Ecological Management Decision Support Model of the Applegate River Basin

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The Ecological Management Decision Support Analysis of the Applegate River sub-basin of the Rogue River basin in southwest Oregon resulted from an integrated effort to develop a watershed health assessment tool. The Rogue River Basin Technical Team, an interagency group formed with the cooperation of 25 federal and state agencies, assessed and identified priority restoration work needed across the 33 sub-watersheds in the Applegate sub-basin. The analysis relied primarily on the Ecosystem Management Decision Support model, which evaluated 11 indicators of watershed health. When fire risk was included in analyses, 29 of the 33 were rated in poor health. Excluding fire, 21 sub-watersheds were rated in poor health. Federally managed areas contained 9 of 12 healthy watersheds. Based on instream conditions (four indicators), 25 of 33 sub-watersheds received poor scores. Across the Applegate basin, all floodplains received poor health scores for function. Generally, the upper reaches of the watershed were in better health than the low gradient areas that have the highest potential for structural and biological diversity. Recommendations for restoration differed by elevation and ownership. Accomplishing restoration priorities in the low gradient areas may be complicated due to the predominance of private ownership in those areas. Although this report is directly applicable to the Applegate sub-basin, the ecosystem indicators evaluated, the relationship between indicators, cumulative effects, and rationale used to prioritize restoration health are appropriate throughout the Rogue River basin.

Keywords: *ecosystem modeling, GIS, watershed health, landscape planning, restoration, collaboration*

Introduction

The Applegate River sub-basin is a 4th-field watershed tributary to the Rogue River basin in southwest Oregon. Traditionally, assessments and restoration planning in the Rogue River and its tributaries have been fragmented, conducted by various agencies or watershed councils. While these assessments provide a useful tool for project level planning, they do not provide priorities at larger scales. Additionally, the disparate efforts have not engaged all land managers in the watershed or incorporated limiting conditions across the landscape, reducing the efficacy of restoration efforts. To coordinate watershed restoration efforts, the Southwest Oregon Provincial Interagency Executive Committee (PIEC) and the Southwest Interagency Group (SWIG) comprising 25 federal and state agencies in the Rogue River basin signed a Memorandum of Understanding (MOU) to develop a basin-scale approach to watershed restoration. To accomplish this task, the agencies formed the Rogue River Basin Technical Team (hereafter referred to as 'the team'; see acknowledgements for members), representing various agencies and skills, to identify and prioritize restoration work needed across the 33 sub-watersheds in the Applegate sub-basin.

A functioning, healthy watershed has the structure, products and resources needed to support productive natural systems (Kolb et al. 1994). Specifically, a healthy watershed is defined as one that has: the physical structure, biotic resources and trophic (energy) levels that support productive systems; the capacity to quickly recover from episodic disturbances at the landscape scale; and the presence of a diversity of habitats for native species.

Based on these definitions of watershed health, the team selected eleven indicators to evaluate conditions in the Applegate River sub-basin. The indicators represent upslope, riparian, and in-channel processes as well as current aquatic conditions. Seven indicators define key processes that directly and indirectly influence aquatic conditions; these are causal process indicators. Process evaluation facilitates the understanding of linkages between the upslope, riparian and aquatic systems and provides insights to cause and effect relationships. Four of the eleven indicators are response indicators and represent current aquatic conditions. Table 1 lists the processes, respective indicators and variables used to measure the indicators.

M Furniss, C Clifton, and K Ronnenberg, eds., 2007. *Advancing the Fundamental Sciences: Proceedings of the Forest Service National Earth Sciences Conference, San Diego, CA, 18-22 October 2004*, PNW-GTR-689, Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Table 1. Watershed processes and indicators (Whitall et al. 2004)

Process	Indicator(s)	Variables
	CAUSAL INDICATORS	
Water delivery	Terrestrial Vegetation	• Diameter • Species • Crown closure • Canopy layers
Sediment yield	Terrestrial Vegetation Erosion	Same as above • Roads in riparian areas • Roads on slopes >30% • Roads crossing streams with gradients 25%
Fire risk	Terrestrial Vegetation	• Diameter • Species • Crown closure • Canopy layers
Streamside shade	Riparian Vegetation (within 30 m of stream)	• Species • Diameter • Crown closure
Large wood delivery to streams	Riparian Vegetation (within 30 m of stream)	• Canopy layers • Species • Diameter • Crown closure
	Wood Removal	• Roads in riparian areas
Channel processes	Floodplain Connectivity	• Entrenchment of low gradient (<3%), with valley bottoms having a valley width index of greater than 2.2
	Bank Stability	• Roads in riparian areas
Aquatic community	Fish Passage	• Percent of watershed upstream of fish barrier
	Water Availability	• Undetermined
	RESPONSE INDICATORS	
Aquatic conditions	Water Temperature	• Water temperature
	Key Pieces of Large Wood	• Number of pieces of large wood per mile
	Fine Sediment Deposition	• % fine sediment in riffles
	Pool Habitat	• Pool frequency

Causal processes data used were derived from spatial GIS data sets including roads, streams, DEMs, and satellite imagery. For current aquatic conditions, Oregon Department of Fish and Wildlife and the USDA Forest Service aquatic habitat surveys provided data sets. Team members used their collective local experience to assign rating criteria, develop ecosystem relationships, and evaluate results.

MODEL

The Ecosystem Management Decision Support (EMDS) model (Reynolds 1999) was selected to evaluate conditions at multiple scales. EMDS integrates GIS, used to store and display data, with Netweaver. Netweaver is the knowledge base that reflects the team's understanding of indicators and their cumulative condition to define watershed health and is founded on a combination of thorough literature review and the team's collective professional experience. This data set provided the reasoning to assign condition ratings to each indicator, and to describe the relationships between indicators.

The Netweaver knowledge base contains two key design features to evaluate watershed health. First, evaluation curves assign condition ratings to each indicator. Secondly, the model establishes relationships between indicators used to synthesize individual scores to generate a watershed health score.

The knowledge base evaluates the condition of each indicator using a set of curves, known as evaluation curves. These curves evaluate the proposition: "This watershed is in good health". Indicator scores range from +1, the indicator supports the healthy watershed proposition, to -1, the indicator does not support the proposition. Figure

Table 2. Indicators and evaluation criteria.

Indicator	Variables	Determination*
	CAUSAL INDICATORS	
Terrestrial Vegetation	• Diameter	• 0" = -1; 10" = 0, 30"= +1
	• Species	• Hardwood = 0; Mixed and conifers = +1
	• Crown closure	• <10% = -1; 10-20% = 0; 50% = +1
	• Canopy layers	• 1 = 0; >1 = +1
Riparian Vegetation	• Species	• Hardwood and mix = 0; Conifer = +1
	• Diameter	• <5" = -1; 5-15"= 0; >30"= +1
	• Crown closure	• <5% = -1; 10-20% = 0; >60 = +1
LWD recruitment	• Ratio of mi. rd. to mile of stream	• 0 = +1; 0.4 = -1
Roads in Riparian Zone	• Mi. of rd. per sq mi on slopes 60+%	• 0 = +1; 1 = -1
Roads on Steep Slope	• # roads crossings/ sq. mi. over streams with slopes 25+%	• 2 = +1; 4 = -1
Road-stream Crossing	• Species	• Hardwoods= 0; Mixed and conifers= +1
Riparian Vegetation-Shade	• Diameter	• <5" = -1; 5-15"= 0; >30"= +1
	• Crown Closure	• <30% = -1; 70% = 0; 90% = +1
Floodplain Connectivity	• Canopy Layers	• Single = 0; Multiple = +1
	• % of low gradient valley bottom streams with an entrenchment ratio < 2.2	• 50% = -1; 10% = +1 • 0 = +1; >20%= -1
Fish Passage	• Percent of watershed upstream of fish barrier	• 0.25 = +1; 0.75 = -1
Water Availability	• Ratio of consumptive water use to natural august flows	• Range subdivided into thirds: Cooler 1/3 = +1; Middle 1/3 = 0; Warmer 1/3 = -1.
	RESPONSE INDICATORS	
Water Temperature	• 7-day maximum water temperature in relation to range of recorded temperatures of similar watershed size	• 8 = -1; 18 = 0; 29 = +1
Key Pieces of Instream Wood	• Number of pieces of large wood/mi.	

** Rating: +1 represents full support of the proposition (the watershed is in good health); 0 represents moderate support, undetermined; -1 represents no support for the proposition. With score values along the Y-axis(from -1 to +1) and existing condition along the X-axis, the points are to be connected creating a graph depicting value/score relationship.*

1 displays an evaluation curve for the indicator pool frequency expressed as number of channel widths between pools. Table 2 lists all indicators and the values used to generate evaluation curves.

The ability to assign a range of values has a distinct advantage over procedures using a dichotomous choice, such as either good or bad. Threshold values that distinguish between healthy or unhealthy rarely exist in natural systems. Rather, there is a gradient of conditions existing between the two extremes; this gradient is captured in the rating curves. The curves provide a more accurate expression of our knowledge by expressing the full spectrum of conditions.

In this study, the EMDS model assesses causal processes health and instream response conditions independently, and uses a hierarchal evaluation. The framework for the model that expresses scoring and relationships is the

Figure 1. Pool frequency evaluation curve.

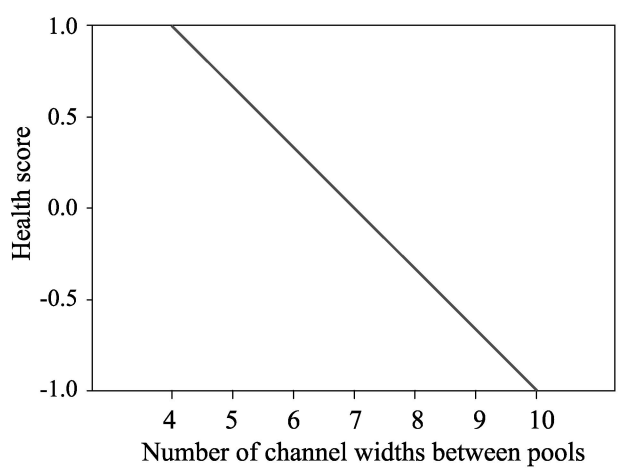
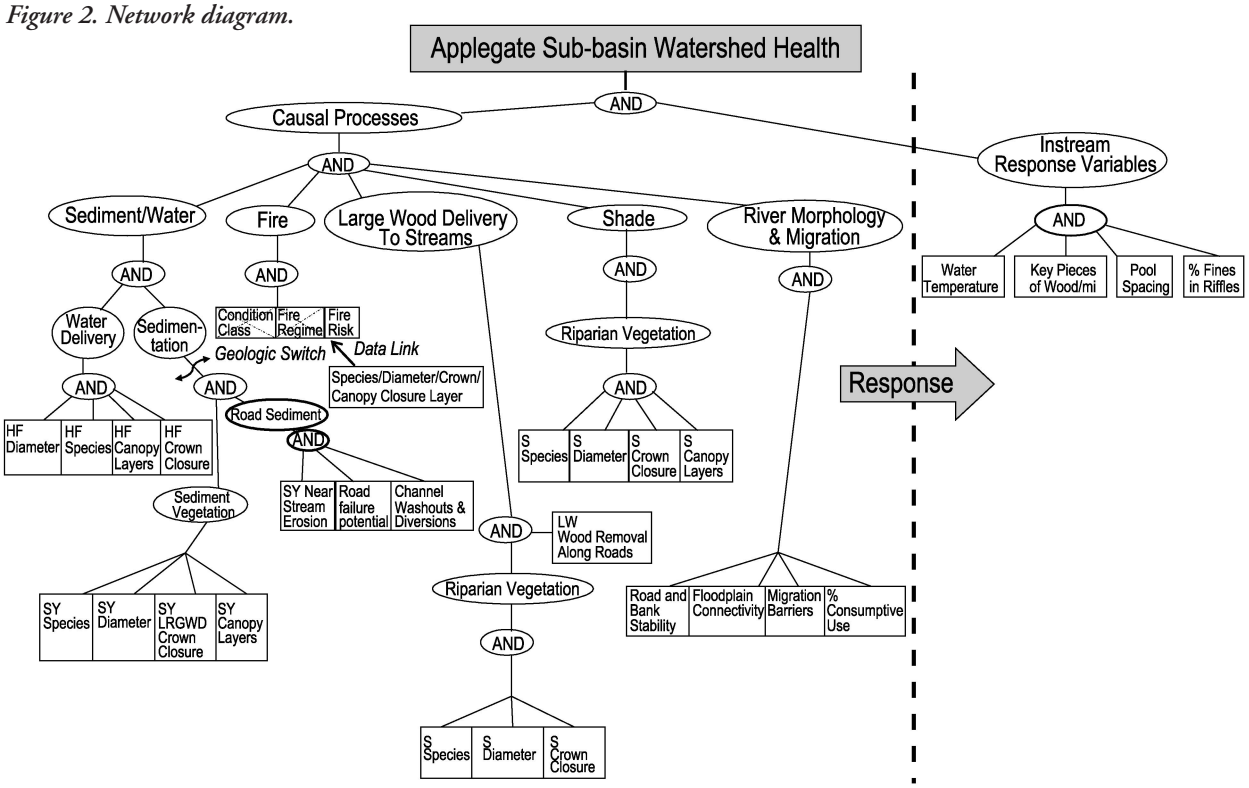


Figure 2. Network diagram.



network diagram (Figure 2). The lowest tier of information, represented by indicator scores, is synthesized providing an interpretation of a watershed process. Each watershed process is then integrated to establish watershed scale evaluation. For example, large wood delivery to streams is the combination of vegetative conditions (species, diameter, and crown closure) and wood removal along roads. The wood delivery to streams is synthesized with all related processes (water delivery, sediment yield, fire risk, streamside shade, large wood delivery, channel-floodplain connectivity, and aquatic connectivity) to generate causal processes health. Aquatic condition health is determined by combining indicators for instream large wood, water temperature, fine sediment, and pool frequency.

The separation of processes and response in the model offers the opportunity to substitute knowledge of process information for current instream condition and vice versa. Namely, if instream wood levels are not known, conditions can be inferred by the condition of wood recruitment and removal processes. Conversely, information on current instream wood levels reflects the process of wood recruitment. Thus, watershed health can be determined by either process-based or response-based conclusions.

RESULTS

Due to the transparency of the model, as the evaluation curves, data input and network diagram were agreed upon prior to output results, outputs were deemed reasonable and defensible during peer review. Additionally, the Applegate River sub-basin maintains a strong collaborative monitoring program, providing a means to verify EMDS model output. When compared to monitoring data, model outputs accurately reflected observed conditions at the 6th-field sub-watershed level.

Recognizing that fire risk was high across the basin, influencing scores for all 33 sub-watersheds in the Applegate River watershed, results of causal processes were examined including and excluding fire. With the inclusion of fire risk, 29 of the 33 sub-watersheds rated in poor health. Excluding fire, the analysis rated 21 sub-watersheds in poor health. Of the 12 sub-watersheds rated healthy, nine are located above Applegate Reservoir where federal management predominates.

While the risk of fire influenced negative scores for watershed health, loss of floodplain connectivity and migration barriers led to poor health scores in all but three sub-watersheds below Applegate Reservoir. Other indicators lowering watershed processes health scores included high numbers of road/stream crossings and roads in riparian zones.

Similar to causal processes, instream conditions were generally in poor health, with 25 of the 33 sub-watersheds in the Applegate sub-basin receiving negative scores. Only five showed support for healthy watershed conditions. A lack of large wood and associated lack of pool habitat were

primarily responsible for poor aquatic conditions. Large woody debris functions to dissipate energy, store sediment, form pools, and provide cover and velocity refugia. In the absence of wood, channel processes become simplified, reducing channel complexity. Combined with a system-wide loss of floodplain connectivity, which provides off-channel habitat and pool formation, pool and rearing habitat has greatly decreased in both moderate gradient and low gradient channel reaches.

Cumulative Effects

At the Applegate River watershed scale, the results show that 100% of the 6th-field watersheds received a poor health score for floodplain connectivity. Seventy-five percent of the watersheds received a poor rating due to lack of large woody debris and pool frequency, while 60% received a negative score due to fish migration barriers.

A number of indicators, when examined together, can reveal cumulative effects that are integral to establishing restoration priorities. Whitall (2004) identified four particularly important process/condition interactions that greatly reduce watershed health and resiliency:

(1) ***Water temperatures and fish migration barriers.*** Flows in salmon spawning areas, typically in the lower gradient reaches, become low and warm during the summer months. Juvenile fish, with the presence of barriers, are unable to access cooler water, resulting in poor survival.

(2) ***Sediment yield and key pieces of wood per mile.*** Large roughness elements create complexity by sorting and storing sediment, as well as providing areas of quality habitat. In the absence of large wood, sediment deposits uniformly across the bed surface.

(3) ***Key pieces of wood per mile and floodplain connectivity.*** The principle mechanisms for pool formation are large wood in moderate gradient reaches and lateral channel movement, both of which create sinuosity in lower gradient reaches. Losing both large wood and meandering creates a lack of complex habitat throughout the length of the stream (i.e., longitudinal profile).

(4) ***Floodplain connectivity and water availability.*** Lowering channel bed and water surface elevations can drastically reduce the adjacent water table. Maintenance of the water table within riparian zones is necessary to preserve wetlands and diverse riparian vegetation.

A third of the Applegate sub-watersheds received a negative score for water temperature/migration barriers and floodplain connectivity/water availability indicator pairs. Negative scores for the indicator pairs of sediment yield/instream large wood, and instream wood/floodplain connectivity were found in 25% of the sub-watersheds.

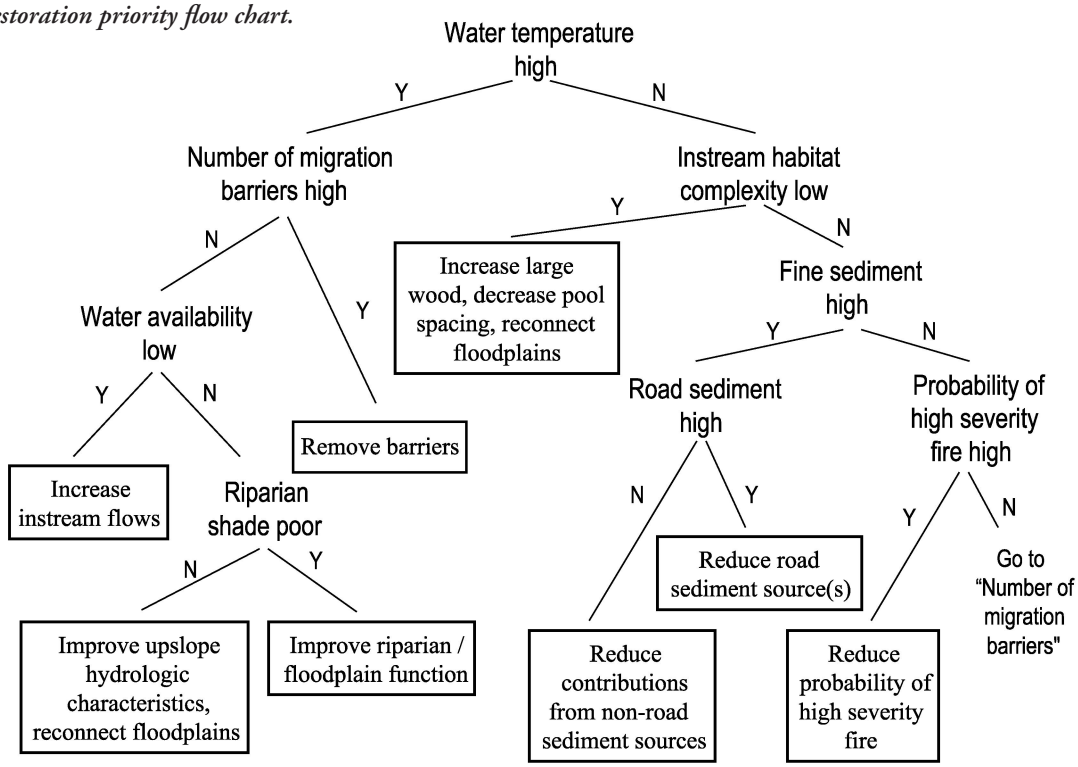
Across the Applegate River watershed, the upper reaches afford better watershed health conditions. The team determined that the lower gradient valley bottom reaches fail to support healthy watershed conditions. These low gradient valley bottoms provide the highest potential structural and biological diversity. Healthy stream channels in low gradient systems contain side channels, alcoves, pool-riffle sequences, undercut banks, off-channel wetlands, and gravel bars. Low gradient floodplain areas also provide conditions for diverse riparian plant and animal species. For a number of species, including coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*), unhealthy conditions of the valley bottoms contribute to population declines and inhibit the opportunity for recovery.

Recommendations

Based on the results of the analysis, the team developed a flow chart identifying restoration needs in the Applegate River sub-basin (Figure 3); this chart could apply equally to many watersheds in southwest Oregon. In sub-watersheds with poor water temperature, restoration actions should focus on removing barriers to allow free movement of cold-water aquatic organisms to thermal refuge areas and increasing base flows. Other restoration actions, though potentially needed, will provide little benefit until water temperature conditions are addressed. In those watersheds with reasonable or good water temperatures, restoration actions should be directed at providing high quality structural habitat (i.e., complex cover, pools, and off channel habitat) and reducing sediment where appropriate. A combination of road improvements and placement of large wood in channels in watersheds with significant increases in erosion is recommended. In the short term, wood provides flow velocity complexity, creating scour and sorting of gravel, partially mitigating high sedimentation rates. Long-term restoration may require road and culvert improvements or removal. Re-establishing healthy riparian vegetation, particularly conifers, and providing the stream access to its floodplain will reduce erosion and contribute to increased habitat complexity.

Final recommendations followed a trend with ownership and elevation. In the upper watershed areas, predominately managed by federal agencies, increasing large woody debris and reducing roads in the riparian zones were the top recommendations. Channel types in the federal land allocations typically have moderate to high gradients with little floodplain development and maintain full surface flows throughout the summer. However, wood removal practices combined with riparian harvest have left many channels lacking large instream wood. In the low gradient

Figure 3. Restoration priority flow chart.



reaches, improving water temperature, instream barriers and floodplain functions were the most frequently recommended actions. Consumptive uses and alteration of channel courses via direct modification have reduced both shade and streamflow volume, leading to increased water temperatures. When these effects are added to instream barriers that prevent migration, there is a basin-wide reduction in salmonid rearing habitat.

The EMDS analysis successfully identified restoration priorities for both moderate- to high-gradient and low-gradient areas of the Applegate River sub-basin. Accomplishing the restoration actions may be problematic, particularly in lower-gradient areas where private ownership predominates. Cooperation and collaboration among agency managers, watershed councils, and local landowners will be necessary to meet these objectives.

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