic complexity is high. High flow events force lateral adjustments, access floodplain and form new side channels.
Swale	Occurs in every LU but most common in Loess dominated LUs lower in watershed	Single-threaded, low sinuosity, sometimes channel planform is indistinct.	Continuous floodplain that forms a diffuse boundary alongside main channel	Loess-soils, sand	Channel is continuous with intermittent ponds and wetlands typically forced through artificial agricultural obstructions. Valleys are unconfined, low gradient and exhibit a rolling hill topography. Swales are largely inactive and may be dry for long periods depending on rainfall/snowmelt. This leads to indistinct boundaries between the active channel and floodplain.

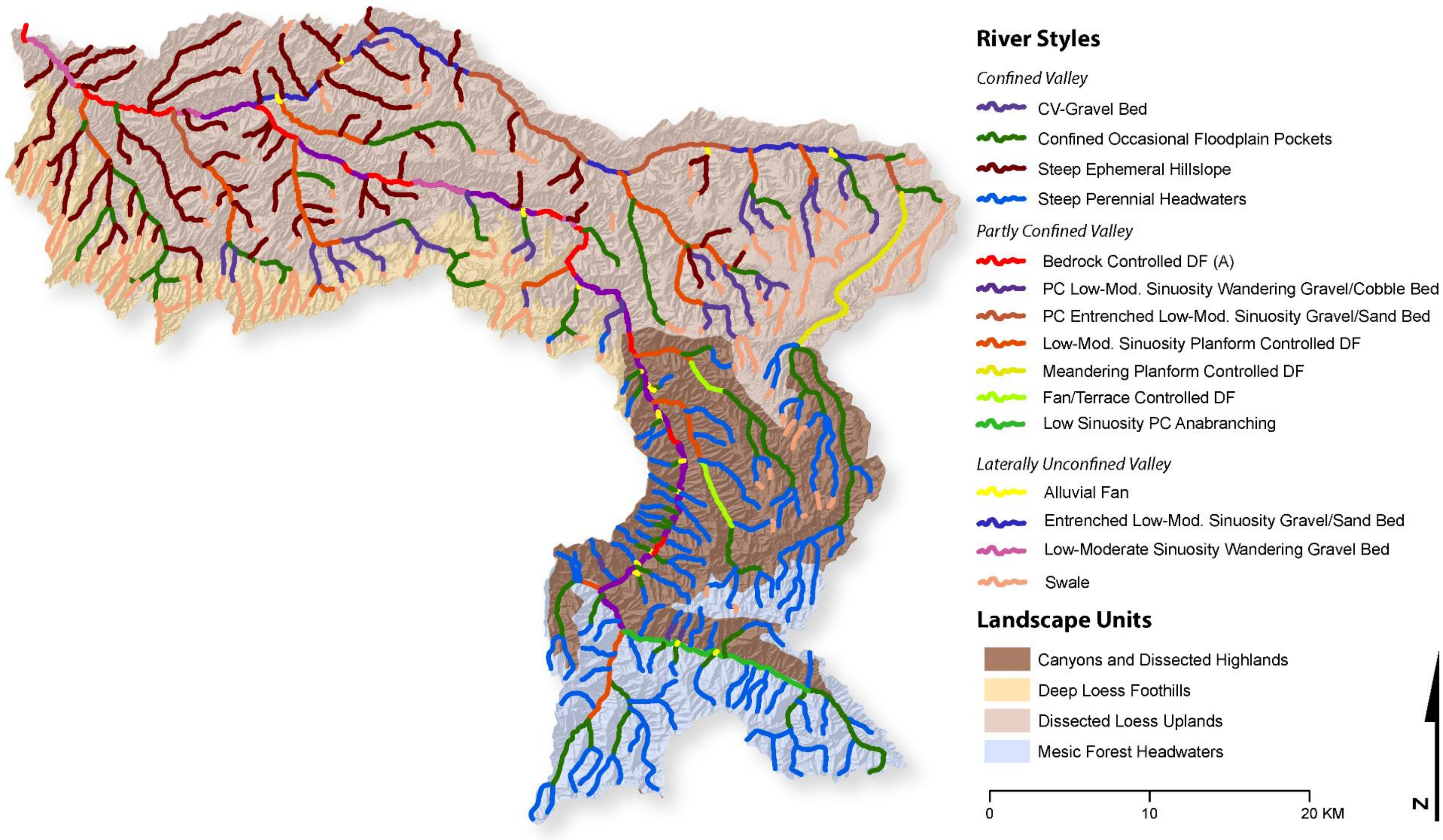


Figure 5 – River Styles of the Tucannon watershed within the perennial stream network. Landscape units are also shown.

Table 5 – Summary of the proportion of total stream length composed of the different River Styles in the Tucannon watershed.

Confined Valley	Lower Tuc	Pataha	Upper TUC	Stream Length (km)	Proportion of Total (%)
Confined Valley Gravel Bed	4.1	35.1	28.1	67.3	6.3
Confined Occasional Floodplain Pockets	26.5	50.4	85.6	162.5	15.2
Steep Ephemeral Hillslope	92.3	55.1	28.7	176.0	16.5
Steep Perrennial Headwaters		44.4	186.8	231.2	21.7
Partly-Confined Valley					
Low Sinuosity PC Anabranching			13.9	13.9	1.3
Bedrock Controlled DF(A)	8.5		17.6	26.0	2.4
PC Low-Mod Sin.Wandering Gravel/Cobble	4.0		63.2	67.2	6.3
PC Entrenched Low-Mod Sin Gravel/Sand Bed	5.6	24.3		29.8	2.8
Low-Mod. Sin. Planform Controlled DF	10.2	27.8	31.4	69.5	6.5
Meandering Planform Controlled DF		13.9		13.9	1.3
Fan/Terrace Controlled DF			7.7	7.7	0.7
Laterally Unconfined Valley					
Alluvial Fan		2.0	5.1	7.1	0.7
Entrenched Low-Mod. Sin. Gravel/Sand Bed		26.7		26.7	2.5
Low-Mod Sin.Wandering Gravel Bed	7.9		10.3	18.2	1.7
Upland Swale	56.9	65.6	25.4	147.8	13.9
Total	**215.9**	**345.3**	**509.1**	**1066.3**	

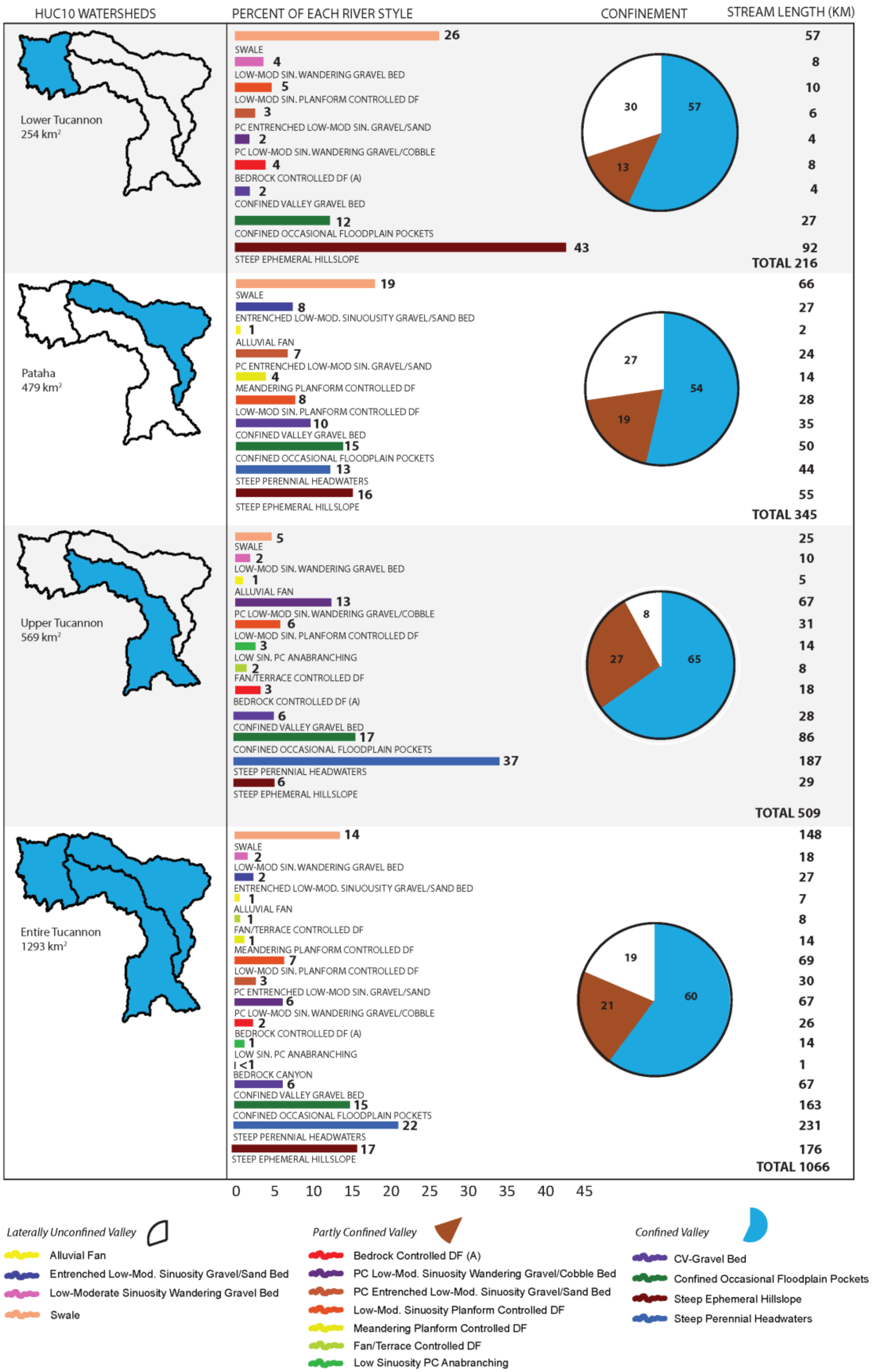


Figure 6 – Distribution of River Styles within the Tucannon watershed organized by HUC10 watersheds. Valley confinement is also displayed.

STAGE TWO: PRELIMINARY CONDITION ASSESSMENT

We are in the process of conducting a geomorphic and riparian condition assessment of all River Styles within the perennial network of the Tucannon watershed. For the purposes of the expert panel process, we reduced the stream network to the fish-bearing portion as identified by the StreamNet database. The geomorphic and riparian assessment is based on, 1) the baseline survey of river character and behavior accomplished in Stage One of the River Styles assessment and, 2) continuous metrics of riparian and floodplain condition derived from three spatially explicit, network based models (Appendix B: Description of Network Models). Geomorphic condition refers to the deviation from an expected form and function of the river given the specific valley setting, boundary conditions of sediment and water flux, and biotic resistance elements. The deviation from reference conditions is driven by historic and current land-use and development. Essentially, good or pristine condition reference reaches are identified for each River Style and each reach-scale occurrence of that RS (hereafter referred to as 'variants') are compared against the reference conditions for that specific RS to assess geomorphic condition. Inherent to the geomorphic condition assessment is the concept of a River Styles natural 'capacity for adjustment' (Brierley and Fryirs, 2005). This is the ability of a given RS to adjust it channel shape and planform, bed material characteristics and instream and floodplain geomorphic units in response to local and system-wide disturbances but do not 'record a wholesale change is River Style'. These disturbances can be driven by natural (e.g., wildfire, changing climate, mass-wasting, etc.) and anthropogenic (e.g., logging, agriculture, grazing, mining, development, etc.) perturbations. The capacity for adjustment is explained in more detail in the next section.

DISCLAIMER: Aside from the model outputs, at the time of writing the geomorphic condition assessment is based on a data set that represents 7 days of field work and is thus considered preliminary. Additional field work will be completed in 2016 to finalize the condition assessment presented herein. Additionally, for this preliminary condition assessment we limited the scope of the perennial stream network to the larger order tributaries which have been delineated as fish-bearing streams by the StreamNet database.

CAPACITY FOR ADJUSTMENT AND REACH SENSITIVITY TO DISTURBANCE

The capacity for adjustment of a River Style is defined as, "morphological adjustments brought about by the changing nature of biophysical fluxes that do not record a wholesale change in river style" (Fryirs and Brierley, 2012; O'Brien, 2014). Morphological adjustments refer to changes in: 1) channel attributes, 2) channel planform, 3) bed material and 4) instream structural elements driven by changes in the boundary conditions (i.e., water and sediment flux, slope, vegetation associations). For example, in the deeply incised portions of lower Pataha Creek the channel planform has changed from historic conditions with lower sinuosity and less side channels. This is due to the incision driven by a change in the water and sediment flux within the watershed likely caused by anthropogenic disturbances to runoff characteristics.

The capacity for adjustment determines how sensitive different portions of the Tucannon watershed are to local and watershed wide disturbance. For example, the confined valley setting RS have low adjustment potential because of the laterally confining features (e.g., hillslopes, bedrock) which don't allow for adjustment in channel shape (e.g., W:D ratio) or planform leaving these reaches relatively insensitive to natural or anthropogenic disturbance. In contrast, the partially confined and laterally unconfined RS have moderate to high adjustment potential because of the lateral accommodation space of floodplains allowing for dynamic modifications in channel shape, planform and bed material. Figure 7 illustrates the variability in the natural capacity for adjustment in a conceptual diagram. We determined the capacity for adjustment of each River Style by tabulating attribute data during proforma site visits and through remote sensing data. Table 6 shows the adjustment potential of channel attributes, channel planform, and bed material characteristics for each River Style.

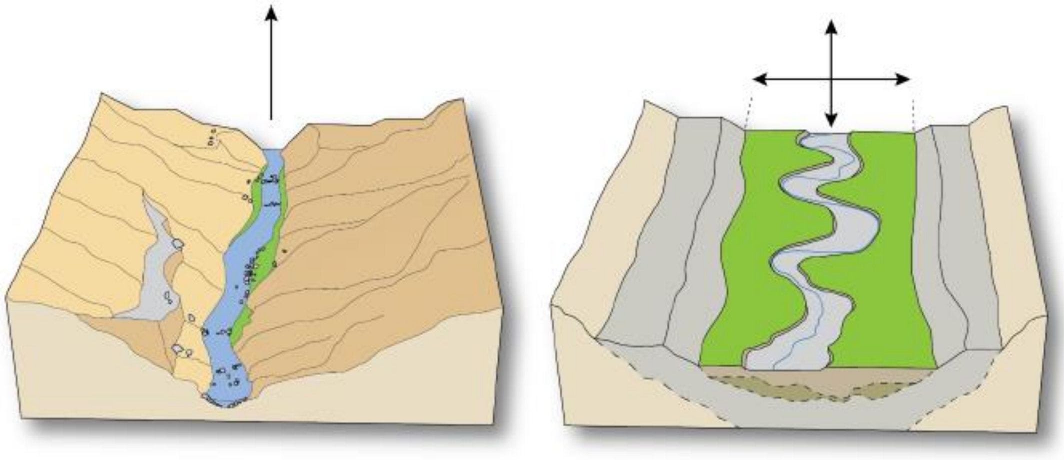


Figure 7 – Variability in the natural capacity for adjustment driven by valley setting. Source: (O'Brien, 2014)

Table 6 – Capacity for adjustment of each River Style within the Tucannon watershed.

River Style	Channel Attributes	Channel Planform	Bed Character	Capacity for Adjustment
Confined Valley settings				
Bedrock Canyon			Localized	Low
Confined Valley Gravel Bed				
Confined Occasional Floodplain Pockets	Localized	Localized	Localized	Low
Steep Ephemeral Hillslope			Localized	Low
Steep Perennial Headwaters			Localized	Low
Partly Confined Valley Settings				
Bedrock Controlled DF (A)	Localized	Localized	Localized	Low
Fan/Terrace Controlled DF	Localized	Localized	Significant	Moderate
Low-Mod. Sinuosity Planform Controlled DF	Localized	Significant	Localized	Moderate
Low Sinuosity Planform Controlled Anabranching	Significant	Significant	Localized	High
Meandering Planform Controlled DF	Localized	Significant	Localized	Moderate
PC Entrenched Low-Mod. Sinuosity Gravel/Sand Bed	Significant	Significant	Significant	High
PC Low-Mod. Sinuosity Wandering Gravel/Cobble Bed	Significant	Significant	Significant	High
Unconfined Valley Settings				
Alluvial Fan	Localized	Significant	Localized	High
Entrenched Low-Mod. Sinuosity Gravel/Sand Bed	Significant	Significant	Significant	High
Low-Mod. Sinuosity Wandering Gravel Bed	Significant	Significant	Significant	High
Swale	Localized		Localized	Low

(white)	Minimal or no adjustment potential
(light)	Localized adjustment potential
(dark)	Significant adjustment potential

DEFINING RELEVANT INDICATORS OF CONDITION

In order to determine the current condition of a specific reach, geomorphic and riparian attributes called geoindicators (Brierley and Fryirs, 2005) are measured as a basis to assess current condition relative to a reference condition. Geoindicators are metrics related to channel and floodplain attributes, channel planform, and bed character (Table 7, Table 8, and Table 9). These attributes were assessed using a combination of remote sensing analysis (i.e. DEM and aerial photography reconnaissance) and field verification. At the time of writing, the field based assessment portion of the analysis represents 7 days of field time and will be expanded upon in 2016. In addition to traditional geoindicators, we added indicators of riparian and floodplain condition based on model outputs from three spatially explicit network models described in Appendix B (Appendix B: Description of Network Models). The, 'Instream Wood Recruitment' parameter within the Channel/Floodplain Attributes class, was generated by a combination of visual observation and model outputs from an instream wood recruitment model. The, 'riparian vegetation' parameter within the Channel Planform class was also generated from a combination of field verification and model outputs which supplies an index of riparian condition. Similarly, the floodplain condition model outputs were leveraged to inform the floodplain specific parameters. It should be noted, that the inclusion of the model results in the condition assessment significantly bolsters the quantitative nature of the condition assessment and represents a departure from a traditional River Styles assessment.

There are several additional geoindicators that are specific to the vertically incised (i.e., entrenched) RS's (i.e., PC Entrenched Low-Mod. Sinuosity Gravel/Sand Bed and Entrenched Low-Mod. Sinuosity Gravel/Sand Bed) that occur on lower Pataha Creek and a tributary to the lower mainstem Tucannon. These include: 1) depth of incision, 2) width of incision trench, 3) existence of inset floodplains. Condition classes were identified through the assessment of condition indicators for each reach of each RS. To be considered "intact" a reach is anthropogenically undisturbed and in its pristine condition. With the history of landuse within the mainstem Tucannon there are currently no intact reaches along the main-stem. "Good" condition reaches must have all three major groups of geoindicators (e.g., channel/floodplain attributes, channel planform, bed material) in good condition. Moderate condition reaches are defined by having one to two of the three main groups of geoindicators in good condition, while "poor" condition reaches are defined by all three main groups of geoindicators in an impaired or degraded condition. The tables of geoindicators are presented in Appendix A (Appendix A: Tables of Geoindicators).

Table 7 – Geoindicators used to measure the geomorphic and riparian condition of river styles within the Confined Valley Settings in the Tucannon watershed. The RS included in the fish-bearing stream network and the preliminary condition assessment are highlighted in red.

Geoindicator/RS	Confined Valley Gravel Bed	Confined Occasional Floodplain Pockets	Steep Ephemeral Hillslope	Steep Perennial Headwaters
Channel/Floodplain Attributes				
Size	Yes	Yes	No	No
Shape	Yes	Yes	No	No
Bank	Yes	Yes	No	No
Floodplain connectivity	No	Yes	No	No
Instream vegetation structure	Yes	No	No	No
Instream wood recruitment	Yes	Yes	Yes	Yes
Channel Planform				
Number of channels	No	No	No	No
Sinuosity of channels	No	No	No	No
Lateral stability	No	Yes	No	No
Geomorphic unit assemblage	Yes	Yes	Yes	Yes
Riparian vegetation	Yes	Yes	Yes	Yes
Riparian corridor				
Bed Character				
Grain size and sorting	Yes	Yes	Yes	Yes
Vertical bed stability	Yes	Yes	No	No
Sediment regime	Yes	Yes	Yes	Yes

Table 8 - Geoindicators used to measure the geomorphic and riparian condition of river styles within the Partly- Confined Valley Settings in the Tucannon watershed. The RS included in the fish-bearing stream network and the preliminary condition assessment are highlighted in red.

Geoindicator/RS	Bedrock Controlled DF (A)	Fan/Terrace Controlled DF	Low-Mod. Sinuosity Planform Controlled DF	Low Sinuosity Planform Controlled Anabranching	Meandering Planform Controlled DF	PC Entrenched Low-Mod. Sinuosity Gravel/Sand Bed	PC Low-Mod. Sinuosity Wandering Gravel/Cobble Bed
Channel/Floodplain Attributes							
Size	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shape	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Floodplain connectivity	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Inset floodplain surfaces	NA	NA	NA	NA	NA	Yes	No
Instream vegetation structure	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instream wood recruitment	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Channel Planform							
Number of channels	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sinuosity of channels	No	Yes	Yes	Yes	Yes	Yes	Yes
Lateral stability	No	Yes	Yes	Yes	Yes	Yes	Yes
Geomorphic unit assemblage	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Riparian vegetation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Riparian corridor	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bed Character							
Grain size and sorting	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vertical bed stability	Yes	Yes	Yes	Yes	Yes	Yes	No
Sediment regime	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 9 - Geoindicators used to measure the geomorphic and riparian condition of river styles within the Laterally Unconfined Valley Settings in the Tucannon watershed.

Geoindicator/RS	Alluvial Fan	Entrenched Low-Mod. Sinuosity Gravel/Sand Bed	Low-Mod. Sinuosity Wandering Gravel Bed	Swale
Channel/Floodplain Attributes				
Size	Yes	Yes	Yes	Yes
Shape	No	Yes	Yes	Yes
Bank	No	Yes	Yes	Yes
Floodplain connectivity	No	Yes	Yes	No
Inset floodplain surfaces	NA	Yes	NA	NA
Instream vegetation structure	No	Yes	Yes	Yes
Instream wood Recruitment	Yes	Yes	Yes	Yes
Channel Planform				
Number of Channels	Yes	Yes	Yes	No
Sinuosity of channels	Yes	Yes	Yes	No
Lateral stability	No	Yes	Yes	No
Geomorphic unit assemblage	Yes	Yes	Yes	Yes
Riparian vegetation	Yes	Yes	Yes	Yes
Bed Character				
Grain size and sorting	Yes	Yes	Yes	Yes
Vertical bed stability	No	Yes	Yes	Yes
Sediment regime	No	Yes	Yes	Yes

WATERSHED MAP OF GEOMORPHIC AND RIPARIAN CONDITION

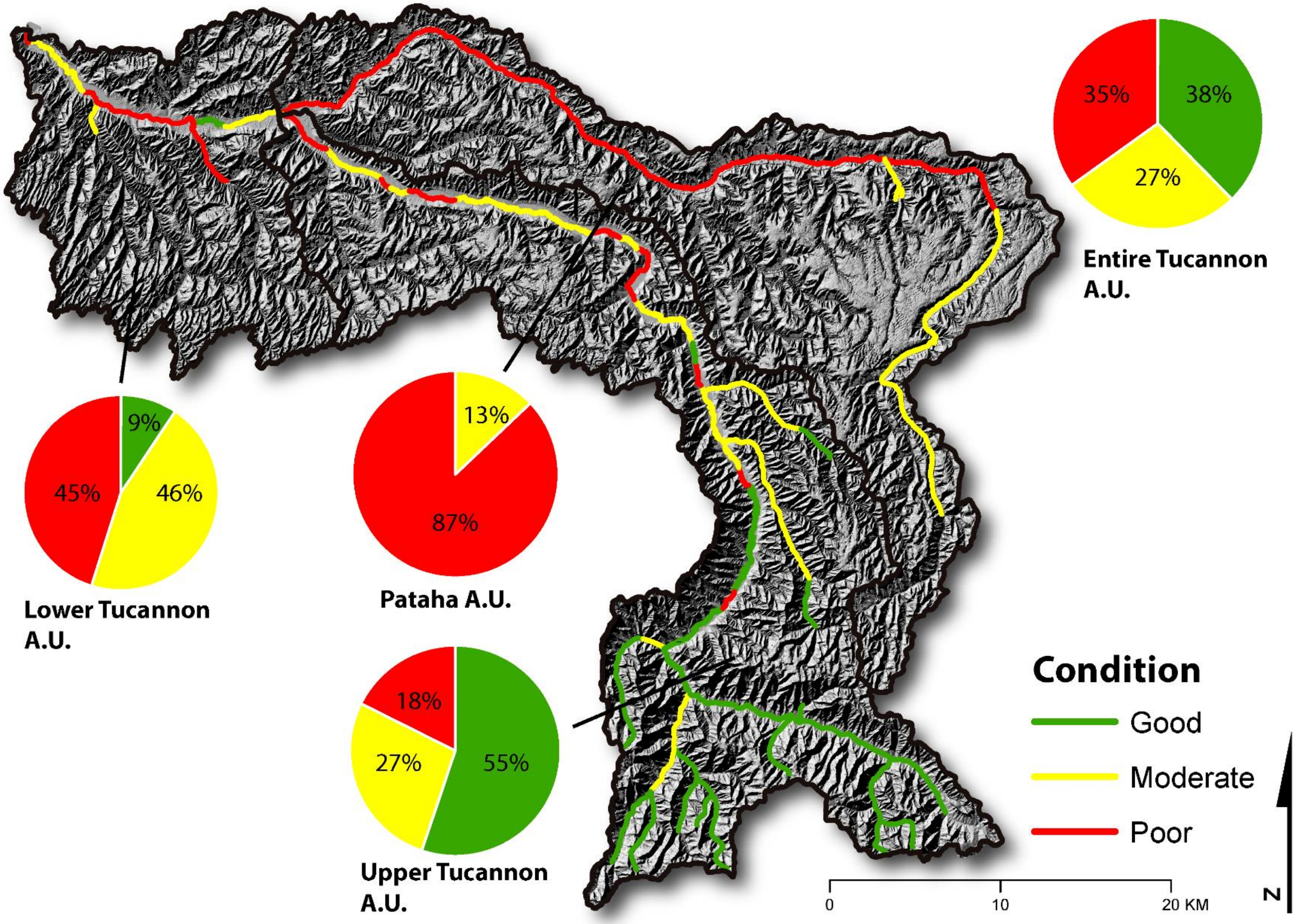


Figure 8 - Preliminary geomorphic and riparian condition map of the fish bearing perennial stream network for the Tucannon watershed

REFERENCES

Brierley, G.J., Fryirs, K.A., 2005. Geomorphology and river management. Blackwell.

Buffington, J.M., Montgomery, D.R., 2013. Geomorphic Classification of Rivers. Treatise on Geomorphology.

Fryirs, K.A., Brierley, G.J., 2012. Geomorphic analysis of river systems: an approach to reading the landscape. John Wiley & Sons.

O'Brien, G.O.W., J.M., 2014 River Styles Report for the Middle Fork John Day Watershed, Oregon, Ecogeomorphology and Topographic Analysis Lab, Fluvial Habitat Center, Watershed Sciences Department, Utah State University

Thorson, T., Bryce, S., Lammers, D., Woods, A., Omernik, J., Kagan, J., Pater, D., Comstock, J., 2003. Ecoregions of Oregon (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia. US Geological Survey (map scale 1: 1,500,000).

APPENDIX A: TABLES OF GEOINDICATORS

Table 10 - Criteria and measures used to assess geomorphic condition of variants of the Steep Perennial Headwaters RS within confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic and riparian condition is then determined by total ticks and crosses for each stream: 3 ticks = good condition; One or two crosses = moderate condition, and 3 crosses = poor condition. (For the purposes of the preliminary condition assessment we only present the results from the fish-bearing stream network)

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of the Step Cascade River Style.	Headwaters Tucannon and Panjab Creek
Channel/Floodplain Attributes	**Question must be answered YES** **For stream to be assessed in GOOD condition**	
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	Yes
		✓
Channel Planform	**1 out of 2 questions must be answered YES**	
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present (planar riffles and runs, cutbanks, pools, point bars)?	Yes
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks? Is the width of the riparian corridor appropriate for this RS?	Yes
		✓
Bed Character	**1 out of 2 questions must be answered YES**	
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	Yes
		✓
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Good**

Table 11 - Criteria and measures used to assess geomorphic condition of variants of the Confined Occasional Floodplain Pockets RS within confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic and riparian condition is then determined by total ticks and crosses for each stream: 3 ticks = good condition; One or two crosses = moderate condition, and 3 crosses = poor condition. (For the purposes of the preliminary condition assessment we only present the results from the fish-bearing stream network)

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of the Step Cascade River Style.	Headwaters of Tucannon, Panjab Cr., and Little Tucannon R.	Upper Tumalum and upper Cummings Cr.
Channel/Floodplain Attributes	**3 out of 4 questions must be answered YES For stream to be assessed in GOOD condition**		
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	Yes	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	Yes
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	Yes	Yes
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	Yes	Yes
		✓	✓
Channel Planform	**2 out of 3 questions must be answered YES**		
Number of Channels	Is the channel single thread as appropriate for this river style or multithreaded if appropriate? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes	Yes
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	Yes	Yes
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks? Is the width of the riparian corridor appropriate for this RS?	Yes	No
		✓	✓
Bed Character	**2 out of 3 questions must be answered YES**		
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	Yes
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	Yes	Yes
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes
		✓	✓
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Good**	**Good**

Table 12 - Criteria and measures used to assess geomorphic condition of variants of the Bedrock Controlled Discontinuous Floodplain (Anthropogenically Created) River Styles in partially-confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of the Bedrock Controlled Discontinuous FP (A).	Lower Tucannon Assessment Unit	Upper Tucannon Assessment Unit
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**		
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	No	No
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	No	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	No	No
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	Yes	Yes
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	No	No
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	No	No
		X	**X**
Channel Planform	**3 out of 4 questions must be answered YES**		
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	No	No
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	No	No
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	No	No
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	No	No
		X	**X**
Bed Character	**2 out of 3 questions must be answered YES**		
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	No	No
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	No	No
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	No	No
		X	**X**
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Poor**	**Poor**

Table 13 - Criteria and measures used to assess geomorphic condition of variants of the Fan/Terrace Controlled Discontinuous Floodplain River Styles in partially-confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of the Bedrock Controlled Discontinuous FP (A).	Upper Tucannon Assessment Unit: Tumalum and Cumming Cr.
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**	
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	Yes
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	No
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	Yes
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	Yes
		✓
Channel Planform	**4 out of 6 questions must be answered YES**	
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes
Lateral Stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	Yes
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	No
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	No
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	No
		X
Bed Character	**2 out of 3 questions must be answered YES**	
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	No
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	Yes
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	Yes
		✓
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Moderate**

Table 14 - Criteria and measures used to assess geomorphic condition of variants of the Low-Moderate Sinuosity Planform Controlled Discontinuous Floodplain River Styles in partially-confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of Low-Moderate Sinuosity Planform Controlled Discontinuous Floodplain River Styles	Upper Tucannon Assessment Unit: Mouth of Tumalum and Cumming Cr.	Pataha Assessment Unit (Upper Pataha and Hutchins Creek)
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**		
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	No	No
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	No	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	No	No
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	Yes	Yes
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	Yes	No
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	No	Yes
		X	**X**
Channel Planform	**4 out of 6 questions must be answered YES**		
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes	Yes
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes	No
Lateral Stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	No	No
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	No	No
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	No	No
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	No	No
		X	**X**
Bed Character	**2 out of 3 questions must be answered YES**		
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	Yes
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	No	No
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes
		✓	✓
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Moderate**	**Moderate**

Table 15 - Criteria and measures used to assess geomorphic condition of variants of the Low Sinuosity Planform Controlled Anabranching River Style in partially-confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of Low Sinuosity Planform Controlled Anabranching River Style	Upper Tucannon Assessment Unit: Upper mainstem Tucannon
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**	
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	Yes
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	Yes
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	Yes
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	Yes
		✓
Channel Planform	**4 out of 6 questions must be answered YES**	
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes
Lateral Stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	Yes
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	Yes
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	Yes
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	Yes
		✓
Bed Character	**2 out of 3 questions must be answered YES**	
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	Yes
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	Yes
		✓
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Good**

Table 16 - Criteria and measures used to assess geomorphic condition of variants of the Meandering Planform Controlled Discontinuous Floodplain River Style in partially-confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of Meandering Planform Controlled Discontinuous Floodplain River Style	Pataha Assessment Unit: Mid-mainstem Pataha Cr
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**	
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	Yes
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	Yes
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	No
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	No
		✓
Channel Planform	**4 out of 6 questions must be answered YES**	
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes
Lateral Stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	Yes
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	No
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	No
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	No
		X
Bed Character	**2 out of 3 questions must be answered YES**	
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	No
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	No
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	No
		X
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Moderate**

Table 17 - Criteria and measures used to assess geomorphic condition of variants of the Entrenched Low-Moderate Sinuosity Gravel/Sand Bed River Style in partially-confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of Entrenched Low-Moderate Sinuosity Gravel/Sand Bed	Pataha Assessment Unit: Mid-to lower mainstem Pataha Cr	Lower Tucannon Assessment Unit- Smith Hollow
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**		
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	No	No
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	No	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	No	No
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	No	No
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	No	No
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	No	No
Inset Floodplain Surfaces	If no historic floodplain connection are there existing or building inset floodplain surfaces?	Yes	Yes
		X	**X**
Channel Planform	**4 out of 6 questions must be answered YES**		
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes	Yes
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes	Yes
Lateral Stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	No	No
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	No	No
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	No	No
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	No	No
		X	**X**
Bed Character	**2 out of 3 questions must be answered YES**		
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	No	No
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	No	No
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	No	No
		X	**X**
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Poor**	**Poor**

Table 18 - Criteria and measures used to assess geomorphic condition of variants of the PC Low-Moderate Sinuosity Wandering Gravel/Cobble Bed River Style in partially-confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of the Low-Moderate Sinuosity Wandering Gravel/Cobble Bed	Lower Tucannon Assessment Unit: Lower Mainstem (DS of Pataha)	Upper Tucannon Assessment Unit: Middle Mainstem (US of Pataha)	Upper Tucannon Assessment Unit: Upper Mainstem (US of Cummings Cr.)
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**			
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	Yes	Yes	Yes
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	Yes	Yes	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	Yes	Yes
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	Yes	Yes	Yes
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	No	No	Yes
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	Yes	Yes	Yes
		✓	✓	✓
Channel Planform	**4 out of 6 questions must be answered YES**			
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	No	No	Yes
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes	Yes	Yes
Lateral Stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	Yes	Yes	Yes
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	No	No	No
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	No	No	Yes
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	No	No	No
		X	**X**	✓
Bed Character	**2 questions must be answered YES**			
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	Yes	Yes
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? Position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes	Yes
		✓	✓	✓
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Moderate**	**Moderate**	**Good**

Table 19 - Criteria and measures used to assess geomorphic condition of variants of the Alluvial Fan River Style- in laterally unconfined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	**Questions to be answered to assess geomorphic condition of each reach of the Alluvial Fan River Style**	**Upper Tucannon Assessment Unit: Mouth of Cold Creek**
Channel/Floodplain Attributes.	**2 questions must be answered YES For stream to be assessed in GOOD condition**	
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	Yes
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	Yes
		✓
Channel Planform	**4 out of 5 questions must be answered YES**	
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	Yes
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	Yes
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	Yes
		✓
Bed Character	**Questions must be answered YES**	
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes
		✓
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Good**

Table 20 - Criteria and measures used to assess geomorphic condition of variants of the Entrenched Low-Moderate Sinuosity Gravel/Sand Bed River Style in Laterally-Unconfined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	Questions to be answered to assess geomorphic condition of each reach of Entrenched Low-Moderate Sinuosity Gravel/Sand Bed	Pataha Assessment Unit: Lower to mid mainstem Pataha Cr
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**	
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	No
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	No
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	No
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	No
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	No
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	No
Inset Floodplain Surfaces	If no historic floodplain connection are there existing or building inset floodplain surfaces?	Yes
		X
Channel Planform	**4 out of 6 questions must be answered YES**	
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	Yes
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes
Lateral Stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	No
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	No
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	No
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	No
		X
Bed Character	**2 out of 3 questions must be answered YES**	
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	No
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber, and sinuosity?	No
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? position (i.e., is it a sediment transfer or accumulation zone?)?	No
		X
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Poor**

Table 21 - Criteria and measures used to assess geomorphic condition of variants of the Low-Moderate Sinuosity Wandering Gravel/Cobble Bed River Style in partially-confined valley settings. Note that cumulative responses to questions in each category (channel/floodplain attributes, planform, and bed character) result in a "X" or a "✓" for that category. Geomorphic condition is then determined by total ticks and crosses for each stream: 3 ticks = good geomorphic condition; One or two crosses = moderate geomorphic condition, and 3 crosses = poor geomorphic condition.

Degrees of Freedom and their relevant Geoindicators	**Questions to be answered to assess geomorphic condition of each reach of the Low-Moderate Sinuosity Wandering Gravel/Cobble Bed**	**Lower Tucannon Assessment Unit: Furthest DS Mainstem Tuc**	**Lower Tucannon Assessment Unit: Lower Mainstem DS Pataha)**	**Upper Tucannon Assessment Unit: Upper Mainstem (US of Pataha)**
Channel/Floodplain Attributes.	**4 out of 6 questions must be answered YES For stream to be assessed in GOOD condition**			
Size	Is channel size appropriate given the catchment area, the prevailing sediment and water regime, and the vegetation character?	No	Yes	Yes
Shape	Is the channel shape consistent with partially confined valley setting (typically symmetrical)?	No	Yes	Yes
Bank	Is the bank morphology consistent with caliber of sediment? Are banks eroding in the correct places?	Yes	Yes	Yes
Instream Vegetation Structure	Are the appropriate types and density of instream aquatic vegetation present?	Yes	Yes	Yes
Instream Wood Recruitment	Is the appropriate amount of woody debris in the channel or a historic potential for recruitment of woody debris?	No	Yes	No
Floodplain Connectivity	Is there a current connection to a laterally expansive or historic floodplain surface?	No	Yes	Yes
		X	✓	✓
Channel Planform	**4 out of 6 questions must be answered YES**			
Number of Channels	Are the appropriate number of channels present for this river style? Are there signs of change such as avulsions or overbank channels forming on the floodplain?	No	Yes	No
Sinuosity of Channels	Is the channel sinuosity consistent with the sediment load/transport regime and the slope of the channel?	Yes	Yes	Yes
Lateral Stability	Is the lateral stability consistent with the sediment texture and channel slope? Are there signs of degradation such as local widening and atypical in-channel reworking of bed material?	Yes	Yes	Yes
Geomorphic Unit Assemblage	Are the number, type and pattern of instream geomorphic units appropriate for the sediment regime, slope, bed material and valley setting? Are key units of this River Style present	No	Yes	No
Riparian Vegetation	Are the appropriate types, and density of riparian vegetation present on the banks?	NO	Yes	No
Riparian Veg. Corridor	Is the width of the riparian corridor appropriate for this RS?	No	No	No
		X	✓	**X**
Bed Character	**2 questions must be answered YES**			
Grain Size and Sorting	Is the range of sediment throughout the channel and floodplain organized and distributed appropriately?	Yes	Yes	Yes
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment? Position (i.e., is it a sediment transfer or accumulation zone?)?	Yes	Yes	Yes
		✓	✓	✓
Geomorphic Condition	Total ticks and crosses are added for each stream reach	**Moderate**	**Good**	**Moderate**

RIPARIAN VEGETATION CONDITION ASSESSMENT

Research Vignette

Wally MacFarlane, Jordan Gilbert, Joe Wheaton, Martha Jensen, Shane Hill, Chris Smith, and Josh Gilber

QUESTION / PROBLEM

Riparian zones in the Western US are particularly important elements of landscape heterogeneity, where they are often the dominant wetland elements in otherwise dry landscapes (Knopf et al. 1988), and support a disproportionately high level of bird and mammalian species diversity and abundance relative to the rest of the landscape (Johnson et al. 1977; Knopf 1985; Soderquist and MacNally 2000). In addition, interactions between intact native riparian vegetation, hydrologic disturbance regimes and channel substrates forms complex fish habitat (Kauffman et al. 1997). Nevertheless, numerous riparian zones throughout the Western U.S. are threatened or impaired by altered flow patterns, water withdrawals, and establishment of non-native plant species (Goodwin et al. 1997; Stromberg et al. 2007; Poff et al. 2011). This degradation is often expressed by a simplification in stream structure (e.g., loss of pools, decreased channel sinuosity, and loss of channel complexity) (Kauffman et al. 1997).

Given both the importance of riparian ecosystems and enormous spatial extent of riparian degradation, watershed-level assessments are critical, yet often not undertaken due to lack of appropriate assessment methodologies. As such, there is a desperate need to develop new methods to identify both areas in natural functioning condition that can be dedicated as conservation zones and areas with the potential for improvement as priority restoration zones (Wissmar and Beschta 1998; Poiani et al. 2000).

IDEA / HYPOTHESIS

The development of a systematic riparian vegetation condition assessment method is critical for watershed-level conservation and restoration planning (e.g., Harris and Olson 1997; Mollot et al. 2007). We believe that such a watershed-level riparian vegetation condition assessment approach can be developed by leveraging LANDFIRE data, a nationally available land cover classifications that is based on 30 m spatial resolution Landsat satellite imagery, to effectively approximate riparian vegetation condition at the reach scale.

METHODS

Riparian Vegetation Condition Assessment (RVCA)

RVCA uses LANDFIRE Existing Vegetation Type (EVT) and Biophysical Settings (BpS) data to estimate riparian vegetation change since Euro-American settlement at a reach level (200 – 500 m segments). The Biophysical Settings (BpS) layer represents the vegetation that may have been dominant on the landscape prior to Euro-American settlement and is based on both the current biophysical environment and an approximation of the historical disturbance regime. We used the BpS layer to represent the reference (pre-settlement) vegetation condition and the EVT layer was used to represent the current (2012) vegetation condition. The vegetation condition assessment was accomplished by coding native riparian vegetation as a 1 and non-native riparian and upland classes as a 0. In addition, within large rivers, the open water class was coded as NoData and outside of large rivers open water was coded as a 1. This coding was determined through test runs of the assessment that found that if all open water was classified as a 1 it skewed large river conditions to appear to be in better shape than they really are and if all open water was classified as NoData it skewed the smaller river riparian areas to appear to be in worse shape than they really are. The following equation was used to calculate a dimensionless ratio:

(mean EVT vegetation value)/(mean BpS vegetation value)

The lower the value (closer to 0) the more degraded the riparian vegetation condition was compared to the pre-settlement condition. Values larger than 1 showed areas that have increased in native riparian vegetation since settlement.

Riparian Conversion Assessment (RCA)

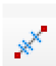
RCA is a supplement to the RVCA method and provides information to explain what might be causing degradation along the stream network. Like RVCA, RCA uses LANDFIRE EVT and BpS data. The BpS riparian vegetation was coded as 1 and all other vegetation types were coded as a 0. The EVT vegetation types were given codes from 1 to 17 using only odd numbers. Overlaying the two layers provided a new layer with values 1 to 18, where even numbers represented conversions related to historic riparian vegetation cover. Each segment of valley bottom was categorized based on the conversion type with the majority of riparian conversion related pixels within the segment. The output of this process displays the most prevalent cause of riparian conversion within each given segment. This output in combination with the results of the RVCA provide a more complete and explicative product for use in assessing riparian area condition.

Both of these processes have been automated and converted into an ArcGIS tool and are described in this vignette.

PREPROCESSING

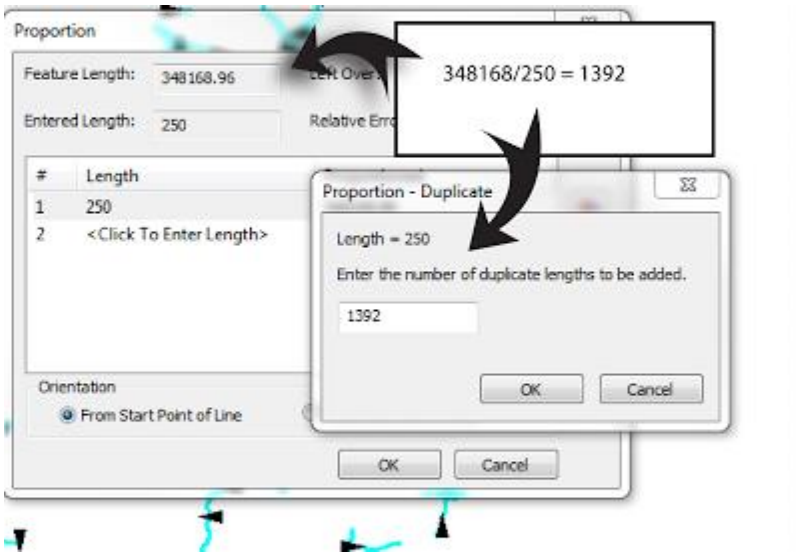
STREAM NETWORK

- Dissolve all segments of NHD perennial streams into one segment. Use the "Dissolve" tool. Do NOT use any Dissolve Field(s) and select (check) "Create multi-part features (optional)"
- Go to Customize - Toolbars - check COGO
- Start **Editing** the dissolved NHD line
- Right Click on the line. Go to Selection - Select All
- Click on the COGO proportion tool in the COGO toolbar



The COGO Proportion tool

- Enter your desired stream length in the length 1 box (i.e. 500 meters)
- Click on the DUPLICATE box on the right hand side of the Proportion tool
- Enter the amount of duplicates of stream length desired. You can obtain this number by dividing the Feature Length (in the proportion tool) by your desired stream length. Enter the number in the duplicate box and hit OK



- Choose FROM END POINT OF LINE, then OK. It may take a few minutes to segment your line
- Convert the multipart drainage network to a singlepart drainage network. Use the tool "Multipart to Singlepart"

VALLEY BOTTOM

A valley bottom polygon is also a required input to run the RVCA tool. Instructions on producing a valley bottom polygon can be found at https://sites.google.com/a/joewheaton.org/et-al/nhd-network-builder-and-vbet. The only required inputs are a digital elevation model (DEM) and stream network.

LARGE RIVER POLYGONS (OPTIONAL)

In areas with large rivers (i.e., Colorado Green, Snake, Columbia, etc.), the tool should be run with a large river polygon as an optional input. When downloading NHD data for a watershed of interest, a shapefile called "NHDArea" is included in the data. This is a polygon that generally delineates the medium to large rivers and can be easily clipped down to whatever rivers are being considered "large" for the analysis and used as the large river polygon.

ADDITIONAL DATA

LANDFIRE EVT and BPS layers should also be downloaded for the area of interest. See http://landfire.gov/ to download the data.

HOW THE RVCA TOOL WORKS

THIESSEN POLYGONS

The segmented network input is used to create point features, a midpoint for each individual segment. These points are then used to generate Thiessen polygons. The valley bottom input is buffered by 30 meters (to ensure that the 30 meter raster calls can be completely contained by the valley bottom in headwater reaches). The buffered valley bottom is then used to clip the Thiessen polygon layer. These Thiessen polygons become the area within which the RVCA Tool calculations will be summarized and applied to the stream network (Figure 1).

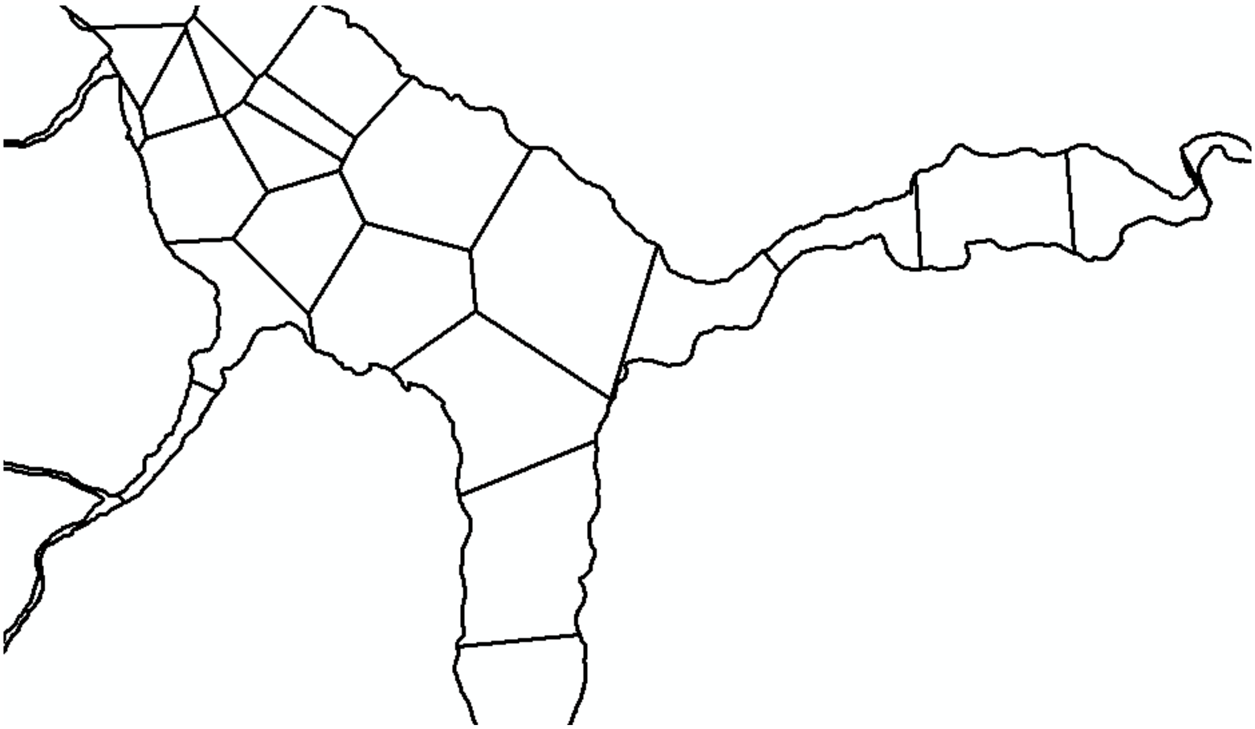


Figure 9 - Example Thiessen polygons clipped to a valley bottom.

LANDFIRE LANDCOVER CLASSIFICATION

After creating the Thiessen polygons, the tool classifies the LANDFIRE rasters. It does this by creating a "VEG_SCORE" field and coding LANDFIRE existing (2012) (US 130 EVT) vegetation and potential (pre-settlement) (US 130 BPS) vegetation based on native riparian (1), and all others (including introduced riparian vegetation) (0) (Figure 2).

Table 22 - Example vegetation score table

US120EVT_ER3.img

SYSTMGRPPH	SYSTMGRPNA	SAF_SRM	Veg_Score
Hardwood	Aspen Forest, Woodland, and Parkland	SAF 217: Aspen	1
Riparian	Western Riparian Woodland and Shrubland	SAF 235: Cottonwood-Willow	1
Riparian	Western Riparian Woodland and Shrubland	SRM 203: Riparian Woodland	1
Riparian	Western Riparian Woodland and Shrubland	SAF 235: Cottonwood-Willow	1
Riparian	Western Riparian Woodland and Shrubland	SRM 422: Riparian	1
Riparian	Western Riparian Woodland and Shrubland	LF 42: Great Plains Riparian	1
Riparian	Western Herbaceous Wetland	SRM 422: Riparian	1
Riparian	Western Riparian Woodland and Shrubland	SAF 235: Cottonwood-Willow	1
Riparian	Western Riparian Woodland and Shrubland	SRM 422: Riparian	1
Riparian	Western Riparian Woodland and Shrubland	LF 42: Great Plains Riparian	1
Riparian	Western Riparian Woodland and Shrubland	LF 42: Great Plains Riparian	1
Riparian	Western Riparian Woodland and Shrubland	SAF 235: Cottonwood-Willow	1
Riparian	Western Riparian Woodland and Shrubland	SRM 203: Riparian Woodland	1
Open Water	Open Water	Non-vegetated	8
Riparian	Depressional Wetland	SRM 601: Bluestem Prairie	1
Sparsely Vegetated	Sparse Vegetation	LF 33: Sparsely Vegetated	0
Sparsely Vegetated	Sparse Vegetation	LF 33: Sparsely Vegetated	0
Sparsely Vegetated	Sparse Vegetation	LF 33: Sparsely Vegetated	0
Hardwood	Bigtooth Maple Woodland	SRM 418: Bigtooth Maple	0

LANDFIRE OPEN WATER CLASSIFICATION FIXER

Within large rivers the open water class is coded as NoData and outside of large rivers open water is coded as a 1. This coding was determined through test runs of the RVCA that found that if all open water was classified as a 1 it skewed large river conditions to appear be in better shape than they really are and if all open water was classified as a NoData it skewed the smaller river conditions to appear to be in worse shape than they really are. This splitting of the open water coding was accomplished by generating a major rivers (Green, Colorado, San Juan, and Yampa rivers) polygon and using this polygon as a clipping extent for the EVT and BPS LANDFIRE data. The Open water classifications within these river areas are re-classified as NoData (Figure 3).

The large river is clipped from the LANDFIRE rasters using the large river polygon. The "VEG_SCORE" field for the portion clipped to the rivers extent is reclassified to a value of 8. This raster of the large river is then added, using map algebra, to the original LANDFIRE rasters, resulting in raster values of 0, 1, 8 and 9, where 8 and 9 are the cells that are within the large river. This raster is then recoded so that 8 and 9 are NoData while 0 and 1 remain the same (Figure 4).

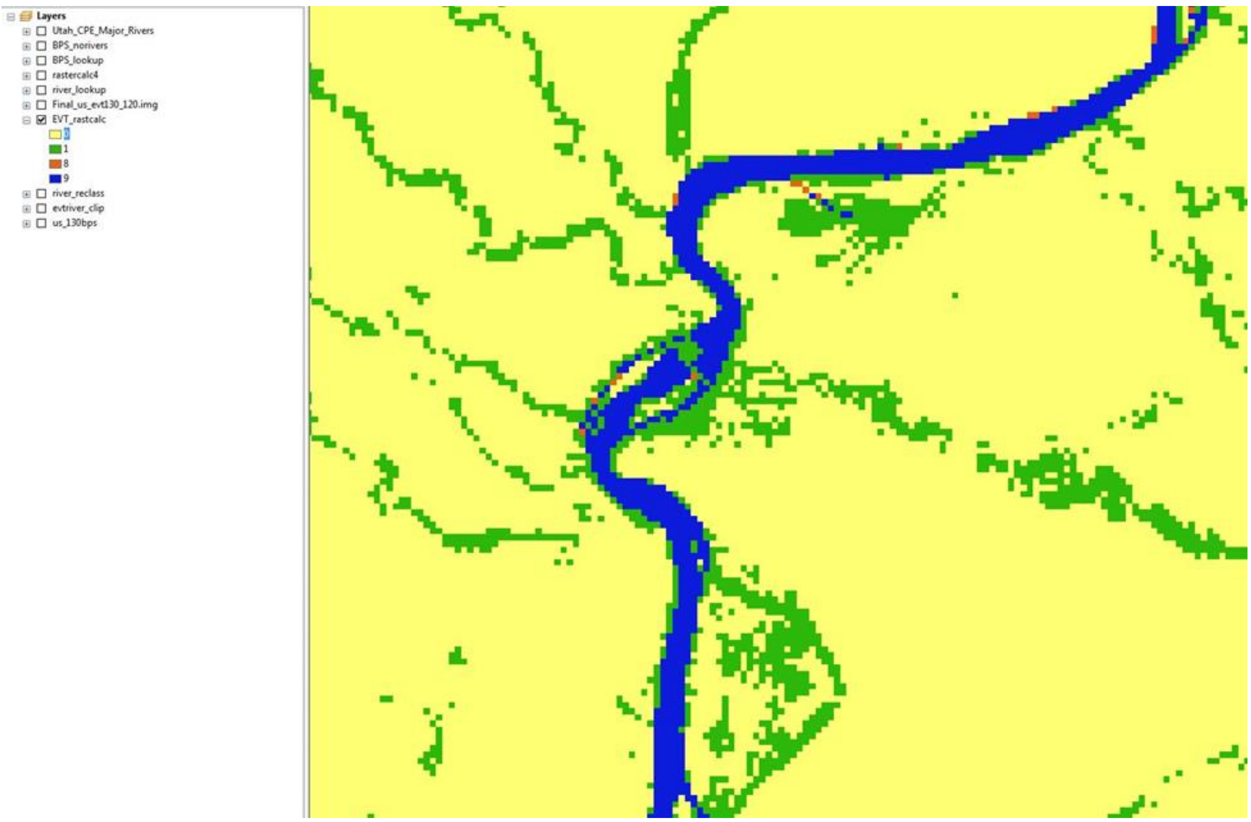


Figure 10 - LANDFIRE data showing open water.

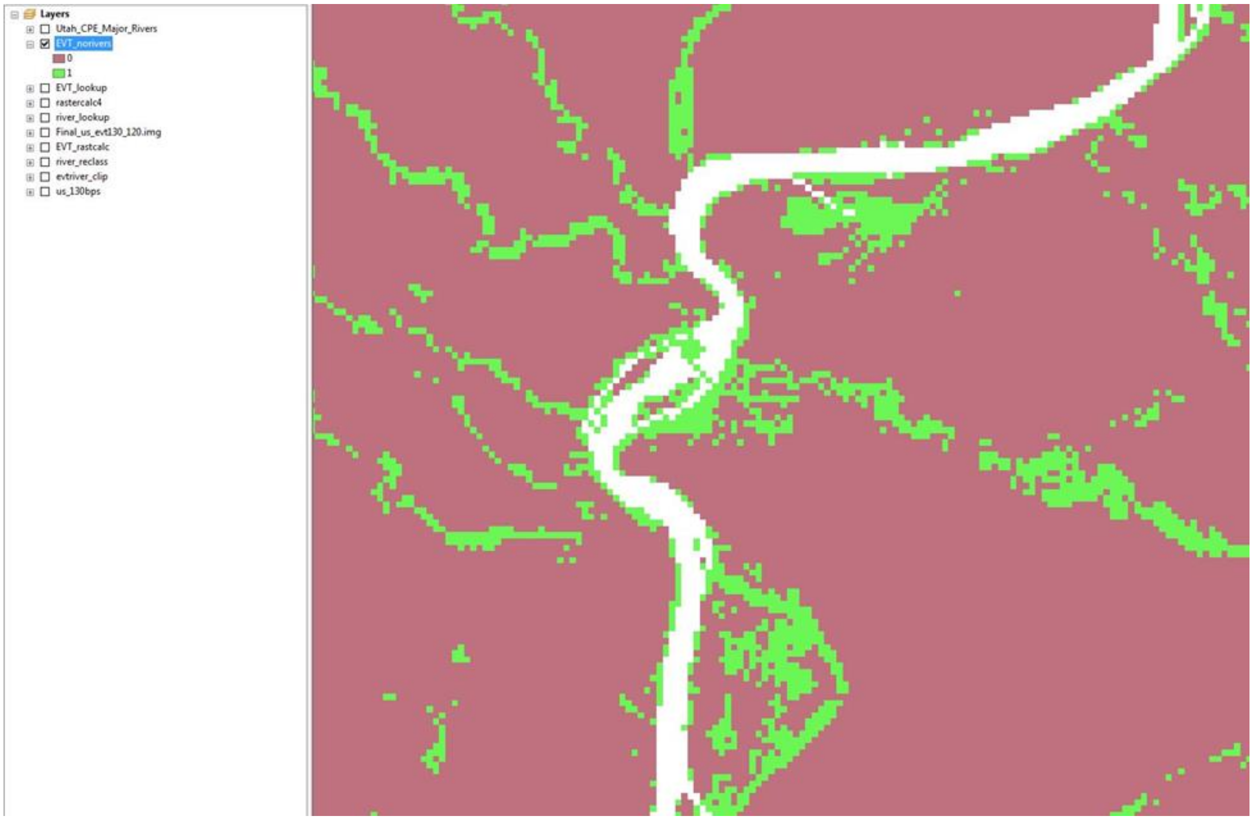


Figure 11 - LANDFIRE data open water recoded as nodata.

ZONAL STATISTICS

The RVCA tool then performs zonal statistics for both the reclassified EVT and BPS LANDFIRE layers. The Thiessen polygons are used as the boundaries, and the mean values are calculated for each raster within each of the Thiessen polygons. The result is two rasters:

1. the current mean riparian cover within each Thiessen polygon (mean EVT), and
2. the historic (potential) mean riparian cover within each Thiessen polygon (mean BPS).

TRANSFERRING RIPARIAN CLASSIFICATION TO THE STREAM NETWORK

These rasters must be converted to polygons in order to extract the values to the network, and in order to covert a raster to a polygon, it must be an integer raster. The zonal statistics rasters are each multiplied by 100 so that the values can be represented as integers, changed to integer rasters, and then converted to polygons. The segmented network is dissolved to be a single polyline, and then intersected with the polygons representing the mean existing and historic riparian cover values. This process segments the network at each Thiessen polygon boundary, and adds two new fields to the network: one it attains from the mean existing riparian cover polygons (mean EVT), and one which it attains from the mean historic riparian cover polygons (mean BPS). A new field called "COND_RATIO" is created and populated by dividing the mean EVT field by the mean BPS field. The result is a value between 0 and 1 representing the proportion of historic or potential riparian vegetation that is currently on the landscape. There are occasional values greater than one that represent a potential increase in riparian vegetation. Before these fields are divided, negative and zero values in the "BPS mean" field are changed to 0.0001 so that division by 0 or by a negative number does not occur.

RIPARIAN CONVERSION ASSESSMENT

LANDFIRE VEGETATION TYPE CODING

The EVT and BPS LANDFIRE rasters are again recoded based on vegetation type (Table 2 and 3).

Table 23 - BPS vegetation codes

BpS	Veg_Code
Riparian	1
All other Veg types	0

Table 24 - EVT vegetation codes.

EVT	Veg_Code
Riparian	1
Invasive Riparian	3
Invasive Upland	5
Conifers	7
Upland	9
Agriculture	11
Development	13
Sparsely Vegetated/Barren	15
Open Water	17

New rasters are generated from the “VEG_CODE” scores, and these two new rasters are added together using map algebra. By adding them together, the following table and figure illustrates how each new value is associated with a conversion type (Table 4 and Figure 4)

Table 25 - Conversion type table.

Conversion Type	Code
Non-Riparian to Riparian	1
Riparian (no change)	2
Non-Riparian to Introduced Riparian	3
Riparian to Introduced Riparian	4
Upland to Introduced Upland	5
Riparian to Introduced Upland	6
Conifer Woodland (no change)	7
Conifer Encroachment	8
Upland (no change)	9
Upland Encroachment	10
Upland Converted to Agriculture	11
Riparian Converted to Agriculture	12
Developed Upland	13
Developed Riparian Zone	14
Sparsely Vegetated (no change)	15
Riparian to Sparsely Vegetated	16
Open Water	17
Flooded	18

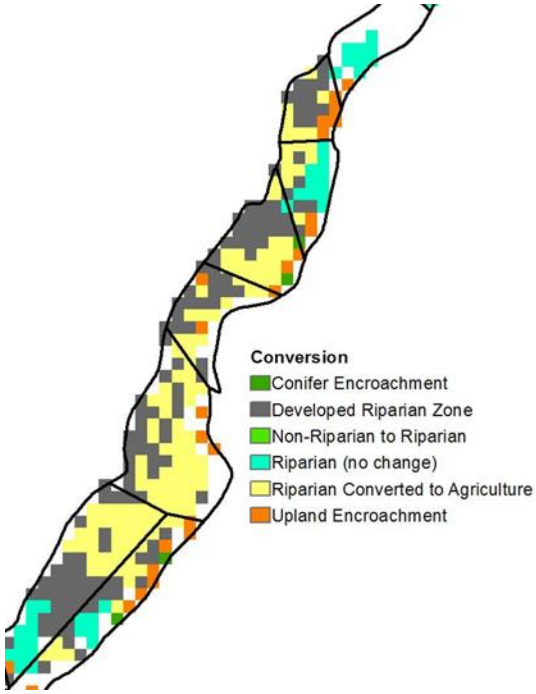


Figure 12- Conversion type by pixel value.

ZONAL STATISTICS

Zonal statistics are performed on this new conversion raster, but in this case the "MAJORITY" statistic is used to calculate which conversion type is most common within each of the Thiessen polygons.

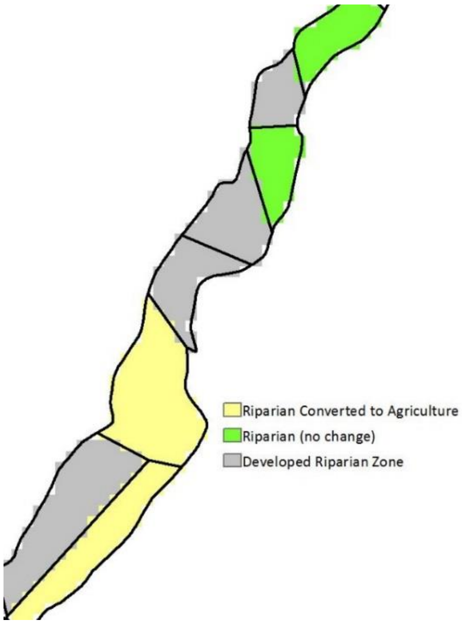


Figure 13 - Conversion type lumped by majority with each Thiessen polygon.

Using the same method as RCVA vegetation conversion information is extracted to the stream network, this conversion type raster is converted to a polygon and transferred to the stream network as a new attribute.

As stated before, this process has been automated using an ArcGIS tool (Figure 6). The inputs of the tool include:

1. a workspace,
2. a segmented stream network,
3. a valley bottom polygon,
4. the LANDFIRE EVT layer,
5. the LANDFIRE BPS layer, and
6. a large river polygon (optional).

The output is a stream network that includes attributes for both the riparian condition assessment values and the conversion type. The tool can currently be downloaded at https://bitbucket.org/jtgilbert/rvca.

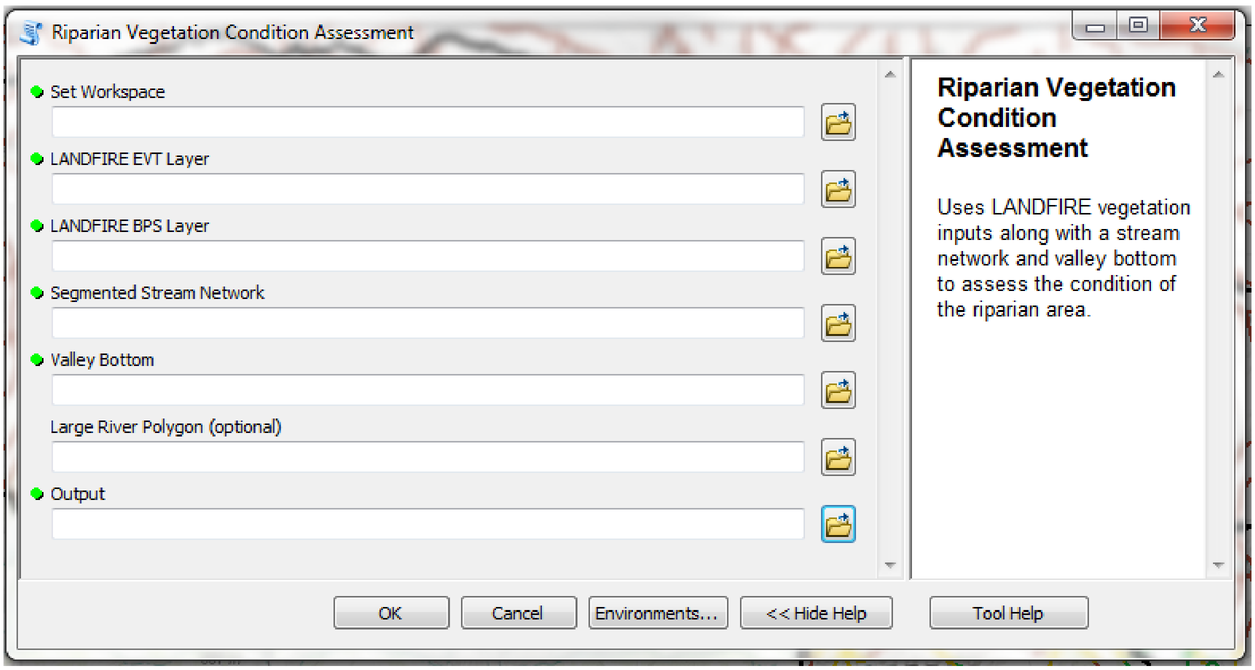


Figure 14 - Screen shot showing the Riparian Vegetation Condition Assessment Tool.

PRELIMINARY RESULTS

Figures 7 and 8 show preliminary outputs for the Weber River watershed in Northern Utah. The top figure shows the output for the riparian vegetation condition assessment, and the bottom figure shows the results of the conversion assessment.

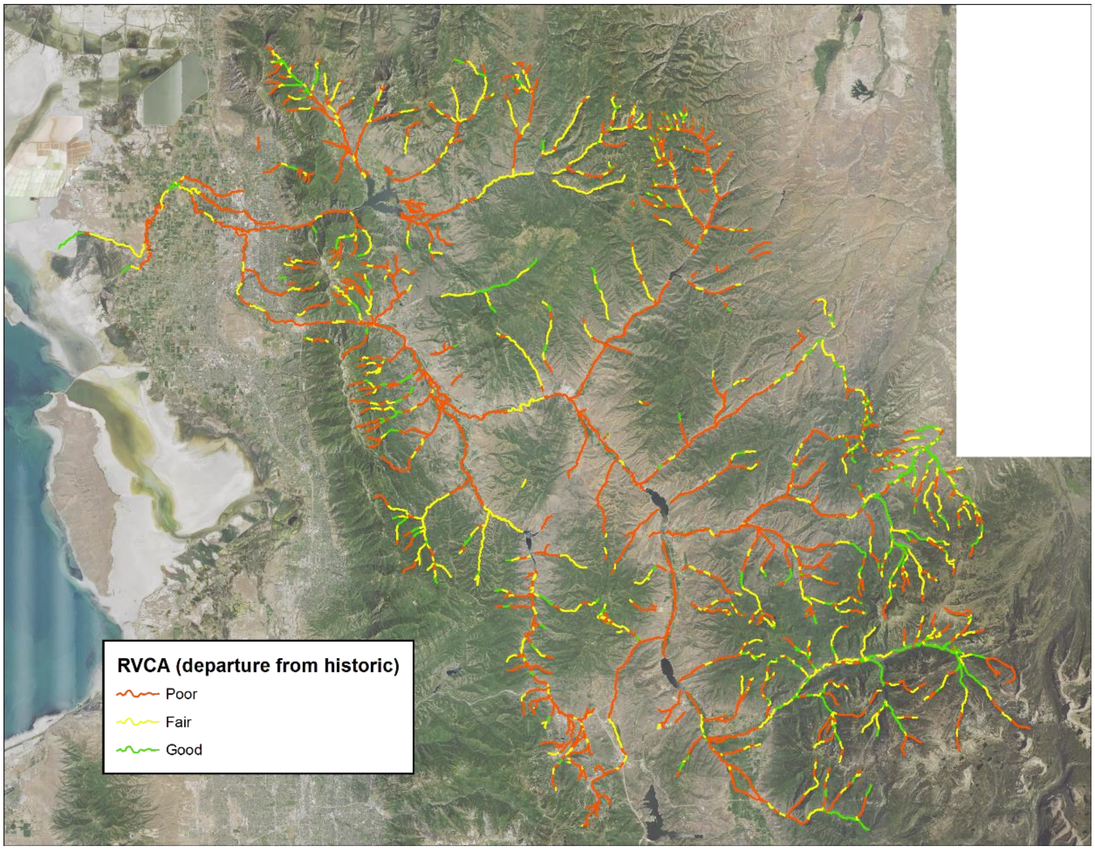


Figure 15 - Example Riparian Vegetation Condition Assessment tool output for the Weber River Watershed.

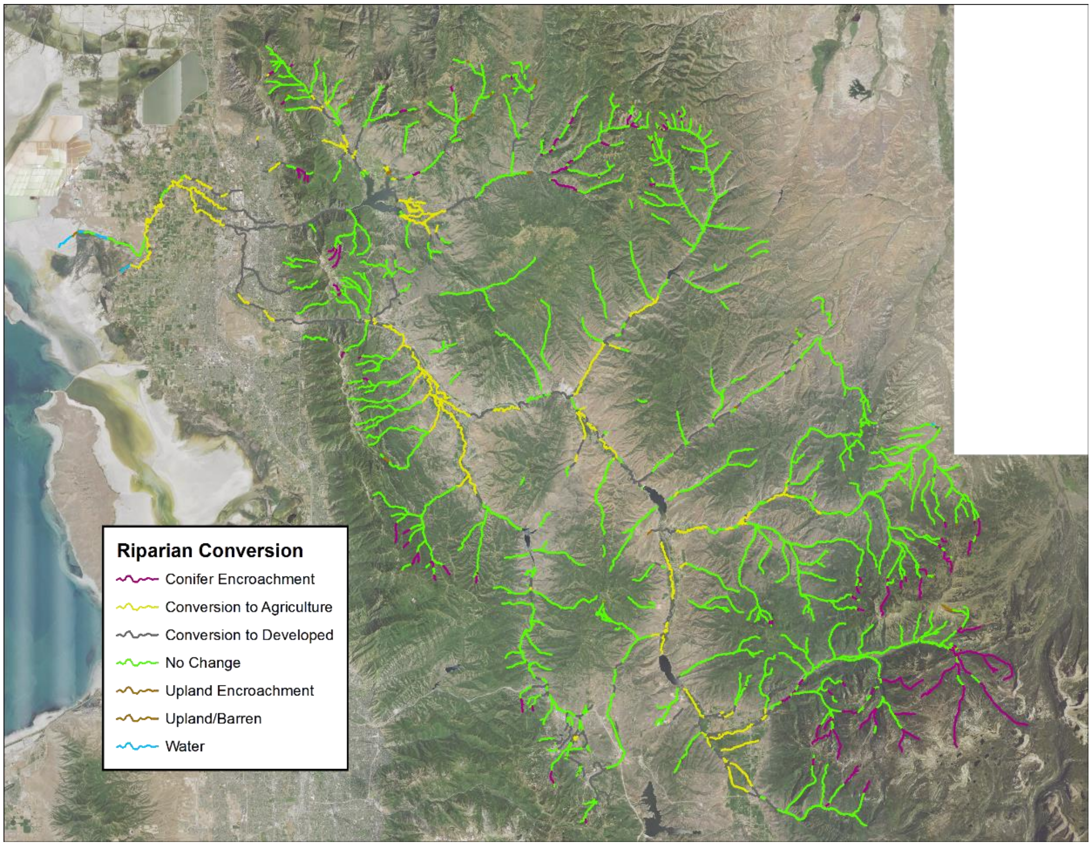


Figure 16 - Example output of the Riparian Conversion tool for the Weber River Waterhsed.

PRELIMINARY INTERPRETATIONS

We have run this method across the entire Colorado Plateau Ecoregion, the state of Utah and are in the early stages (Aug 2015) of testing the tool in the Columbia River Basin. Preliminary interpretations are that the method is appropriate for course evaluations of riparian vegetation conditions across large watersheds. However, in some instances LANDFIRE EVT data does not provide sufficient detail because the 30 m dataset lumps riparian vegetation into classes such as shrub cover, herbaceous cover, or cultivated crops and/or pasture.

FUTURE WORK & QUESTIONS

Further validation of LANDFIRE EVT data is needed. Re-coding of LANDFIRE EVT data in some riparian areas might be worth the effort. In the highest priority areas it might be worthwhile to collect new riparian vegetation data.

REFERENCES

Goodwin CN, Hawkins CP, Kershner JL (1997) Riparian restoration in the western United States: overview and perspective. Restor Ecol 5(Suppl s4):4-14

Harris R, Olson C (1997) Two-stage system for prioritizing riparian restoration at the stream reach and community scales. Restor Ecol 5(Suppl s4):34-42

Johnson RR, Haight LT, Simpson JM (1977) Endangered species vs endangered habitats: a concept. In Johnson RR, Jones DA (eds) Importance, preservation and management of riparian habitat: a symposium. USDA Forest Service General Technical Report RM-43, pp 68-79

Kauffman, J. B., R. L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries **22**:12-24.

Knopf FL (1985) Significance of riparian vegetation to breeding birds across an altitudinal cline. In Johnson RR, Ziebell CD, Patten DR, Folliot PF, Hamre RH (eds) Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120, pp 105-111

Knopf FL, Johnson RR, Rich T, Samson FB, Szaro RC (1988) Conservation of riparian ecosystems in the United States. Wilson Bull 100:272-284

Mollot LA, Munro D, Bilby R (2007) Classifying fine-scale spatial structure of riparian forests using hyperspectral high-resolution remotely sensed imagery at the Cedar River municipal watershed in western Washington, USA. Can J Remote Sens 33:99-108

Poff B, Koestner KA, Neary DG, Henderson V (2011) Threats to riparian ecosystems in western North America: an analysis of existing literature. 47:1241-1254

Poiani KA, Richter BD, Anderson MG, Richter HE (2000) Biodiversity conservation at multiple scales: functional sites, landscapes, and networks. BioSci 50:133-146

Soderquist TR, Mac Nally R (2000) The conservation value of mesic gullies in dry forest landscapes: mammal populations in the box-ironbark ecosystem of southern Australia. Biol Conserv 93:281-291

Stromberg JC, Lite SJ, Marler R, Paradzick C, Shafroth PB, Shorrock D, White JM, White MS (2007) Altered stream-flow regimes and invasive plant species: the *Tamarix* case. Glob Ecol Biogeogr 16:381-393

Wissmar RC, Beschta RL (1998) Restoration and management of riparian ecosystems: a catchment perspective. Freshw Biol 40:571-585

Woinarski JCZ, Brock C, Armstrong M, Hempel C, Cheal D, Brennan K (2000) Bird distribution in riparian vegetation in the extensive natural landscape of Australia's tropical savanna: a broad-scale survey and analysis of a distributional data base. J Biogeogr 27:843-868

FLOODPLAIN CONDITION ASSESSMENT

Research Vignette

Jordan Gilbert, Wally MacFarlane, Josh Gilbert

QUESTION / PROBLEM

The biological and geomorphic condition of streams and rivers is strongly influenced by riparian vegetation, transportation infrastructure (roads and railroads) and land use within the surrounding valley bottoms (Allan 2004). Land use intensity and location of transportation infrastructure within the valley bottom can decrease floodplain connectivity, and instream wood recruitment and retention thus degrading stream and floodplain condition (Blanton and Marcus 2013). The degree of valley confinement can also increase with transportation infrastructure thus decreasing the ability of river and streams to adjust. Nevertheless, methods that quantifies riparian vegetation condition, land use intensity and transportation infrastructure on floodplain condition are limited (However see Blanton and Marcus 2013). Further research and methods that explore and quantify these important potential forms of floodplain degradation are warranted.

IDEA / HYPOTHESIS

We believe that floodplain condition at the watershed-level can be effectively approximated using three nationally available datasets that include:

1. a riparian vegetation condition assessment, which has already been developed using LANDFIRE data,
2. a land use intensity raster which is derived using National Land Cover Dataset (NLCD) data, and
3. a floodplain connectivity layer derived using a valley bottom polygon and road/ railroad data.

Overall floodplain condition can be assessed by combining these three spatial datasets into a simple model where each input is equally weighted.

METHODS

One of the desired products of the expert panel process for the Columbia Basin, is a floodplain condition assessment. A similar assessment was performed for the Weber River watershed of Utah, however this assessment used land use GIS layers that are only available for the state of Utah. This vignette outlines a new method that uses nationally available datasets so that it is repeatable throughout the Columbia Basin and beyond.

The methodology for the floodplain condition assessment is mostly automated with an Arcpy script, but does include some manual geoprocessing. The manual processing will be covered first, followed by a description of the automated process.

MANUAL GEOPROCESSING

To derive the floodplain connectivity layer, some manual geoprocessing is required beforehand. First, a valley bottom polygon is required for the analysis. Instructions on creating and finalizing a valley bottom polygon can be found at https://sites.google.com/a/joewheaton.org/et-al/nhd-network-builder-and-vbet. In addition, the most comprehensive transportation (road and railroad) layers should be obtained.

- All relevant transportation layers should be merged to form a single layer that includes all of the unique features.
- Begin editing the valley bottom polygon.
- Right click on the finalized transportation layer. Hover over “Selection” and click “Select All.”
- On the “Editor’ toolbar click on the “Editor” button, navigate to “More Editing Tools” and click on “Advanced Editing.”
- On the Advanced Editing toolbar, click on the “Split Polygons” tool, and select the valley bottom as the target feature (leave default cluster tolerance). The valley bottom will be split by the transportation network.

At this point, manual editing is required to produce the floodplain connectivity layer. The valley bottom has been split using the transportation layer into separate polygons. To differentiate between the polygons within the valley bottom where connectivity exists with the stream network and areas that have been fragmented by roads, or railroads a “select by location” analysis is used to select the portions of the valley bottom that intersect the stream network. Those that intersect are considered connected and those that do not are considered disconnected. Because of this, it is necessary to manually go through the new split valley bottom polygon and draw additional lines to ensure that portions that should be disconnected from the network are disconnected (Figure 1).

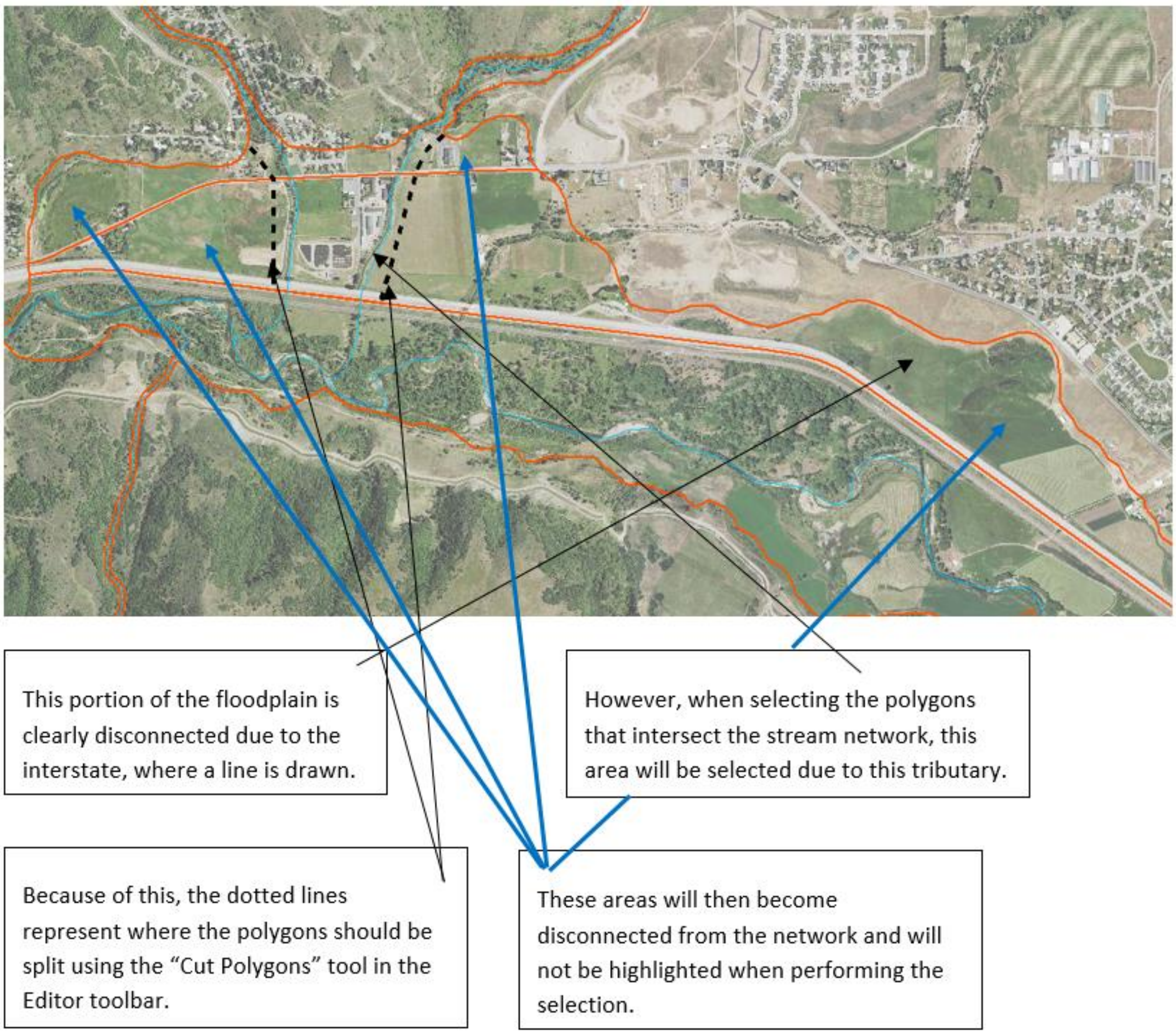


Figure 1 – Manual floodplain connectivity geoprocessing explanation.

- When this manual editing is complete, add a field to the split valley bottom layer. Call it “Connected,” and for the type choose SHORT INTEGER.
- Make sure you are editing the split valley bottom, and perform a “Select By Location.” For the target layer select the split up valley bottom that was just edited. For the source layer select the stream network. For the spatial selection method choose “intersect the source layer feature.” Hit apply and the selection will be made.
- Open the attribute table of the layer, and click on the bottom to show only the selected features. In the new “Connected” field modify it so that all highlighted features have the value of 1 (Table 1; Figure 2).

Table 26 Connectivity coding.

Table

Tucannon_FP_connectivity

FID	Shape *	Id	Connected
4	Polygon	0	1
5	Polygon	0	1
8	Polygon	0	1
9	Polygon	0	1
13	Polygon	0	1
15	Polygon	0	1
16	Polygon	0	1
17	Polygon	0	1
19	Polygon	0	1
20	Polygon	0	1

- The remaining features that are not part of the selection should be left with a value of 0.
- Examine the network and determine if there are any polygons that need to be manually changed between from 1 and 0.
- Save the edits and stop editing.

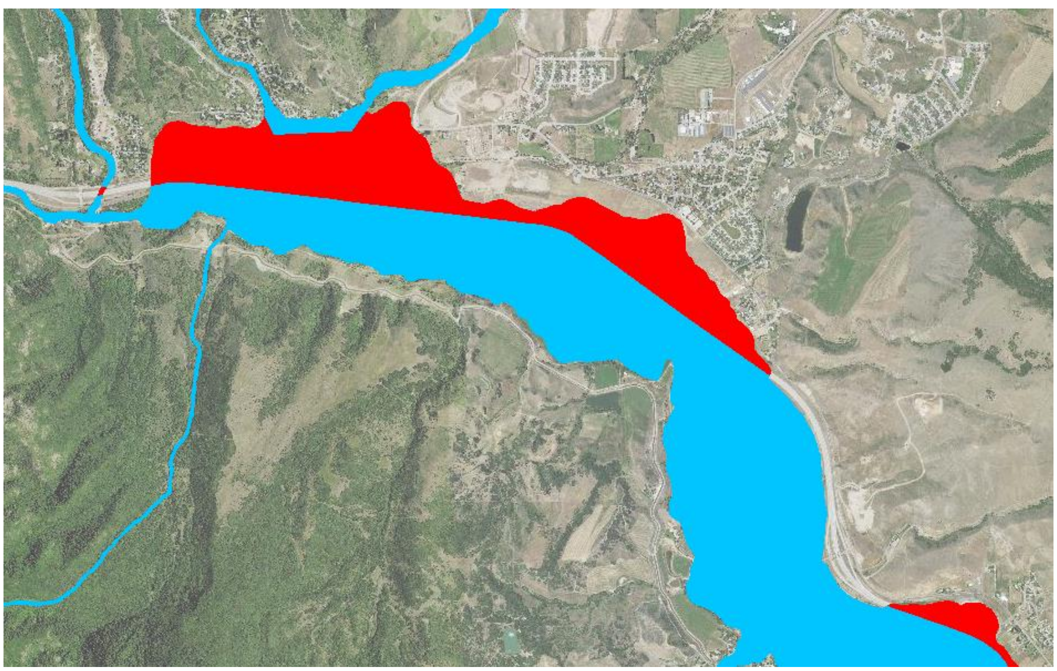


Figure 2 – Edited floodplain connectivity vector where blues are connected and reds are disconnected portions of the floodplain.

Use the “Polygon to Raster” tool to convert the final polygon to a raster. Change the value field to the “Connectivity” field, and the cell size to 30. Leave the rest of the default settings. This floodplain connectivity raster will be used as an input for the automated process of determining floodplain condition.

AUTOMATED GEOPROCESSING

An arcpy script was developed and requires six inputs:

1. a segmented stream network,
2. a valley bottom polygon,
3. a LANDFIRE EVT layer,
4. a LANDFIRE BPS layer,
5. NLCD raster layer, and
6. A manually created floodplain connectivity raster.

The script then performs the following tasks:

CREATION OF THIESSEN POLYGONS

The segmented stream network input is used to create point features, a midpoint for each individual segment. These points are then used to generate Thiessen polygons. The valley bottom input is buffered by 30 meters (to ensure that the 30 meter raster cells can be completely contained by the valley bottom in headwater reaches). The buffered valley bottom is then used to clip the Thiessen polygon layer. These Thiessen polygons become the area within which various raster calculations will be summarized and applied to the stream network (Figure 3).

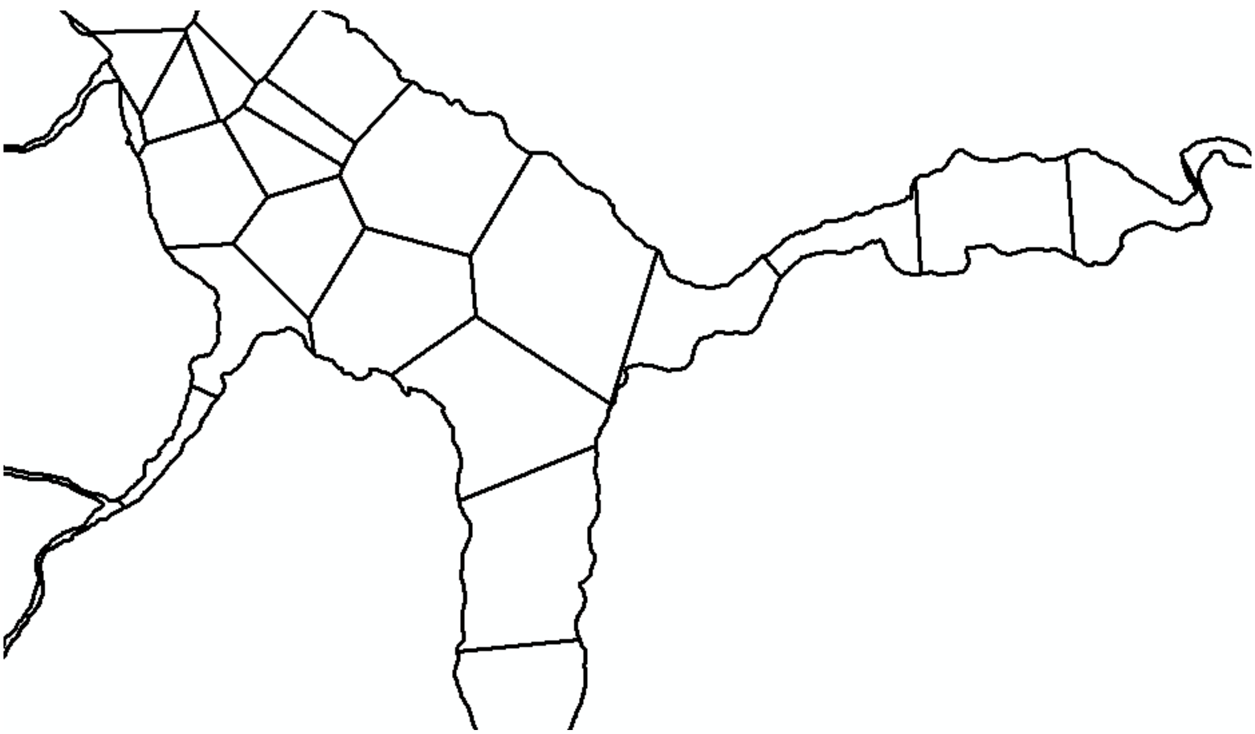


Figure 3 – Example of Thiessen polygons clipped to a valley bottom.

RIPARIAN VEGETATION CONDITION

A more in depth description of riparian vegetation condition is found in the riparian vegetation condition assessment (RVCA) vignette, specific to the RVCA ArcGIS tool. In brief, the process uses two LANDFIRE rasters: the existing vegetation type (EVT) and the Biophysical Settings (BPS) (likely pre-settlement vegetation types). The rasters are recoded so that cells representing native, riparian vegetation receive a score of 1 and all other cells receive a score of 0. Zonal statistics are calculated on these rasters using the "MEAN" function and the Thiessen polygon layer as the bounding feature, creating two layers: a mean EVT layer and a mean BPS layer. A new raster is created by dividing mean BPS layer into the mean EVT layer. This assigns each Thiessen polygon a value between 0 and 1 representing the proportion of the likely historic riparian vegetation cover that exists on the landscape today. In rare cases a value greater than 1 occurs, meaning that riparian vegetation cover has theoretically increased since pre-settlement times.

LAND USE INTENSITY

A new field for land use intensity is added to the NLCD raster input. This field is populated using data from the "Value" field that already exists in the NLCD layer, which describes the type of land cover dominant within each cell of the raster. The land use intensity is classified from 0 to 4 based on the "Value" field (Table 1).

Table 2 – Land use intensity coding values.

Land Cover	LUI Value
Open Water	0
Perennial Ice/Snow	0
Developed, Open Space	3
Developed, Low Intensity	4
Developed, Medium Intensity	4
Developed, High Intensity	4
Barren Land	2
Deciduous Forest	1
Evergreen Forest	1
Mixed Forest	1
Shrub/Scrub	0
Grassland/Herbaceous	2
Pasture/Hay	3
Cultivated Crops	3
Woody Wetlands	0
Emergent Herbaceous Wetlands	0

A lookup raster is then created from this land use intensity field, and mean zonal statistics are calculated on this raster using the Thiessen polygon layer as the bounding feature. The output is a raster, clipped to the extent of the valley bottom that represents a continuum from 0 to 4 of land use intensity values (see Figures 4, 5 & 6).

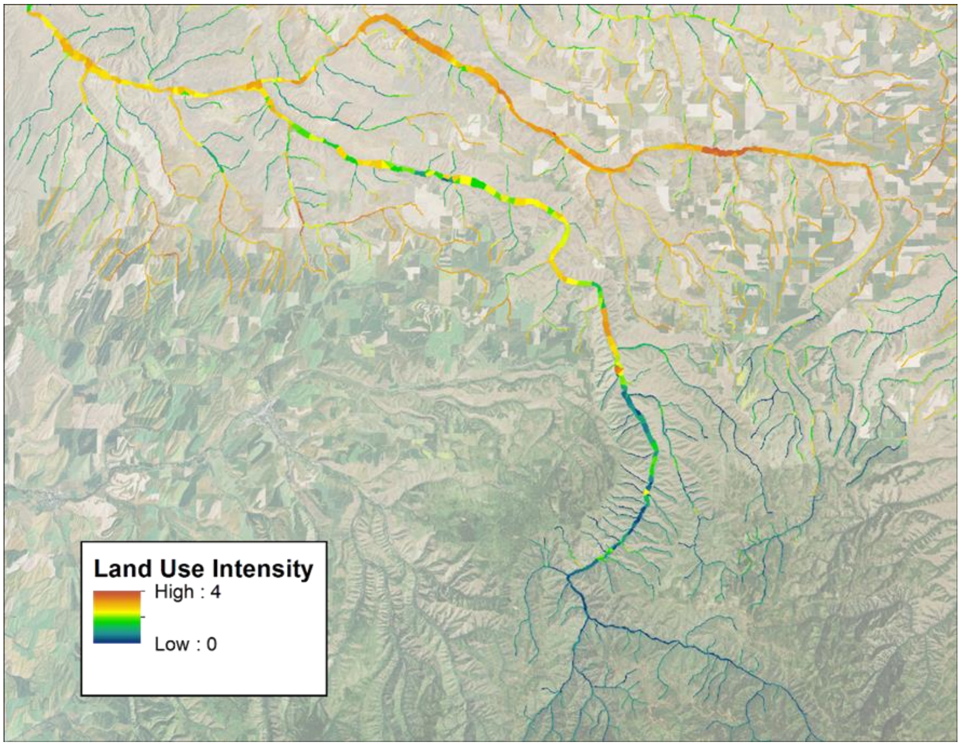


Figure 4 – Land Use Intensity raster for the Tucannon River watershed

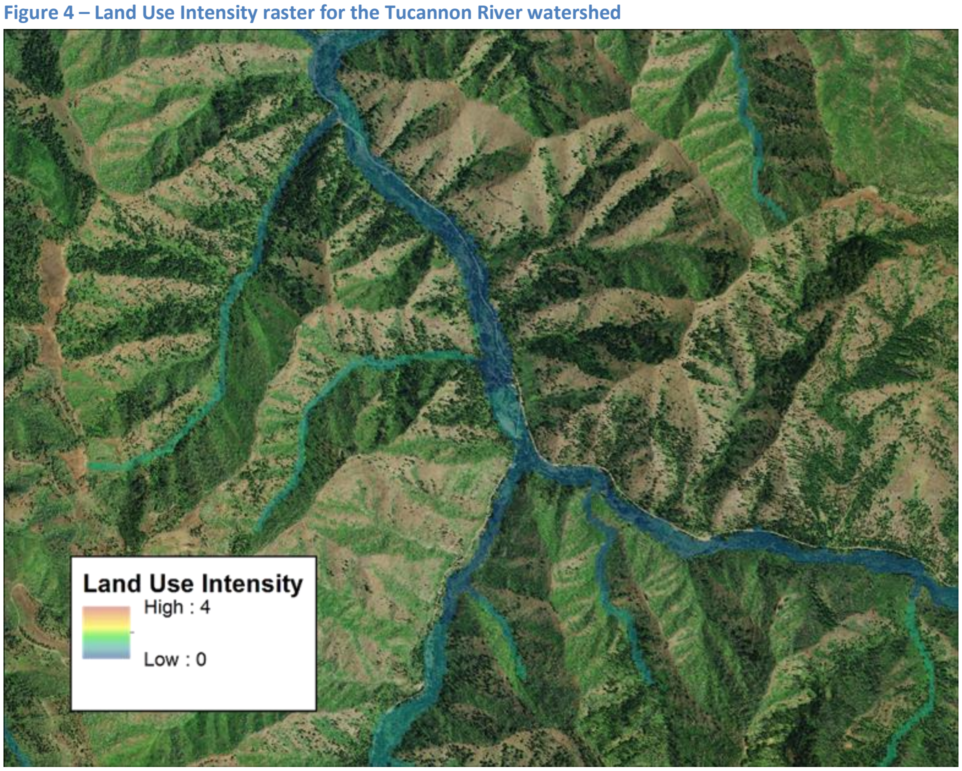


Figure 5 – Example of area of low land use intensity in the Tucannon River watershed

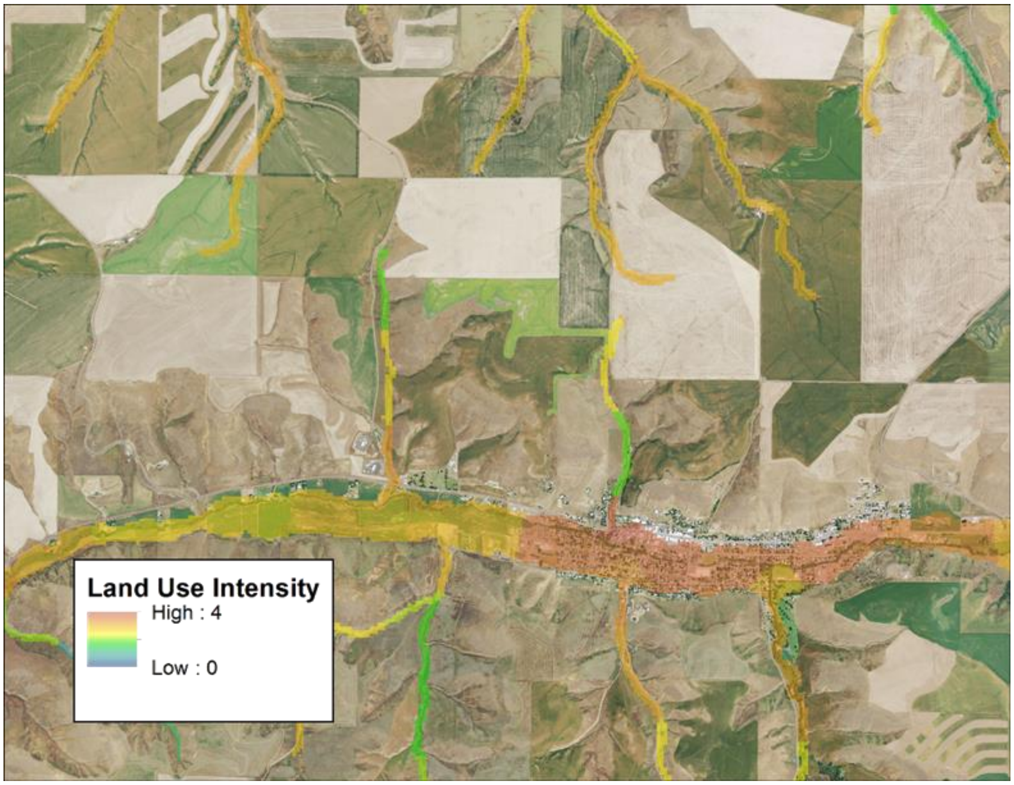


Figure 6 – Example of area of high land use intensity in the Tucannon River watershed

FLOODPLAIN CONNECTIVITY

The manually derived input for the floodplain condition analysis is a 30 meter raster where areas of the floodplain that are connected to the stream channel have a value of 1 and those that are not have a value of 0. The script performs zonal statistics on this raster, again using the Thiessen polygons as the bounding features, and using the "MEAN" function. The result is a raster where the area within each Thiessen polygon has a value between 0 and 1 that represents the proportion of that area that is connected to the stream network.

FINAL OUTPUT

Each of the three rasters (riparian vegetation condition, land use intensity, and floodplain connectivity) are then normalized to a range of values from 0 to 10, which creates three equally weighted inputs for the final floodplain condition output. The three rasters are then added together and divided by three, creating a condition raster with values from 0 (poor condition) to 10 (intact condition). This raster is converted to a polygon and intersected with a dissolved stream network to create a polyline output that is divided into reaches, with each reach being attributed with a floodplain condition score.

PRELIMINARY RESULTS

Figure 7 shows the output of the floodplain condition assessment after completing the manual and automated geoprocessing steps. In this example, the output is binned into 5 categories by the natural breaks in the data. The output values range from 0 to 10 and are relative to the input data, so 10 represents the portions of the floodplain that are in the best condition within the watershed, and 0 represents the portions that are in the worst condition. Figures 8 and 9 show the output in portions of the watershed in poor and good condition respectively.

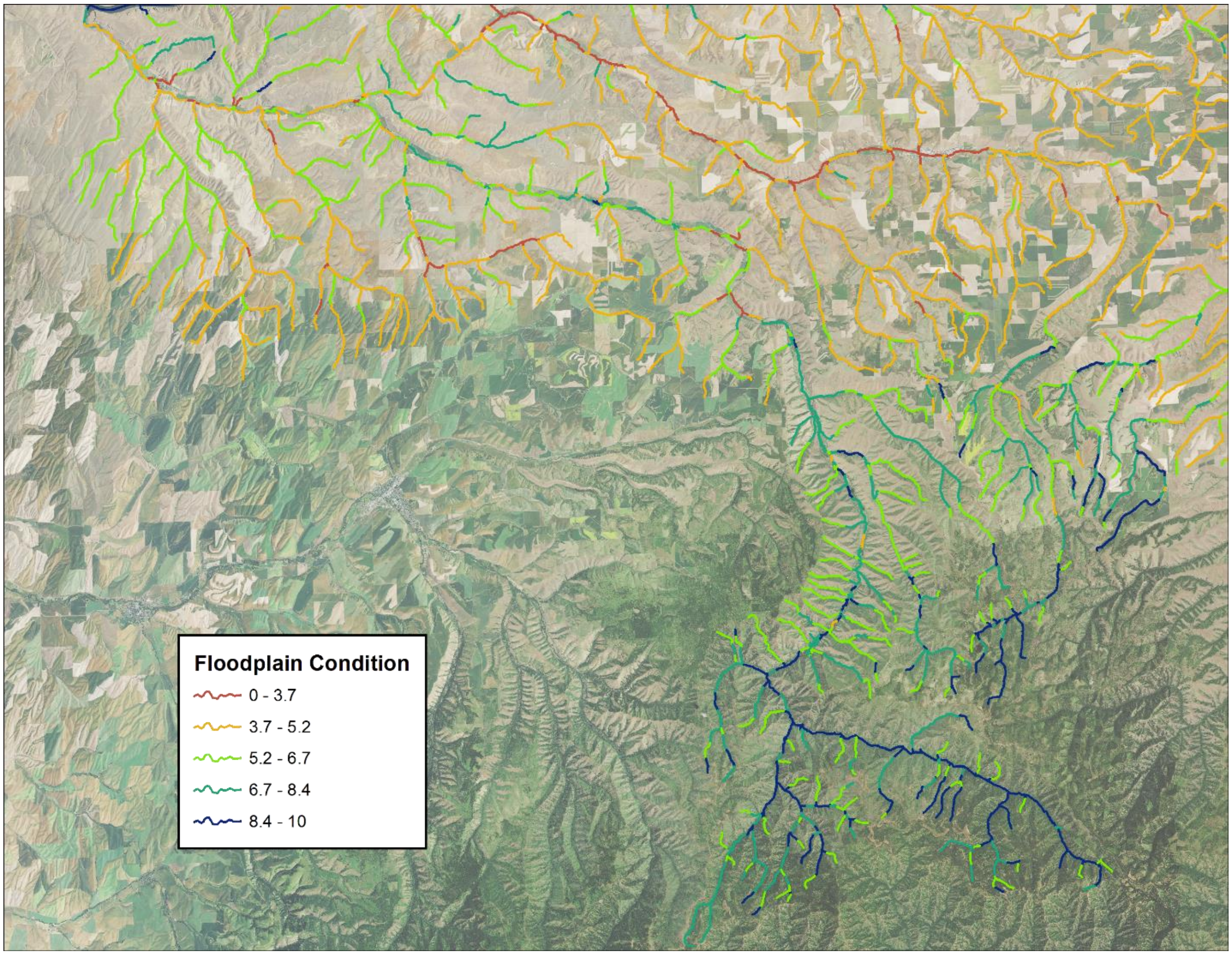


Figure 7 – Final output for floodplain condition for the Tucannon River watershed

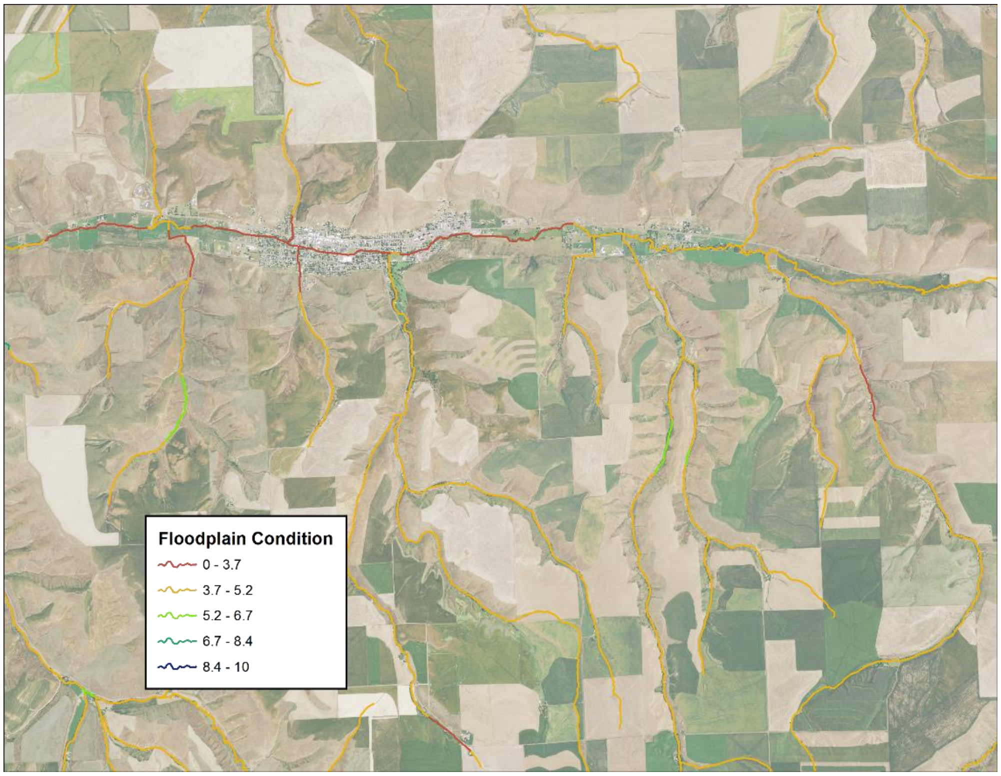


Figure 8 – Area of poor floodplain condition in the Tucannon River watershed

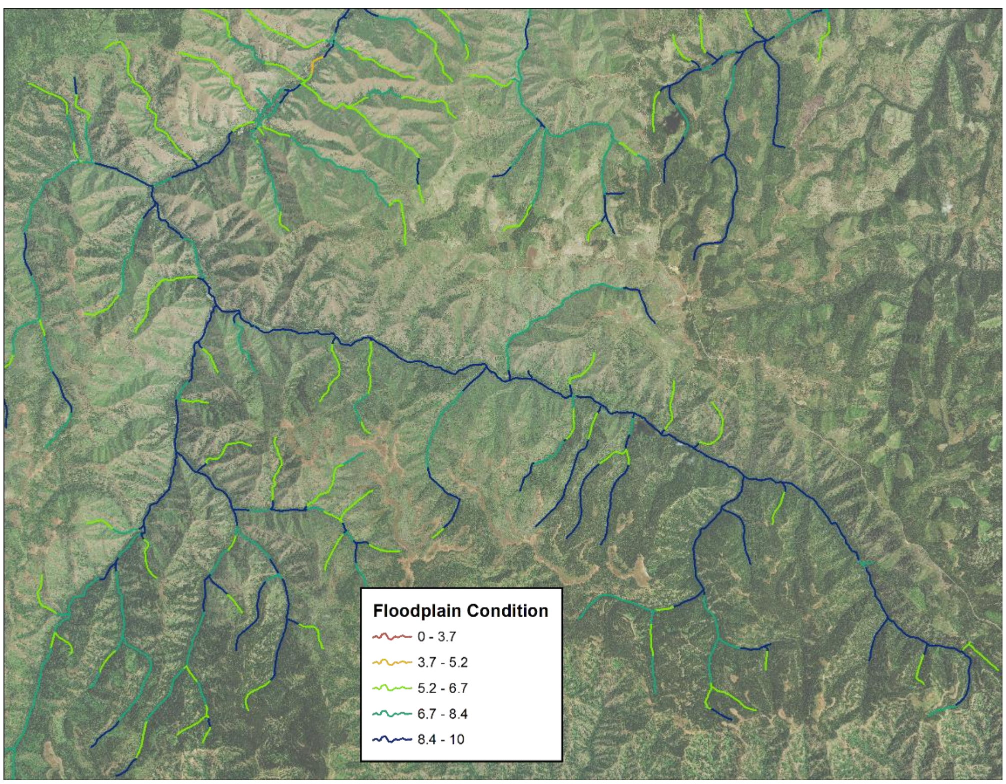


Figure 9 - Area of good floodplain condition in the Tucannon River watershed

PRELIMINARY INTERPRETATIONS

The results of the floodplain condition assessment using this methodology appear coherent and meaningful. Using the NLCD to derive land use intensity provided satisfactory results, however a more accurate assessment may be possible where better data is available. For example, the "Water Related Land Use" layer from which land use intensity was derived for the state of Utah is highly spatially accurate and contains information that NLCD does not for determining the land use intensity. Where possible, it seems worthwhile to rerun this process with the best available data and compare the results.

FUTURE WORK & QUESTIONS

More field based validation is warranted to assess the accuracy of this floodplain condition assessment tool.

REFERENCES

Allan, J. D. 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. Annual review of ecology, evolution, and systematics:257-284.

Blanton, P. and W. A. Marcus. 2013. Transportation infrastructure, river confinement, and impacts on floodplain and channel habitat, Yakima and Chehalis rivers, Washington, USA. Geomorphology **189**:55-65.

INSTREAM WOOD RECRUITMENT MODEL

Research Vignette

Jordan Gilbert, Wally MacFarlane, and Josh Gilbert

QUESTION / PROBLEM

Instream wood provides critical habitat and cover for salmonids. Nevertheless, dependable and inexpensive watershed-scale models that estimate instream wood recruitment potential at the reach scale are lacking.

IDEA / HYPOTHESIS

Riparian and adjacent upland vegetation height, density, and distance to the stream channel are key elements of instream wood recruitment potential. Shallow landslide potential, disturbance severity (e.g. wildfire, beetle kill, etc.) and channel position (e.g., outside vs. inside bends) influences instream wood recruitment intensity. We believe that each of these key inputs can be effectively approximated using nationally available, remotely sensed data and that the probability (0-1) of instream wood recruitment at the reach level can be estimated using Fuzzy Inference Systems (FISs).

METHODS

Remotely sensed nationally available input data:

- LANDFIRE Existing Vegetation Cover (EVC) data (LANDFIRE 2015a) was used to estimate *percent vegetative cover.*
- LANDFIRE Existing Vegetation Height (EVH) data (LANDFIRE 2015b) was used to estimate *vegetation height*.
- A 10 m Euclidian distance geoprocessing algorithm with National Hydrography Data (NHD) perennial flowlines as the input was used to assess *distance of woody vegetation to the stream channel*.
- A Topographic Index, which accounts for both local slope geometry and the site location on the landscape, was used to estimate *shallow landslide potential.*
- LANDFIRE Vegetation Disturbance (VDIST) data (LANDFIRE 2015c) was used to estimate *disturbance severity.*
- The *Stream channel* was estimated using a regional curve based estimate of bankfull width (Beechie and Imaki 2014)
- In the near future, a binary raster where in-channel cells are 1 and out-of-channel cells are 0 will be used to calculate *outside and inside meander bends of stream channel* (Van De Wiel et al. 2007).

Preprocessing:

EVC, EVH, and VDIST layers were downloaded from the LANDFIRE website in UTM projection.

A python script was developed in-house to accomplish the following preprocessing tasks:

Vegetation Height: A field was added to the LANDFIRE vegetation height (EVH) raster, and the median value of the height bins was assigned to this field (only the heights of forest and shrubs was entered, the remaining non-woody vegetation types were given values of 0). A new raster was then creating by generating a "lookup" table of the newly created field. This created a 30 m raster of vegetation height. This 30 m raster was then resampled to a 10 m, and a low pass filter (3x3 moving window) was applied to the raster to average the height values across the newly created 10 m raster. This process created a more continuous surface representing vegetation height. A 10 m Euclidean distance raster was then derived, where the surface represents distance (in m) from the bankfull channel. The Euclidean distance raster was subtracted from the vegetation height raster, creating a new raster in which the values represent the distance that fallen vegetation could protrude into the channel (Figure 1). Values of 0 or less mean that the vegetation is not tall enough to reach the channel, and that consequently there is no potential for recruitment.

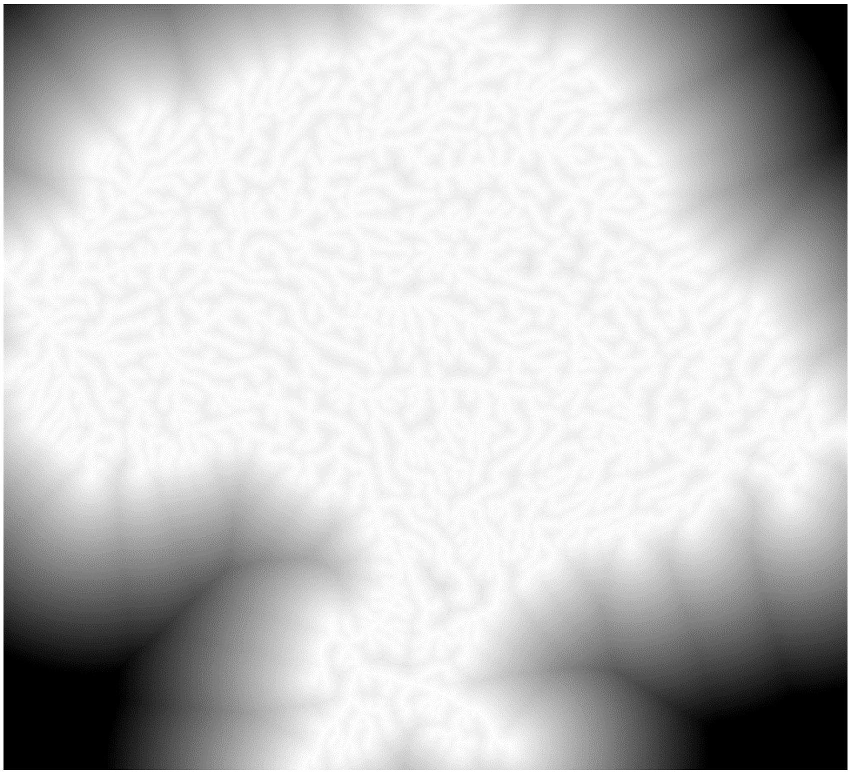


Figure 17 – Raster showing distance of woody vegetation to the stream channel. Lighter values are closer to the stream and darker values are farther away.

Vegetation Cover: A field was added to the LANDFIRE EVC raster, and the median value of the percent cover bins were assigned to the new field (again only percent cover for tree and shrubs are entered into this field, with the remaining rows of non-woody vegetation being set to 0). A 30 m percent cover raster was creating by generating a "lookup" table of the EVC raster based on the newly created field. This raster was resampled to 10 m, and a low pass filter (3x3 moving window) was applied to average the percent cover values across the 10 m raster (Figure 2).

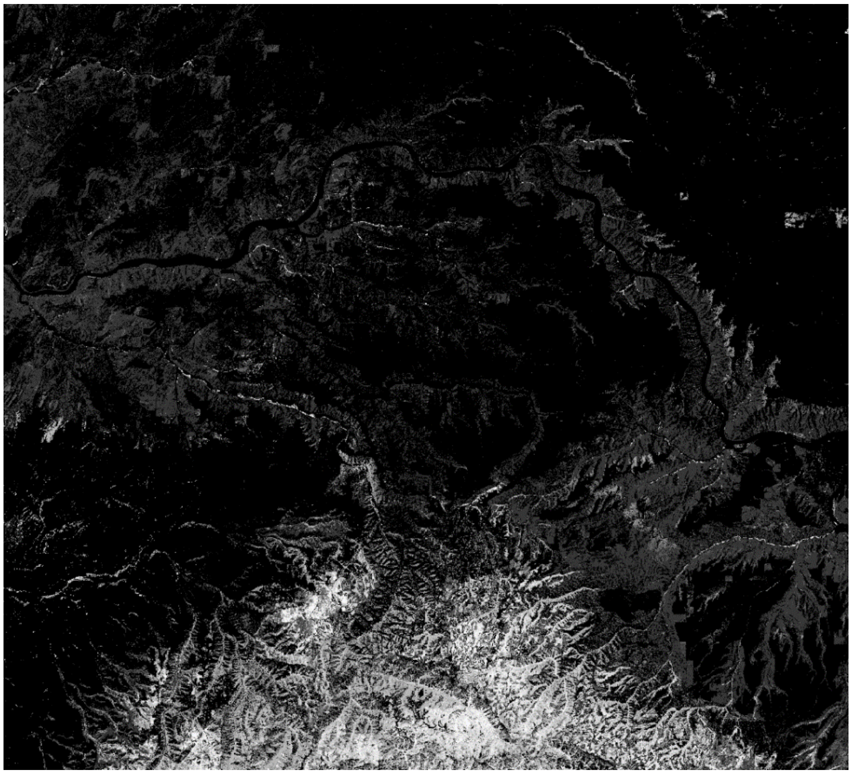


Figure 18 – 10 m percent vegetation cover raster. Lighter values represent denser vegetation cover, and darker values more sparse.

Vegetation Disturbance: A field was added and values between 0 and 3 assigned representing the disturbance severity based on other attributes in the LANDFIRE data. A lookup was performed to generate a raster representing this disturbance severity (Figure 3). The lookup raster was then resampled to 10 m to maintain orthogonality with the other LANDFIRE derived rasters.

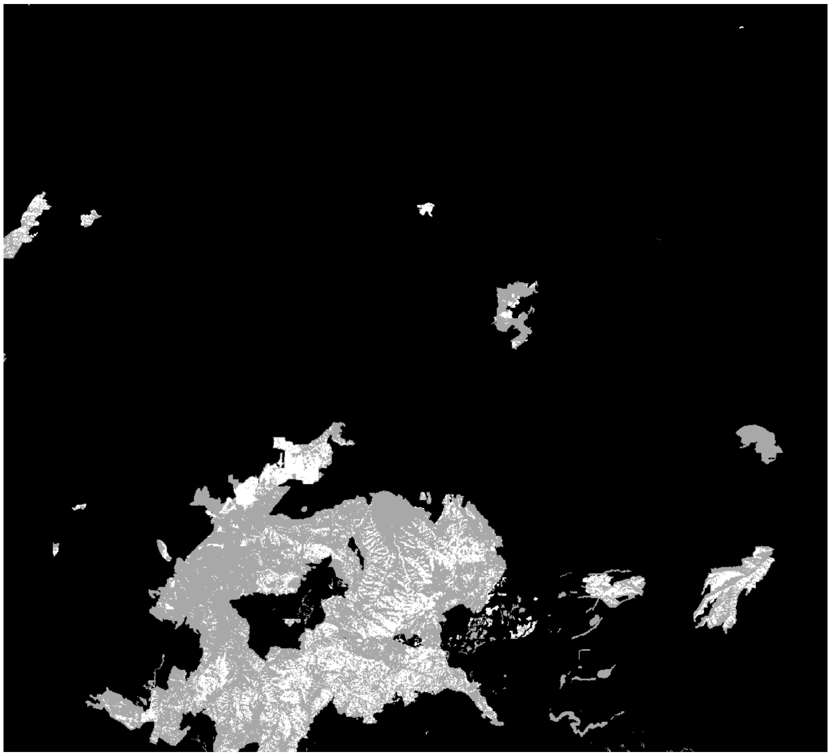


Figure 19 – 10 m disturbance severity raster. Darker values represent less disturbance, and lighter values greater disturbance.

A topographic wetness index was calculated using the DEM of the area of interest (see document "Creating a Topographic Index"). The Topographic Index was then resampled from the DEM resolution to exactly 10 m so that it would be orthogonal with the other three input rasters (Figure 4). It was then normalized to values from 1 to 10 so that TWIs from any area with any output range can be used in the same FIS.

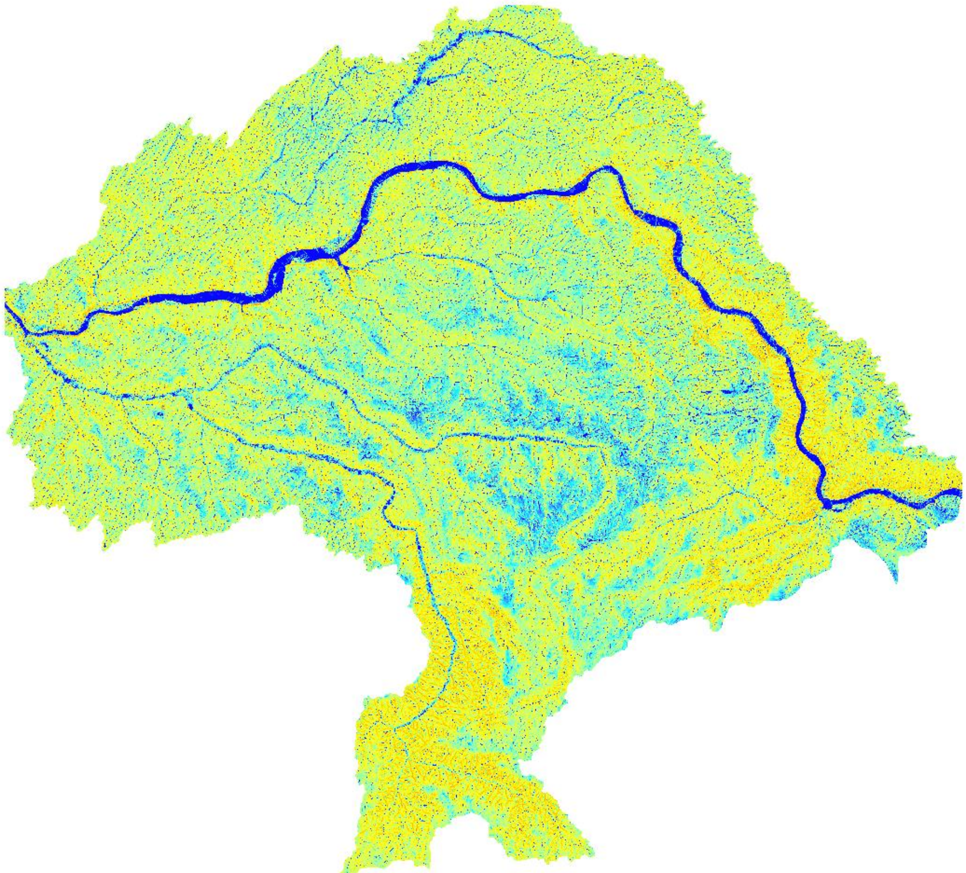


Figure 20 - Topographic Index raster. Blue (high values) have higher index values than orange (low values).

All input rasters are then clipped to the extent of the smallest raster, and you end up with 4 concurrent input rasters to be used in the fuzzy inference systems.

FIS Models

The instream wood recruitment model was driven by three FIS models, the vegetation FIS, the landscape FIS, and the combined recruitment potential FIS.

Vegetation FIS

To assess potential instream wood recruitment the woody vegetation availability, density, and proximity to the channel was assessed using nationwide LANDFIRE vegetation datasets, which are based on classification of 30 m resolution LandSat satellite imagery. Specifically, the input data for this two input FIS that includes concurrent 10 m rasters: percent vegetative cover and vegetation height (filtered using the Euclidian distance from the channel).

Landscape FIS

The Landscape FIS is a two input FIS that includes: vegetation disturbance severity, calculated from LANDFIRE VDIST layers, and a topographic wetness index (representing shallow landslide potential). Future work includes adding a third input, which represents inside and outside meander bends.

Combined FIS

Outputs of the vegetation and landscape FIS are the inputs of the combined FIS. The landscape FIS output serves to filter the vegetation FIS output by increasing potential where high landscape potential overlaps high vegetation potential, and not altering the potential where there is no overlap.

Initial results for the Tucannon River HUC8 watershed are shown below in figures 5, 6 and 7.

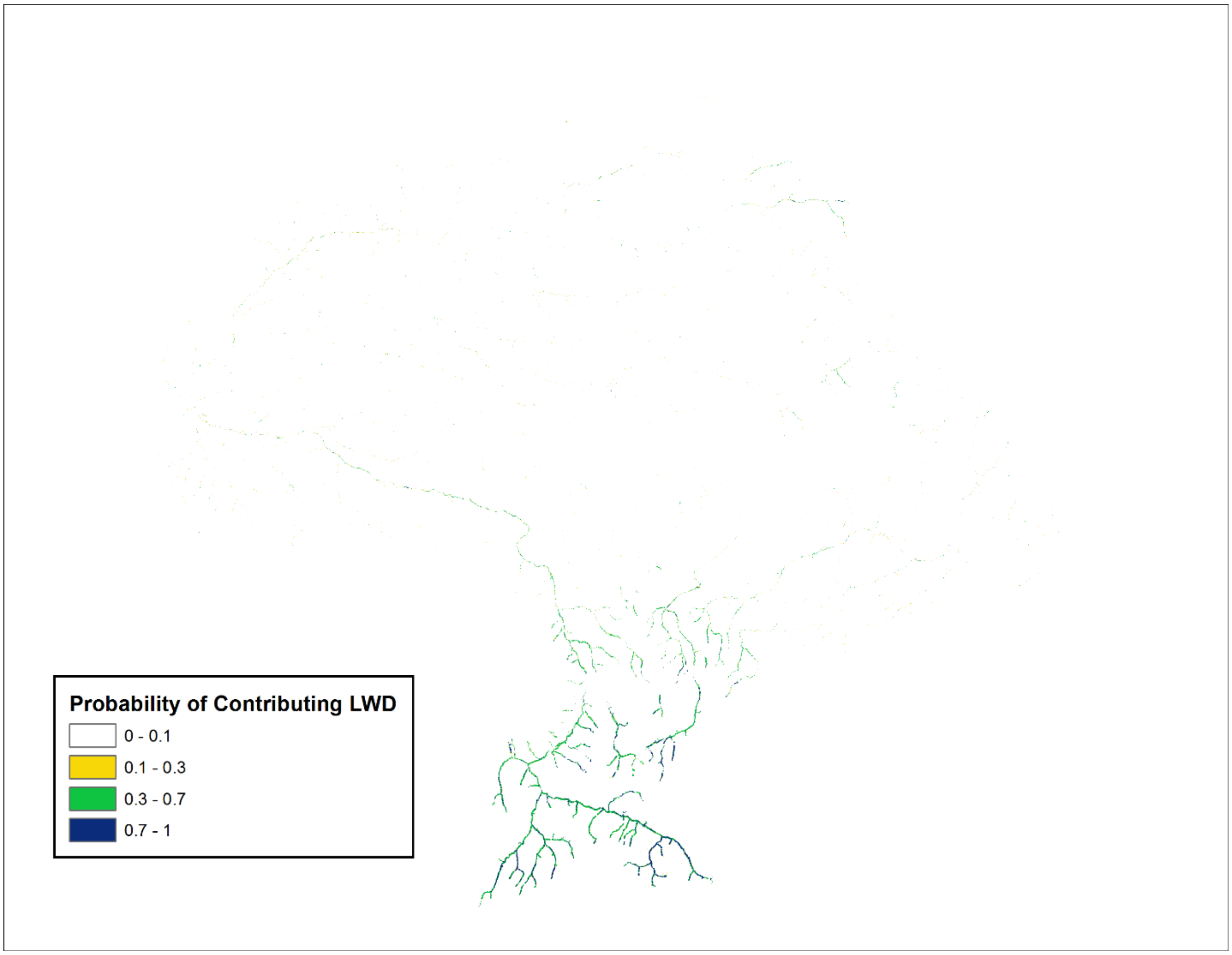


Figure 21 - Raster showing probability of instream wood recruitment.

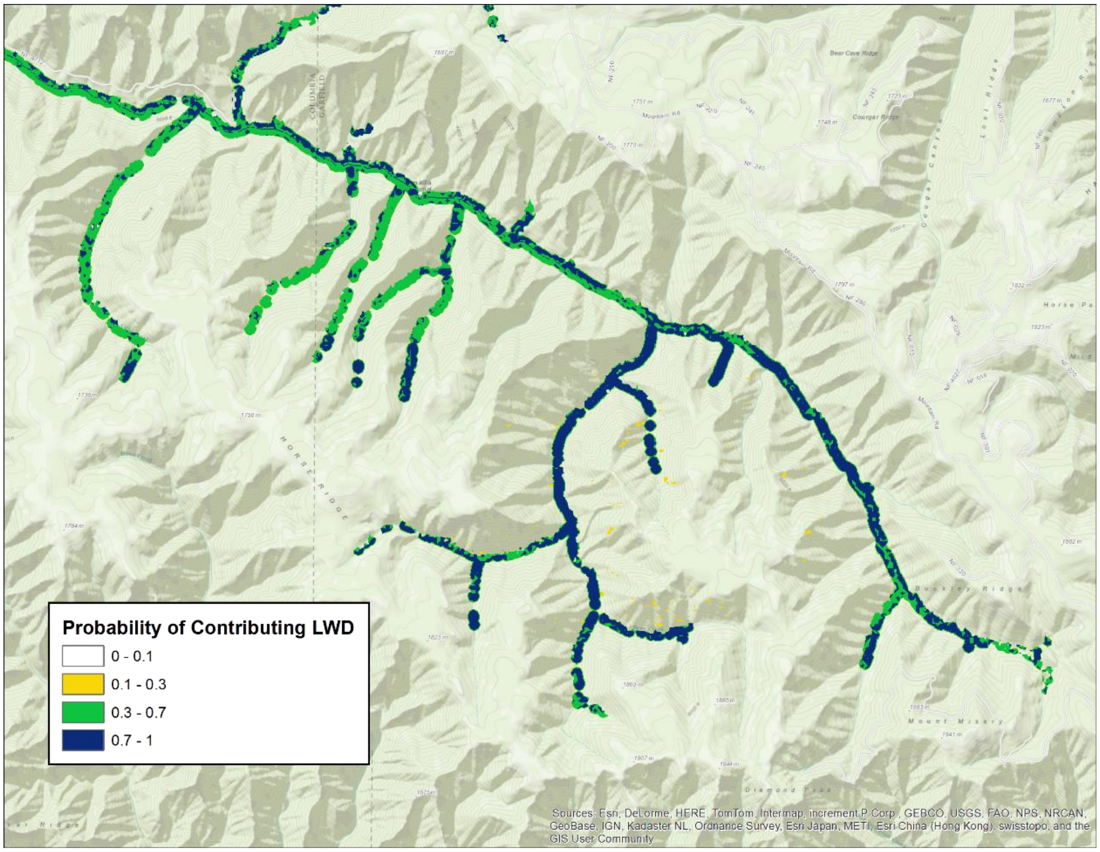


Figure 22 – Zoom-in of headwater area showing high probability of instream wood recruitment.

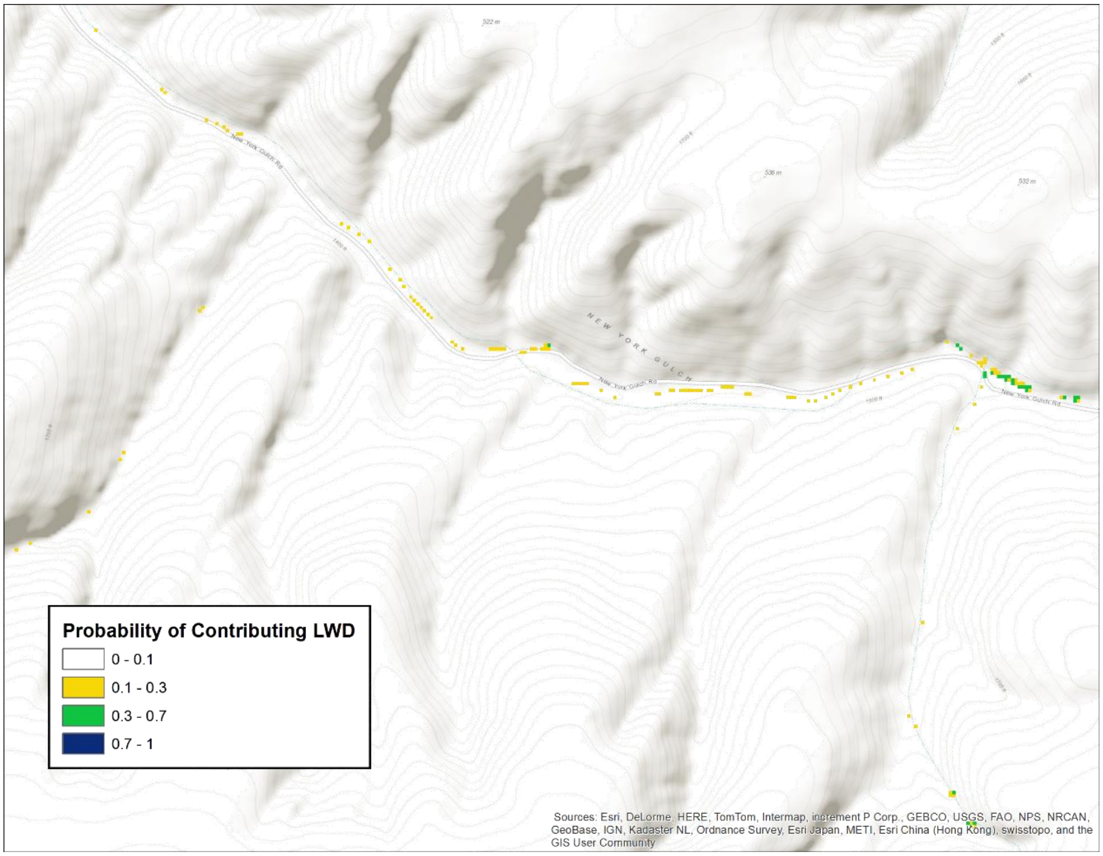


Figure 23 – Zoom-in of area showing low probability of instream wood recruitment.

After the raster output is generated, the probabilities are summarized over reach scales and applied to the stream network for display.

A segmented stream network (1 km segments in this case), is buffered by 75 meters, which, using the input data is the maximum distance from the stream at which wood can be contributed. The buffer type is "full" and the end type "flat" with NO dissolve.

Zonal Statistics are then calculated using the 75 m buffer as the bounding feature, and the derived LWD probability raster for calculating the statistics. The "SUM" statistic is used, and a new raster generated (Figure 8).

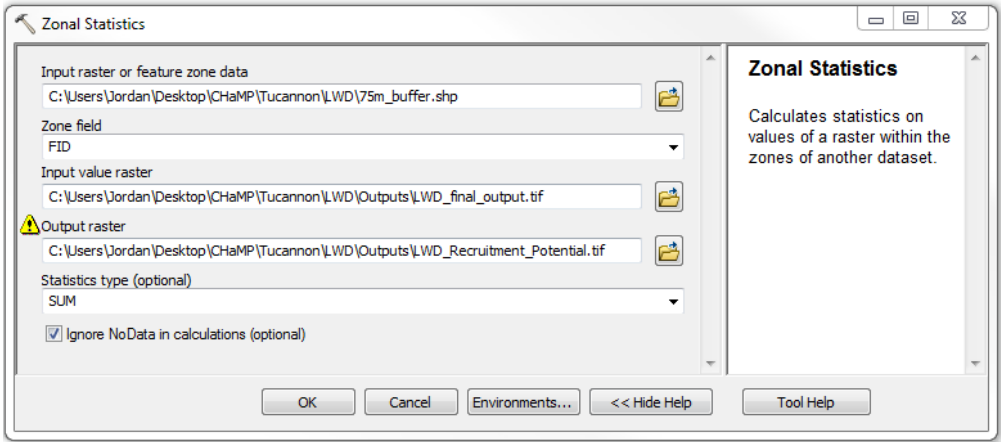


Figure 24 Zonal Statistics.

The output raster should then be normalized to values from 0 to 1 using the following equation in "Raster Calculator":

$$a + (x-A)(b-a)/(B-A)$$

where A – dataset min B – dataset max a – chosen min(0) b – chosen max (1)

The information from the normalized output raster (representing probability of contributing wood) can then be extracted to the stream network using "Geospatial Modelling Environment" (GME).

Use the "isectlinerst" command in GME. For "in" select the segmented line network. For "raster" select the new raster with values 0 to 1. For the "prefix" use PROB, and click RUN. Open the segmented network in ArcMap and delete all of the newly created fields EXCEPT FOR "PROBMAX."

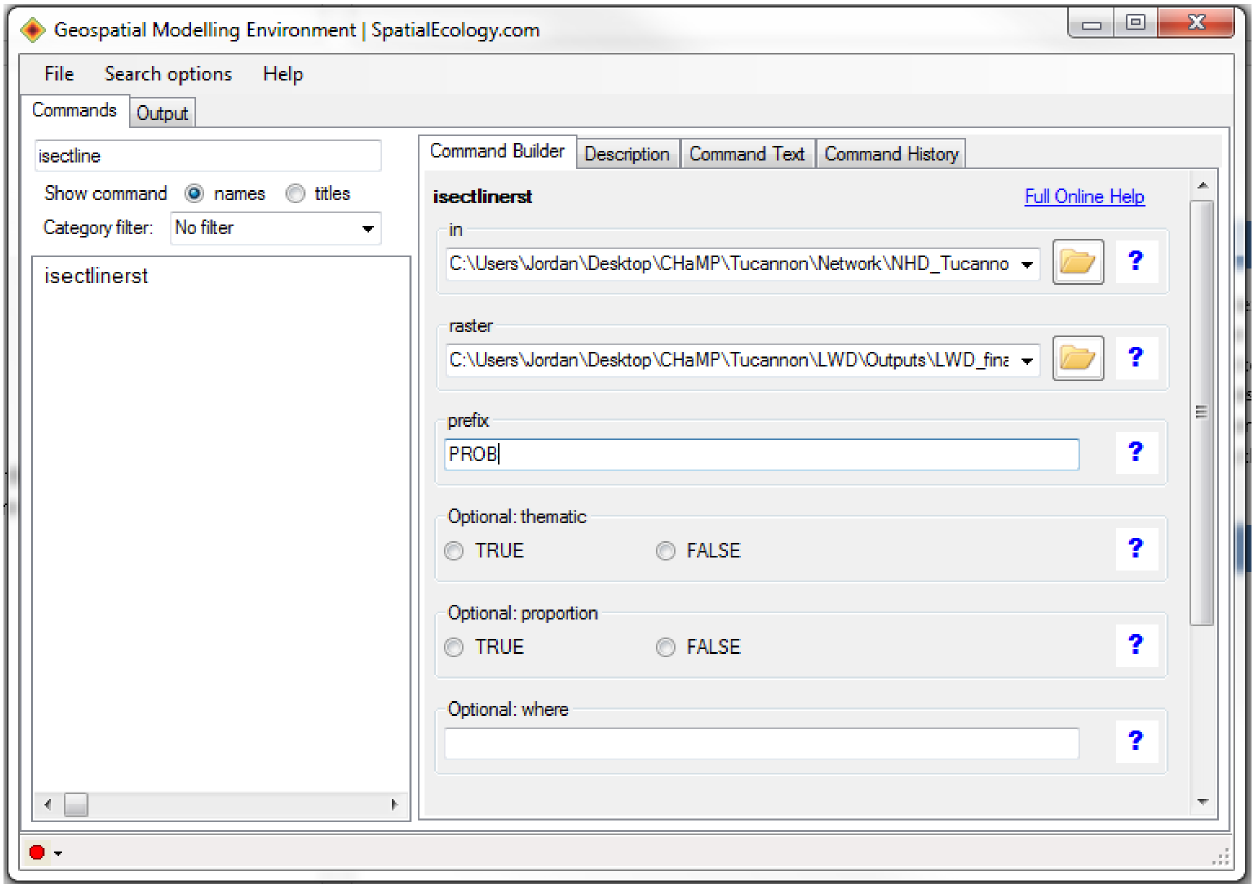


Figure 8 – Geospatial Modelling Environment interface

Export the segmented network and name it something indicating that it is the final LWD probability output. The "PROBMAX" field can then be symbolized to display the final output.

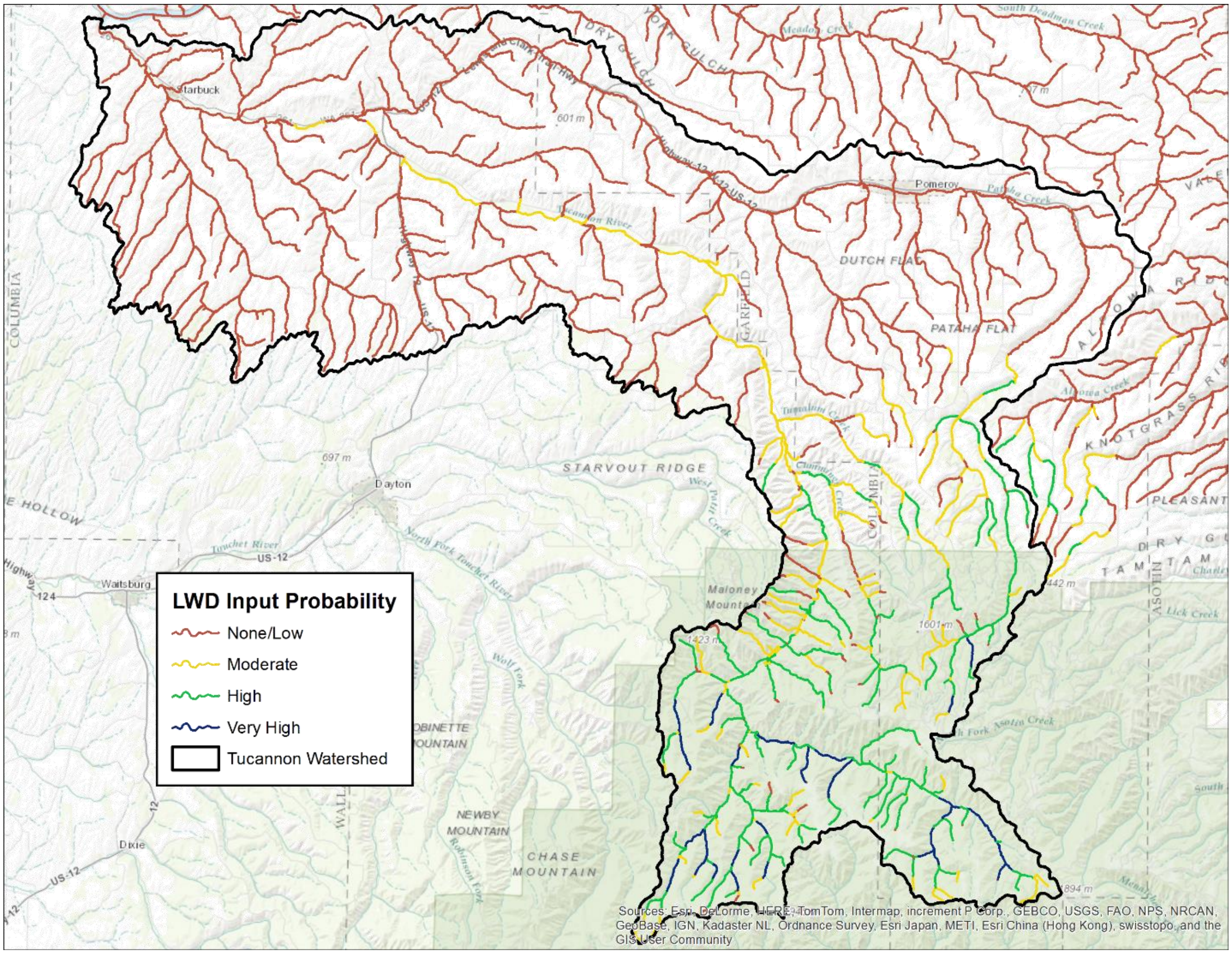


Figure 8 – LWD Input Probability output applied to the stream network

PRELIMINARY INTERPRETATIONS

On July 17, 2015 Joe Wheaton, Jordan Gilbert and Wally Macfarlane examined LANDFIRE EVC and EVH data throughout the Weber River Basin, Utah and determined that both the percent cover and height estimates were accurate enough to conduct a pilot study in the Tucannon watershed.

On July 30, 2015 Jordan Gilbert generated and successfully ran a script to prepare the inputs. All inputs appear to be coherent, and appear relevant to modelling wood recruitment potential. Initial drafts of the three FISs were created and run using the derived input rasters. The initial rule tables of the FISs were tweaked slightly for input from researchers that are familiar with the Tucannon watershed. The current run (8/14/15) looks very promising, with the output results displaying logical patterns, in line with what one would expect to see on the landscape.

On August 18th, the raster process was extended to applying the data from the output raster to the stream network, and this vignette was updated accordingly.

FUTURE WORK & QUESTIONS

The instream wood recruitment model developed and tested in this case study was limited to modeling living vegetation to the extent that it provides a recruitment source for instream wood. As mentioned previously, in the near future a third input, which represents inside and outside meander bends. Future research will extend the focus and attempt to model wood transport and storage potential along with instream wood loading.

REFERENCES

Beechie, T. and H. Imaki. 2014. Predicting natural channel patterns based on landscape and geomorphic controls in the Columbia River basin, USA. Water Resources Research **50**:39-57.

LANDFIRE. 2015a. Existing Vegetation Cover Layer LANDFIRE 1.1.O. Department of the Interior, Geological Survey.

LANDFIRE. 2015b. Existing Vegetation Height Layer LANDFIRE 1.1.O. Department of the Interior, Geological Survey.

LANDFIRE. 2015c. Vegetation Distrubance Layer LANDFIRE 1.1.O. Department of the Interior, Geological Survey.

Van De Wiel, M. J., T. J. Coulthard, M. G. Macklin, and J. Lewin. 2007. Embedding reach-scale fluvial dynamics within the CAESAR cellular automaton landscape evolution model. Geomorphology **90**:283-301.

Wohl, E. 2013. Floodplains and wood. Earth-Science Reviews **123**:194-212.