ROAD MANAGEMENT IN THE CONTEXT OF WATERSHED RESTORATION

Notes from the Second Meeting of the Pacific Northwest Forest Restoration Learning Network

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Foreword

This paper synthesizes information from presentations and discussions that occurred as part of a two-day workshop, titled: "Road management in the context of watershed restoration." The workshop was the second annual meeting of the Pacific Northwest Forest Restoration Learning Network (see below) and emphasized planning and prioritization of road management treatments, public/private/tribal partnerships, and specific strategies to improve effectiveness of road upgrading and decommissioning projects. It was hosted by The Nature Conservancy in Astoria, OR, on April 23-24, 2009, and included a field tour of watershed restoration treatments at the Conservancy's Ellsworth Creek Preserve in southwestern Washington. The information presented in this paper is a high-level summary representing years of innovative thinking and experience on the part of several individuals, many of whom were in attendance. Presentations from the workshop can be viewed and downloaded here: http://conserveonline.org/workspaces/ellsworth.creek. Speakers and attendees included:

Speakers *(name, job title, affiliation, presentation title)*

Liane Davis, *Ecologist, The Nature Conservancy*: Workshop introduction and overview of TNC's Ellsworth Creek watershed restoration project.

Bill Weaver, *Geomorphologist, Pacific Watershed Associates:* Identifying high risk roads and prioritizing road treatments.

Michael Furniss**,** *Hydrologist, US Forest Service, Pacific Northwest Research Station, Arcata, CA*: Climate intensification and the loss of the stationarity assumption: Implications for road management and restoration.

Brian Staab**,** *Regional Hydrologist, US Forest Service, Region 6*: Prioritizing road restoration at a regional scale.

Bill Shelmerdine**,** *Hydrologist, US Forest Service, Olympic National Forest*: Road Restoration: Forest level prioritization to defining treatments at the project scale.

Todd Bohle**,** *Watershed Hydrologist, Seattle Public Works* and ***David Beedle*****,** *Sr. Watershed Hydrologist, Seattle Public Works*: Planning road work at a watershed scale: An example from the Cedar River (WA)

Anne Connor**,** *Forest Watershed Engineer, US Forest Service, Clearwater National Forest*: Watershed restoration and road decommissioning partnerships: An example of the Clearwater National Forest and Nez Perce Tribe.

Sungnome Madrone**,** *Landscape Contractor, Madrone Enterprises:* Private roads and road associations in the watershed mix: The whole equation.

Dave Burns *Geomorphologist, Burns Ecosystems Solutions:* Road decommissioning: what it takes from a contractor's perspective.

Rick Thoreson, *Engineering Supervisor (retired), Oregon Department of Forestry, Clatsop State Forest:* Least cost approach to field layout and accomplishing road decommissioning.

Bill Weaver**,** *Geomorphologist, Pacific Watershed Associates:* The Basics of road upgrading for watershed/aquatic habitat protection and restoration.

***Adam Switalski*, *Science Coordinator, Wildlands CPR*: Identifying key questions and conclusion.

Tom Kollasch*, Willapa Program Director, The Nature Conservancy*; **Bill Lecture*****,*** *Willapa Forester, The Nature Conservancy*; and **Rick Thoreson***, Engineering Supervisor (retired), Oregon Department of Forestry, Clatsop State Forest*: Restoration at Ellsworth Creek (facilitated field tour).

Attendees

Kyle Smith, *Willapa Assistant Forester, The Nature Conservancy*; **Nathan Poage**, *Facilitator, Clackamas Stewardship Partners; Consulting Forester, Poage's Black Inc.*; **Chris Frissell**, *Director of Science and Conservation, Pacific Rivers Council*; **Kim Johnson**, *Biologist, Army Corps of Engineers Northwest Division*; **David Rolph**, *Director of Conservation Programs – Washington Coast, The Nature Conservancy*; **Carlo Abbruzzese**, *Natural Areas Manager, Washington Department of Natural Resources*; **Dave Halemeier**, *Hydrologist, US Forest Service Detroit Ranger District*; **Sue Gunn**, *Washington State Representative, Wildlands CPR*; **Robin Stoddard**, *Forest Hydrologist, US Forest Service Olympic National Forest*; **Jennifer Carah**, *Field Scientist, The Nature Conservancy*; **Tom Leroy**, *Associate Geologist, Pacific Watershed Associates*.

Pacific Northwest Forest Restoration Learning Network

The Pacific Northwest Forest Restoration Learning Network (hereafter, the "Learning Network") is an affiliation of managers and scientists involved with restoration projects within young, managed forest landscapes on private and public lands throughout the Pacific Northwest, with an emphasis on coastal areas from southeastern Alaska to northern California. Intensive timber management in this region over the last century has left a legacy of altered forests and extensive road networks across public and private lands. To abate ongoing threats to freshwater, estuarine, and terrestrial habitats associated with these altered conditions, watershed restoration efforts aimed at increasing complexity in forest structure and reducing impacts from forest roads on terrestrial and aquatic habitat are being implemented across an array of ownerships, landscapes, and forest types. Some current large-scale projects include: Redwood Creek (National Park Service, BLM, and Green Diamond Resource Company, CA, 75,000+ acres); Mill Creek (National Park Service, CA State Parks, Save the Redwoods League, CA, 25,500 acres); Cedar River Watershed (City of Seattle, WA, 91,500 acres); Hollow Tree Creek watershed (South Fork Eel River; Trout Unlimited and Mendocino Redwood Company, CA, 19,000 acres); Garcia River, Big River and Salmon Creek Conservation Forests (Conservation Fund, The Nature Conservancy, CA, 40,000 acres); and South Willapa Bay (The Nature Conservancy, Willapa National Wildlife Refuge, WA, 15,000 acres). Additional restoration projects have begun or are planned for thousands of acres of federal lands, particularly those within "key" or priority watersheds (e.g., Northwest Forest Plan, Record of Decision 1994) as well as on significant areas of other public (e.g., Washington State Department of Natural Resources) and private lands. On many of these projects, land managers are trying innovative restoration approaches and scientists are conducting research to better understand and inform future restoration practices. The Learning Network was founded to capitalize on synergies among these restoration efforts and facilitate communication between managers and scientists to catalyze growth in practical restoration knowledge. Annual meetings of the Learning Network are held to discuss topics pertinent to forested watershed restoration, such as road decommissioning and upgrading, commercial thinning, ecological monitoring, and ecosystem services. This paper synthesizes information presented during the second annual meeting of the Learning Network.

Technical Notes and Terminology

Technical Notes

This paper is intended to provide an overview of current thinking regarding the intersection of road management and watershed restoration. It is *not i*ntended to be a complete synthesis of the impacts of roads on watersheds nor a technical guide for road management. For more detailed information, readers should refer to the following selected references (*Note: this list highlights frequently cited resources but is not comprehensive):*

Impacts of Roads on Watersheds:

Furniss, M.J., T.D. Roelofs, and C.S. Yee, 1991. Road construction and maintenance. Pages 297-324 *In*: W. Meehan (Ed.), Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats, Special Publication 18, American Fisheries Society, Bethesda, Maryland.

Gucinski, H., M.J. Furniss, R.R. Ziemer, and M.H. Brookes (Eds.) 2001. Forest roads: a synthesis of scientific information. General Technical Report. PNW-GTR-509. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon. 103 pp.

Switalski T.A., J.A. Bissonette, T.H. DeLuca, C.H. Luce, and M.A. Madej. 2004. Benefits and impacts of road removal. Frontiers in Ecology and the Environment **2**: 21-28.

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14:18-30.

Technical Guides:

B.C. Ministry of Forests. 2001. Best management practices handbook : Hillslope restoration in British Columbia. Resource Tenures and Engineering Branch, B.C. Ministry of Forests, Victoria, B.C. Watershed Restoration Program. *http://www.for.gov.bc.ca/RTE/engineering/engineering.htm*

Luce, C. H., B.E. Rieman, J.B. Dunham, J.L. Clayton, J.G. King, and T.A. Black. 2001. Incorporating aquatic ecology into decisions on prioritization of road decommissioning. *Water Resources Impact* **3**: 8-14.

Mills, K., L. Dent, and J.L. Cornell. 2007. Rapid survey of road conditions to determine environmental effects and maintenance needs. *Transportation Research Record: Journal of the Transportation Research Board.* 1989/2007: 89-97.

Oregon Department of Forestry. 2000. State Forests Program: Forest roads manual. http://www.odf.state.or.us/DIVISIONS/management/state_forests/RoadsManual/RMSEC1-INTRO.pdf

USDA Forest Service. 1999. Roads analysis: Informing decisions about managing the National Forest Transportation System. Misc. Rep. FS-643. Washington, D.C.: U.S. Dept. of Agriculture Forest Service. 222 p. http://www.fs.fed.us/eng/road_mgt/01titlemain.pdf

U.S. Forest Service Water-Road Interaction Technology Series Documents: http://www.stream.fs.fed.us/water-road/index.html

Weaver, W. and D. Hagans. 1994. Handbook for forest and ranch roads: A guide for planning, designing, constructing, reconstructing, maintaining, and closing wildland roads. *Prepared by Pacific Watershed*

Associates for The Mendocino County Resource Conservation District in cooperation with The California Department of Forestry and Fire Protection and the USDA Soil Conservation Service. http://www.krisweb.com/biblio/gen_mcrcd_weaveretal_1994_handbook.pdf

Weaver, W.E., D.K. Hagans, E. Weppner. 2006. Part X: Upslope erosion inventory and sediment control guidance, *in* Flosi, G., et al., eds., California Salmonid Stream Habitat Restoration Manual, 3rd ed.: Sacramento, CA, California Department of Fish and Game, 207 p. http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp

Wise, M., M. Leslie, G. Horel, D. Collins, W. Warttig. 2001. Road deactivation for hillslope restoration: Lessons learned on the Escalante watershed restoration project, *In:* Proceedings, Land Reclamation Geotechnique, Vancouver Geotechnical Society Symposium, May 2001.

Terminology

Figure 1 illustrates common road terminology used throughout the paper

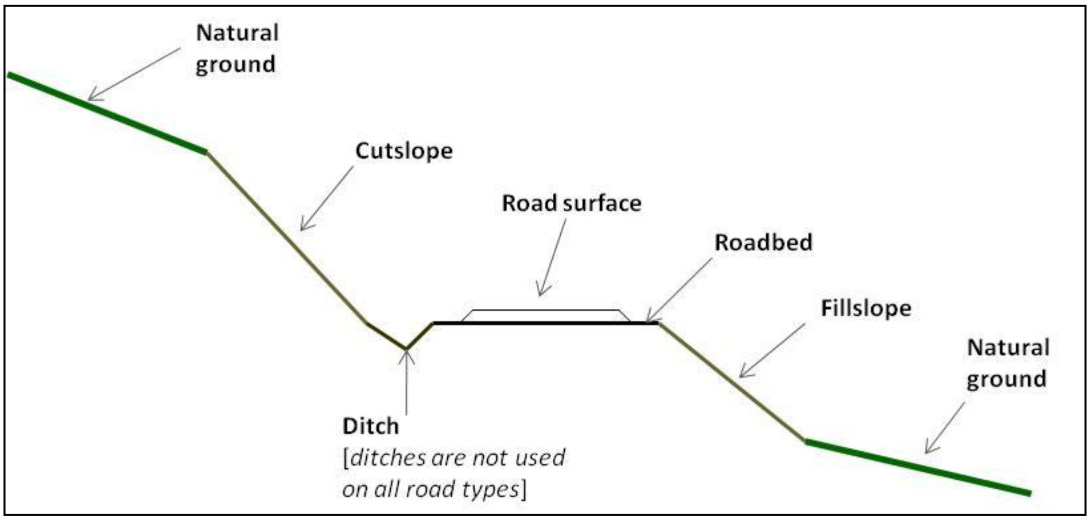

Figure 1: Diagram of typical road prism

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Introduction: How Roads Fit into Watershed Restoration

Watershed Restoration

Watershed restoration is now a priority for many public resource and land management agencies (e.g., U.S. Forest Service; Washington State Department of Natural Resources; California Department of Fish and Game), private landowners, non-government organizations (NGOs), and numerous other watershed stakeholders. Watershed restoration generally involves restoring degraded habitat (e.g., forest, estuarine, stream) or ecological processes (e.g., wood recruitment and sediment transport) to improve long-term function of aquatic and terrestrial ecosystems. Watershed restoration programs, especially those dealing with forest roads, also commonly include protective actions aimed at eliminating or reducing threats to habitat before it becomes degraded (e.g., removal of an old culvert before it has a chance to fail). Activities that encompass watershed restoration can range from forest thinning, to invasive species removal, to dike removal in marshes. A very critical issue for watershed restoration in areas previously, and sometimes currently, dominated by intensive timber management is forest roads. This issue has gained attention in recent years as understanding of the impacts from roads on terrestrial and aquatic systems has improved and as road networks age, often exposing problems that had previously been unnoticed. This paper addresses forest road management within the context of forested watershed restoration, highlighting many of the concerns stemming from roads and outlining goal-setting, prioritization, and techniques for road management that can improve watershed condition. While roads can also have impacts in other types of systems (i.e., non-forested) and from other resource extraction practices (e.g., mining), it is beyond the scope of this paper to address all of these.

Road Benefits and Costs

On U.S. Forest Service lands alone, roads cover nearly 375,000 miles (USFS 2006), enough to circle the Earth's equator 15 times. Roads have been built over many decades and provide a myriad of societal benefits. Some of these include: (1) access to forestlands for recreation (e.g., camping, hiking, fishing, hunting, biking); (2) forest management (e.g., timber harvest); (3) restoration treatments (e.g., riparian tree planting); (4) fire management ; (5) research and monitoring; (6) access to private in-holdings; and (7) access to cultural and tribal resources (e.g., sacred sites).

Despite these benefits, roads have drawbacks and come with unwanted side effects (Images 1-3). Ecological impacts of roads have been well documented many studies and reviews (e.g., Switalski et al. 2004, Gucinski et al. 2001, Trombulak and Frissell 2000, Furniss et al. 1991,). Roads fragment terrestrial habitat and reduce habitat connectivity for many species (e.g., bears, wolves) while also leading to high levels of road-related mortality. Roads also act as vectors to spread invasive species and diseases, including many species of noxious weeds that can devastate native ecosystems and fungal infestations such as that responsible for Port Orford Cedar (*Chamaecyparis lawsoniana*) root disease (*Phytophthora lateralis*). Perhaps the most widely cited concern related to roads is their impact on water quality and aquatic resources. Roads are generally impervious surfaces that alter the hydrology of watersheds. By impeding water infiltration and intercepting near surface groundwater, roads can consequently expand the stream drainage and increase the amount of surface water that is carried directly to the stream network (Image 1: "hydrologic connectivity" of road to streams; Jones and Grant 1996, Wemple et al. 1996). This runoff is a chronic source of fine sediment and toxins to streams. Landslides triggered from culvert or road failures can also transport massive amounts of sediment and debris to streams in episodic events (Image 2, Image 3). High levels of fine sediment in water have been linked to detrimental effects on fish, amphibians, and other aquatic species and can also be harmful to humans when they infiltrate the water supply. Roads can also increase stream temperatures by reducing stream-side vegetative cover and by reducing water depths through debris flows or high in-puts of fine sediments. Culverts at stream crossing can also block fish and amphibian passage, often cutting off critical fish spawning and rearing habitat. Roads have also been shown to increase the magnitude and severity of flooding events and block or disrupt natural transport of habitat-forming materials (e.g., gravels, large wood) into streams. Finally, roads can reduce productivity of lands and increase human access to remote areas for illegal activities, such as trash dumping, wildlife poaching, destruction/theft of cultural resources and private property, and drug production (e.g., methamphetamine labs, marijuana fields). The permeating nature of roads into once remote wildland areas has also been associated with increasingly frequent and destructive forest fires.

In addition to high ecological costs for terrestrial and aquatic species, these road-related problems carry heavy health and economic burdens for humans. Illegal activities are difficult and costly to control and remediate. Noxious weeds result in an untold amount of damage to water quality and working lands, including forestry, ranching, and agriculture. Fine sediment has huge detrimental impacts on commercial species, such as salmon and oysters, and can also result in the need for costly filtration systems at water treatment facilities. Finally, though roads can allow access to productive lands for resource extraction, the land devoted to road surfaces is no longer productive; for example, assuming a conservative road width of 35 feet and assuming all land would return to forest, this would result in an additional 1.6 million acres of forestland if all roads on USFS roads were removed. This loss of productivity reduces many ecological services that forests can provide, including carbon sequestration and water filtration.

Setting Goals and Priorities for Road Management

Goals

Given the benefits that roads can provide and the costs that can be inflicted on human resources and natural ecosystems, a balance generally needs to be struck in determining how roads should be managed within the context of watershed restoration. This is generally driven by the management goals (e.g., improve water quality to protect aquatic species; increase habitat connectivity for grizzly bears, etc.). In many cases, the primary goal may be to protect high quality watersheds rather than to "restore" a watershed, as it is typically defined. For example, in a relatively undisturbed watershed where salmon still thrive, a goal may be to remove all threats from existing roads in order to maintain high-quality habitat into the future. In other places, where habitat is already degraded, the goal may be to restore natural hydrologic processes. Because an overwhelming number of road-related management issues relate to preventing, reducing, or eliminating sediment delivery from roads to improve and protect water quality and aquatic habitat, this section will focus primarily on "sediment driven restoration" to clearly highlight key principles. As previously discussed, there are many other ways that roads impact aquatic and terrestrial systems other than through sediment delivery, and road management strategies to

> High risk roads must be assessed for ***existing and potential*** sources of sediment, not for past failures. Once identified, they must be quantified and prioritized for treatment. **Treat roads and sediment sources that: (a) have a high potential to erode of fail; (b) contain large volumes of sediment at potential failure sites; and (c) contain sediment volumes or grain sizes that would be deleterious if delivered to streams during biologically sensitive periods.**

Image 1. Road hydrologically connected to stream and delivering chronic sediment (*photo provided by: William Weaver, Pacific Watershed Associates)*

Image 2. Landslide initiated from road

Image 3. Streamflow diversion (*photo provided by: Brian Staab, U.S. Forest Service*)

achieve other goals will necessarily be different. However, many of the same principles recommended for sediment reduction goals are applicable to other goals as well.

Road management goals related to sediment delivery must often differentiate between *prevention* versus *control*, with it being much less expensive to prevent problems than to control them. “High risk” roads, from an aquatics perspective, are roads that are likely to deliver sediment either through episodic delivery (landslides, failed stream crossing, fill-slope debris slides) or chronic delivery (roads connected hydrologically to streams via gullies and poor surface and ditch drainage). With all the roads on the landscape, it is important to ensure that the roads we focus on are those that are most ‘important’ to focus on for protecting high quality aquatic habitat and restoring those streams that have been degraded. Questions that need to be addressed include: (1) Have the roads been an “important” source of sediment in the past (what was the volume, rate, timing, size classes involved), and, perhaps more importantly, (2) Will roads continue to be important? This question is critical and necessitates a *forward-looking approach*.

Prioritizing

Once goals are set, it is important to prioritize road management activities. There are numerous ways to prioritize, but it is nearly always necessary to set goals and priorities for road management at different spatial scales. Examples of different spatial scales typically evaluated include: (a) ecoregion; (b) river basin, (c) watershed; (d) sub-watershed; and (e) individual sites. Within and among these spatial scales, several levels of risk factors also often need to be considered, including (a) hillslope position (upper, middle, lower); (b) proximity to valuable aquatic streams; (c) road maintenance class (e.g., all-weather roads, seasonal roads, legacy roads); and (d) age and engineering quality of the road segment and/or network.

Why Prioritize?

Four simple reasons:

1. You can’t treat everything all at once.
2. There won’t be enough money to do everything.
3. Some sites are more “important” than others.
4. To improve efficiency and get the greatest return for limited funds.

Thus, those making prioritization decisions will need access to different tools and data, depending on the scale. Prioritization generally must also account for operational and socio-economic goals in addition to ecological protection and restoration goals. Again, these components will differ depending on the scale in question, ownership pattern, landscape condition, and numerous other factors.

While it is difficult to provide a generalized method that will work for all circumstances, a comprehensive, *forward-looking* analysis of these factors will prevent managers from falling into one of the many common prioritization schemes that are often used but are neither efficient nor effective and *should **be avoided***, such as:

1. The “shotgun” technique, where projects are undertaken all over the landscape in response to a variety of pressures, needs, and priorities.
2. The “eyesore” treatment where restoration targets sites that are visually ugly but which are often not an important part of the real problem.
3. The “reactive” strategy where publicly funded emergency “restoration” or repair is performed only after storms have already caused serious infrastructure damage (e.g., FEMA, ERFO, etc)

4. The “barter” approach where restoration projects are undertaken in “exchange” for approval of regulated land use activities as a method of mitigation for the expected impacts of the proposed land management.

Information, including a comprehensive road inventory and a thorough road needs assessment (transportation plan) are undertaken to avoid these ineffective prioritization schemes and complete a more effective and systematic assessment of road management needs and priorities.

Road Inventories

There are many ways to identify high risk roads and road management needs (e.g., anecdotal information, LiDAR analysis, inventories of past erosion problems). In general, though, the best and most complete method is to conduct a comprehensive road inventory. This inventory can form the basis for road management planning and provides site-specific information needed to make decisions on treatment needs and prioritization. This inventory should be closely coordinated with the timing of project implementation as ground conditions can change, or, if a long time has passed, inventory data should be updated prior to initiating specific projects. The best type of inventory is that which is forward-looking.

The forward-looking inventory (for sediment):

1. is predictive
2. is a systematic, repeatable, semi-quantitative single pass inventory that identifies, quantifies and prioritizes future sediment delivery sites
3. develops logical and effective erosion control and erosion prevention treatments
4. prioritizes sites for treatment (treatment immediacy) based on erosion potential, potential sediment delivery, treatment cost-effectiveness and other variables
5. produces a final product (plan) that contains all elements needed to identify, quantify, prioritize and implement erosion control and erosion prevention work

If aquatic resource conservation is a goal, which is often the case, it is best to focus on future sources of sediment delivery. The first step in the inventory is to determine what road(s) need to be inventoried. This is also highly scale dependent. For example, a manager working across an entire USFS region may only inventory roads in key watersheds while a manger working within a sub-watershed may inventory the entire road network. Often air photos can be helpful in this step to identify “hot-spots” as well as “ghost” or “legacy” roads that have been abandoned and are no longer maintained. The second step is to conduct a quantitative survey of current and future road-related sediment sources. This should be done using a standardized data collection protocol and data form, preferably one that has been reviewed and accepted by regulatory agencies (e.g., http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp), that employs systematic, repeatable, and quantitative data collection and measurement techniques. Models that are coupled to the road inventory (e.g., GRAIP – see sidebar) can also facilitate a forward-looking assessment by predicting which areas are likely to pose a high risk to aquatic systems. Such models can also be useful when large areas need to be assessed and as monitoring tools that can provide quantitative evaluation of treatment effectiveness.

Road-related sediment delivery sources are usually located at stream crossings, landslides, and where road surface runoff is directed into stream channels. *A road location with erosion but no future sediment* *delivery is not an "erosion site" that needs to be inventoried or treated for the protection of water quality or aquatic habitat*. Inventories should include data on the following:

1. stream crossings
   - culvert capacity (100-yr+)
   - plugging potential
   - diversion potential
   - site erosion (streambanks, fillslopes, etc)
2. road-related landslides
   - potential road and landing fill failures
   - debris slides from steep swales
   - larger deeper landslides
3. road surface runoff and related erosion
   - hydrologically connected roads and ditches
   - hydrologically connected gullies

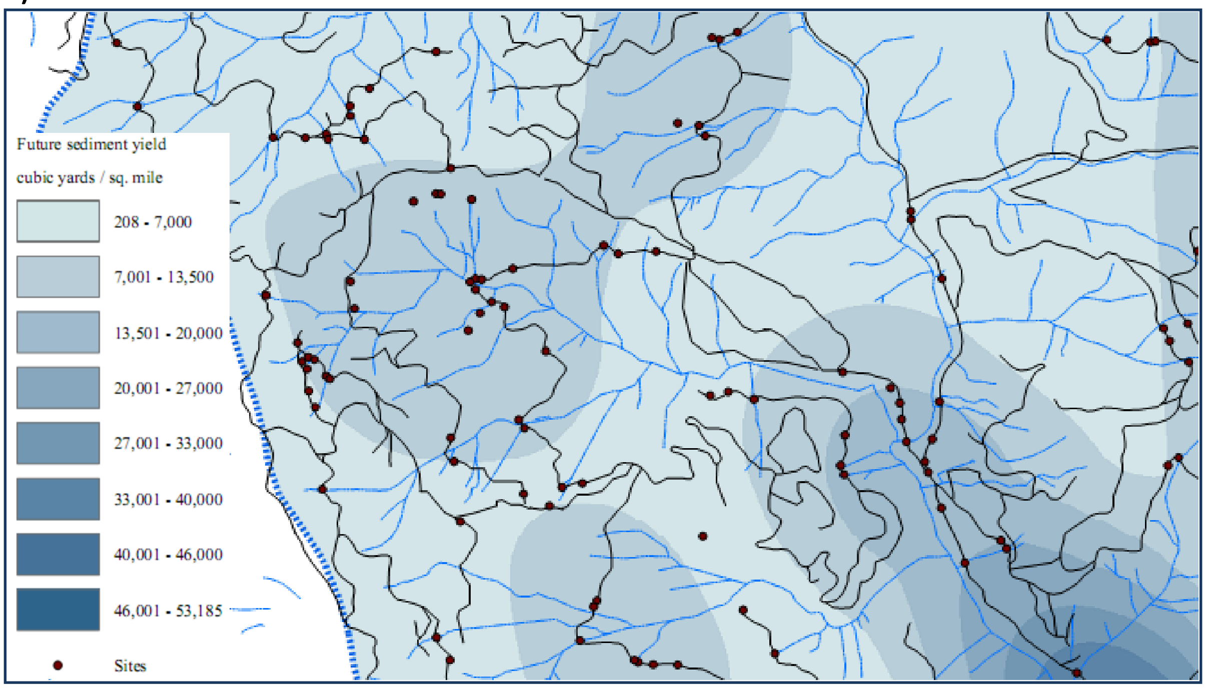
GIS mapping of specific sediment delivery sites that have been identified during the inventory can facilitate identification of spatial relationships among sediment-delivery sites and can increase overall efficiency in treatment prioritization (e.g., Figures 2a and 2b). If resources are limited, the inventory can be restricted to the most vulnerable watershed and hillslope locations (e.g., hydrologically or geomorphically sensitive areas). This will save money, but some key information may be missed.

Figure 2: GIS mapping of: (*images courtesy of William Weaver, Pacific Watershed Associates)*

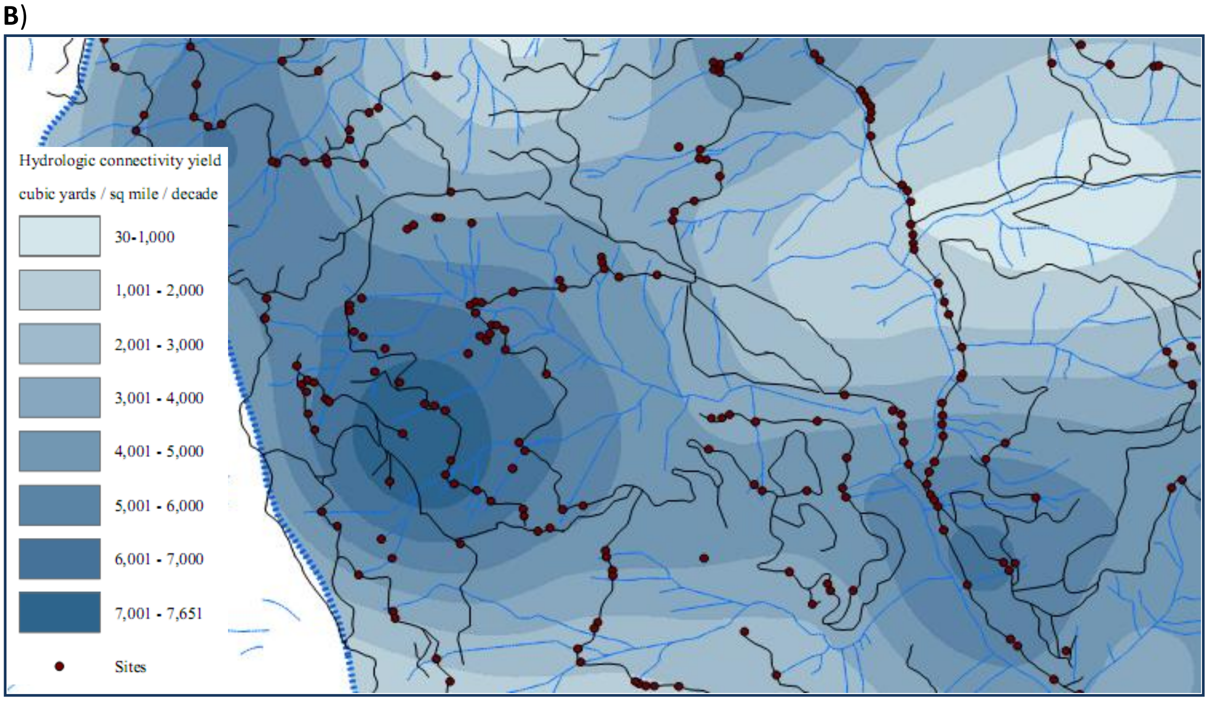
(**A**) Prioritizing high risk roads based on the density of future road-related *episodic* sediment delivery sites, North Fork Mad River, CA (yards^3/mile^2). Sites include stream crossings and potential road-related landslides:

(**B**) Prioritizing high risk roads based on the density of future road-related *chronic* sediment delivery from hydrologically-connected road reaches, North Fork Mad River, CA (yards^3/mile^2/decade)

A)



B)



Road Needs Assessment

Many factors will influence prioritization, including: (a) willing landowner(s); (b) forest management plans, including timber harvest planning, Habitat Conservation Plan (HCP) or other regulatory priorities; (c) cost-effectiveness of treatment; (d) biological priorities or level of threat; (e) water quality priorities; (f) transportation priorities (road use level); and (e) maintenance priorities. While it is impossible to describe every scenario, this section provides examples of common issues and options associated with roads that must be considered when determining road management priorities.

Forest management (forest harvest, restoration)

Harvest and removal of trees can be difficult, if not impossible, if an adequate road system does not exist. While it is possible to "drop and leave" trees for a restoration thinning operation, treatments of this type on commercial sized trees are generally rare for many reasons, but most often due to economic considerations and an unacceptably high fire risk. Thus, all road management decisions must be made in tandem with current and *future* forest harvest and restoration plans and legal requirements. If management is expected to occur within a short time frame (< 5 years) and/or if multiple entries are expected to be needed to meet forest restoration goals, it may be beneficial to maintain a functioning, intact road system to access the stand(s). This may entail significant road upgrades and maintenance to protect aquatic resources. If forest management is not expected to occur for several years, then a cost/benefit analysis of maintaining the road(s) should be conducted. Just because a road is not in use for an extended period of time is not sufficient reason to ignore maintenance and upkeep. If the road is kept, all necessary and regular maintenance should be conducted to ensure protection of aquatic resources. Depending on the level of risk that a road poses and the length of time it will be unused, measures such as replacing or removing all culverts, ripping the road surface, and removing unstable fill material may need to be done. If the road is a seasonal road that will not be used over the winter, when precipitation is heaviest, it should be "winterized," which includes adding waterbars and cleaning all culverts. The need to harvest or treat the forest stand should also be weighed with the risk of keeping the road. In many cases, new logging techniques may make it possible to harvest the stand from other nearby roads or short extensions

Including Climate Change in Road Management

- Climate change is ongoing and projected, but uncertain
- Likely impact of climate change: acceleration of global water cycle (NASA Global Water and Energy Cycle, 2000), leading to more climatic variability and more frequent/extreme floods, droughts, and fires
- Pacific Northwest is very likely to experience more extreme floods.
- Best way to adapt for climate change is to have resilient watersheds that resist adverse changes and recover quickly
- Most prevalent, appropriate treatment to achieve resilient watersheds in a wildlands environment: ***improve and decommission roads***
- We may need to re-think the way we calculate risk and "acceptable risk" when determining culvert sizes and likelihood of failures (i.e., planning based on 'known variability' in 100-year flood intervals may no longer hold).
- Must manage with uncertainty. The notion of "stationarity"- the idea that natural systems fluctuate within an unchanging envelope of variability - is more limited than before.

added to nearby roads on stable terrain may make it possible to still harvest the stand while enabling removal of larger segments of "high risk" roads in the stand. Forest engineers should be consulted to assess these options.

Fire management

Fire management is a major concern for many landowners and land managers and its implications for aquatic resources and road management involves tough trade-offs and decisions. Roads can often indirectly increase fire risk by permitting human access to fire-prone areas, thereby increasing the chance of human-ignited wildfires. In some areas, roads can also create drier, windier conditions that exacerbate conditions already favorable for fire. Finally, roads can also intensify post-fire run-off erosion and landslides that can severely damage aquatic systems. However, roads also provide access for firefighters to control wildfires and also act as fuel breaks that can slow or stop a fire from spreading. In many areas this act of fire suppression is believed to have increased the extent and frequency of high severity fires, which can, in some cases, have deleterious effects on aquatic systems. Despite calls for reduction of fire suppression in wildland areas, fires in close proximity to homes and developed areas will likely continue to be suppressed for the foreseeable future. If a fire breaks out and an adequate road system does not exist, crews will "re-open" roads that have been removed or closed. This often simply entails plowing through excavated stream crossings and dumping fill material directly into streams, directly counteracting the sediment controls that road-removal was intended to provide. In addition to fire-fighting, roads also provide access to forested areas that can be treated (e.g., with mechanical thinning or prescribed burning) to reduce fuel loads, restore more natural fire severity regimes, and prevent the need for costly, and often damaging, fire suppression efforts. Such treatments are becoming more common across vast stretches of western forests and will likely require low-impact access roads. Failure to coordinate fuel treatment and road management plans could highly jeopardize the success of both programs. These few examples highlight the need for a road management plan that is highly integrated with other land-use decisions. Thus, a landscape level perspective and future looking plan is necessary to establish a road network that reduces the risk of roads on aquatic resources while maintaining those roads most critical for fire management. An overall strategy is likely to include may involve decommissioning of unnecessary roads, re-routing of some roads to more stable and "lower risk" locations, and converting some roads to low-impact trails.

Human needs

There are many other human needs that also have to be carefully assessed when determining road management priorities. Access to public utility facilities (e.g., water treatment plants, dams, power lines) will have to be maintained, especially when facility operators have legal easements on roads accessing these sites. In some cases it may be possible to coordinate with the facility operators to cost-share some of the road maintenance or to re-align a road network on unstable ground to a more suitable location. Other private landowners in the area may also have interest in the road management plans, especially if they have easements on the roads that are needed to access their properties; efforts to engage these landowners early in the process and establish clear communication is important in building trust and collaboration for road management activities. Recreational interests (camping, hiking, biking, fishing, hunting, ORVs) and access to cultural resources are also necessary considerations. Determining these needs can often lead to contentious debates, especially on public lands; sorting out these needs will likely require numerous public meetings combined with out-reach and education efforts. Again, early engagement and clear communication are key for building trust and cooperation. Current and future research and monitoring plans should also be considered when removing roads. Converting roads to trails to maintain a relatively accessible "hike-in" option should be considered when access to an area is needed or desired, but the road poses a high risk to other resources.

Examples of Goal and Priority Setting for Different Scales and Ownerships

Due to the numerous factors involved in goal setting and prioritization, it is impossible to prescribe a single "best approach". Examples highlighted below, though, illustrate different approaches to road management prioritization according to different scales, ownerships and management objectives.

EXAMPLE 1 - Region scale: ***U.S. Forest Service - Region 6***

U.S. Forest Service (USFS) Region 6 encompasses all of Washington, Oregon, and portions of Idaho, Nevada, and northern California. In total, the area holds 50% of the Pacific Northwest's water supply (over 90,000 miles of streams), 25 million acres of land, and over 100,000 miles of roads. The most significant problems on USFS lands in this region are impaired water quality and water quantity, as well as severely declining fish populations; hence, at this regional scale, prioritization for road management is on aquatic conservation and the focus is on determining the highest priority basins (Figure 3). At this broad scale, modeling is essential and requires accommodation of: (1) integrated aquatic priorities, (2) whole river basins, (3) quantitative data, (4) various scales. The model should include socio-economic considerations and at least three ecological elements: (1) resource conditions, (2) basin sensitivity, and (3) management threats (e.g., road density, consumptive water use, etc.). Resource conditions are evaluated by examining physical and biological indicators. Physical indicators include: "key watersheds", as defined by the U.S. Forest Service Northwest Forest Management Plan (NWFP; Record Of Decision 1994), percentage of basin protected, and number of impaired streams. Biological indicators include native fish biodiversity and number of healthy fish stocks. Basin sensitivity also evaluates physical and biological indicators. In this case, physical indicators include surface erosion risk and mass erosion risk while biological indicators include federally listed species. This high-level regional planning must then be integrated into forest-level and district-level planning efforts for watershed protection and habitat restoration.

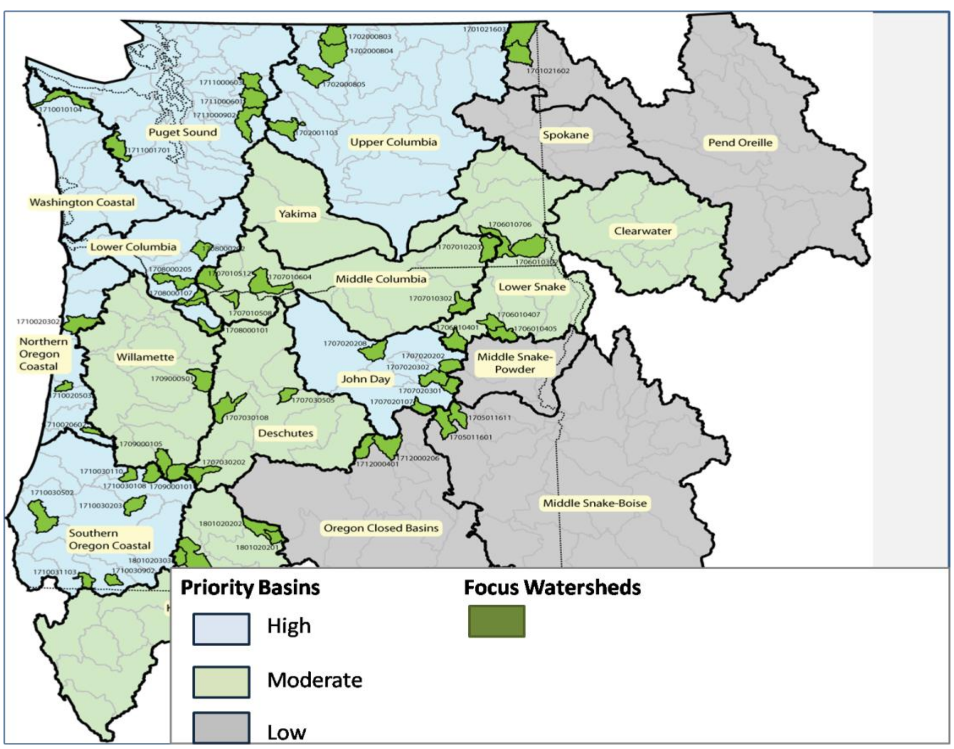


Figure 3. Priority basins and focus watersheds for aquatic restoration, USFS Region 6 (USFS 2005)

EXAMPLE 2 - Forest scale: *Olympic National Forest*

Olympic National Forest (ONF) falls within USFS Region 6. It covers 632,000 acres, has 910 miles of fish-bearing streams, and 2,200 miles of roads. Road management objectives at the forest-scale must be integrated with the regional objectives using a process similar to that described for Region 6, but must also take into account interest of local stakeholders and more site-specific information. On the ONF, a road assessment determines (a) what geologic processes are at work (b) what landscapes the geologic hazards exist, (c) where there is connectivity of roads with the aquatic system and (d) the characteristics of earth materials involved (e.g., fine lakebed sediments or coarse glacial outwash materials). This information is incorporated into a Road Management Strategy (RMS) model that evaluates: (a) geologic hazard (% of road segment within geologic each hazard area); (b) potential for delivery of sediment to fish habitat; (c) stream crossing density (stream crossings/mile for each road segment); (d) riparian zone proximity (% of road segment within 50-meters of the stream); and (e) upslope hazard (amount of area above the road segment with hazards upslope). These assessments are then overlaid with assessments of aquatic value and high value watersheds.

Accurate road inventories and data on aquatic habitat as well as powerful spatial tools (see side-bar) are critical to these assessments. Once the road analysis is complete, this information is then used to prioritize road segments for different types of management actions that may include repairs, upgrades, and decommissioning. Public meetings are held throughout the process and all analysis is fully disclosed to engage public stakeholders in the decision making process.

ROAD MANAGEMENT TOOL-BOX

Many spatial tools and models are used by agency scientists and other land managers to evaluate the impact of roads on watersheds and to assist with watershed and road analysis and road inventories.

A few examples include:

GRAIP: Geomorphic Road Analysis and Inventory Package. GRAIP is a set of tools for analyzing the impacts of roads on forested watersheds. It combines a detailed road inventory with a GIS analysis tool set to predict road sediment production and delivery, mass wasting risk from gullies and landslides, and road hydrologic connectivity. *http://www.fs.fed.us/GRAIP/index.shtml*

SEDMODL2: Sediment Model 2. SEDMODL2 is a GIS-based road surface erosion and delivery model designed to identify road segments with high potential for delivering sediment to streams *http://www.ncasi.org/Support/Downloads/Detail.aspx?id=5*

WEPP: Watershed Erosion Prediction Project. WEPP is a complex computer program that describes the processes that lead to surface erosion, including infiltration and runoff; soil detachment, transport, and deposition; and plant growth, senescence, and residue decomposition *http://forest.moscowfsl.wsu.edu/fswepp/*

NetMap: NetMap is a powerful spatial watershed analysis application that can be used to examine spatial relationships among watershed processes, aquatic habitat, and anthropogenic activities/influence (e.g., roads). It incorporates WEPP technology. *http://www.netmaptools.org*

EXAMPLE 3 - Watershed scale: *Cedar River watershed*

Cedar River watershed is a 92,000 acre watershed located in the Cascade Mountains of Washington and is the municipal water supply for 1.3 million people. It has 546 miles of roads, many in poor condition. Despite a history of extensive logging and road building, the watershed still has relatively clean water, but has several ESA listed species (e.g., Chinook salmon, marbled murrelet, bull trout). In 2000, a Habitat Conservation Plan (HCP) was created for the watershed that charted an agreement to conserve and restore the watershed while ensuring the required water supply. The HCP outlined many upland and aquatic conservation and restoration goals, including:

1. Maintain and restore natural connectivity within and/or between forest patches that are old growth or high quality second growth (*upland*)
2. Maintain and restore natural connectivity within special habitat types (e.g., talus slopes, meadows) (*upland*)
3. Reduce delivery of fine sediment from roads to streams (*aquatic*)
4. Maintain amphibian habitat connectivity between wetlands and adjacent forests (*aquatic*)
5. Reduce landslides triggered by roads (*aquatic*)
6. Maintain natural hydrologic flow paths and reduce hydrologic connectivity between roads and streams (*aquatic*)

The impacts of roads on these goals are evaluated at the watershed scale by performing a roads analysis. Information needed for this analysis includes: road abandonment costs, road improvement costs, location of high priority access areas (e.g., tribal huckleberry fields, dams, gauging stations, fire control zones), plan for institutional use of road (e.g., forest management, monitoring needs), operational constraints, legal constraints (state-required Road Maintenance and Abandonment Plans, HCP commitments), and spatial data for fire hazard risk, forest and aquatic restoration sites, research and monitoring sites, watershed protection, and cultural resources. This information is then used to assess which resources are most sensitive to road management or use and which roads have the greatest potential impact on these sensitive areas at a watershed scale. The first step of this process employs spatial tools to model each of the six goals and rank (High, Moderate, Low) areas according to resource sensitivity and road segments according to management impact/vulnerability. Roads are then ranked (scored) according to each restoration goal and for all goals total. Figure 4 illustrates this ranking system.

Road rankings are then integrated with management constraints described previously (e.g., forest management, dam access), costs for road management options are calculated, and a cost/benefit analysis is performed. This cost/benefit analysis is done through a value model developed by the City of Seattle and includes the following steps: (1) identify benefits of roads; (2) identify criteria for fitting roads into listed benefits; (3) determine weighting factors; (4) compare environmental impacts and the use and benefit of roads at multiple scales; and (5) develop costs associated with road management (including upgrade) activities. Maps are then generated showing different road options at the landscape scale and a check is done to ensure that no orphaned road segments are left and access to all high priority sites/areas is maintained. If benefits/costs of keeping roads exceed decommissioning costs, it is kept; if benefits/costs of keeping road are less than decommissioning costs, it is planned for removal. As is obvious, the process involves many conflicting and competing needs and while it provides a great starting point, <u>comprehensive road management in the watershed means recognizing the need for an iterative process, open dialogue and information exchange among watershed stakeholders, road users, managers, and scientists, and adaptive management that adjusts as values, information, and resources change</u>.

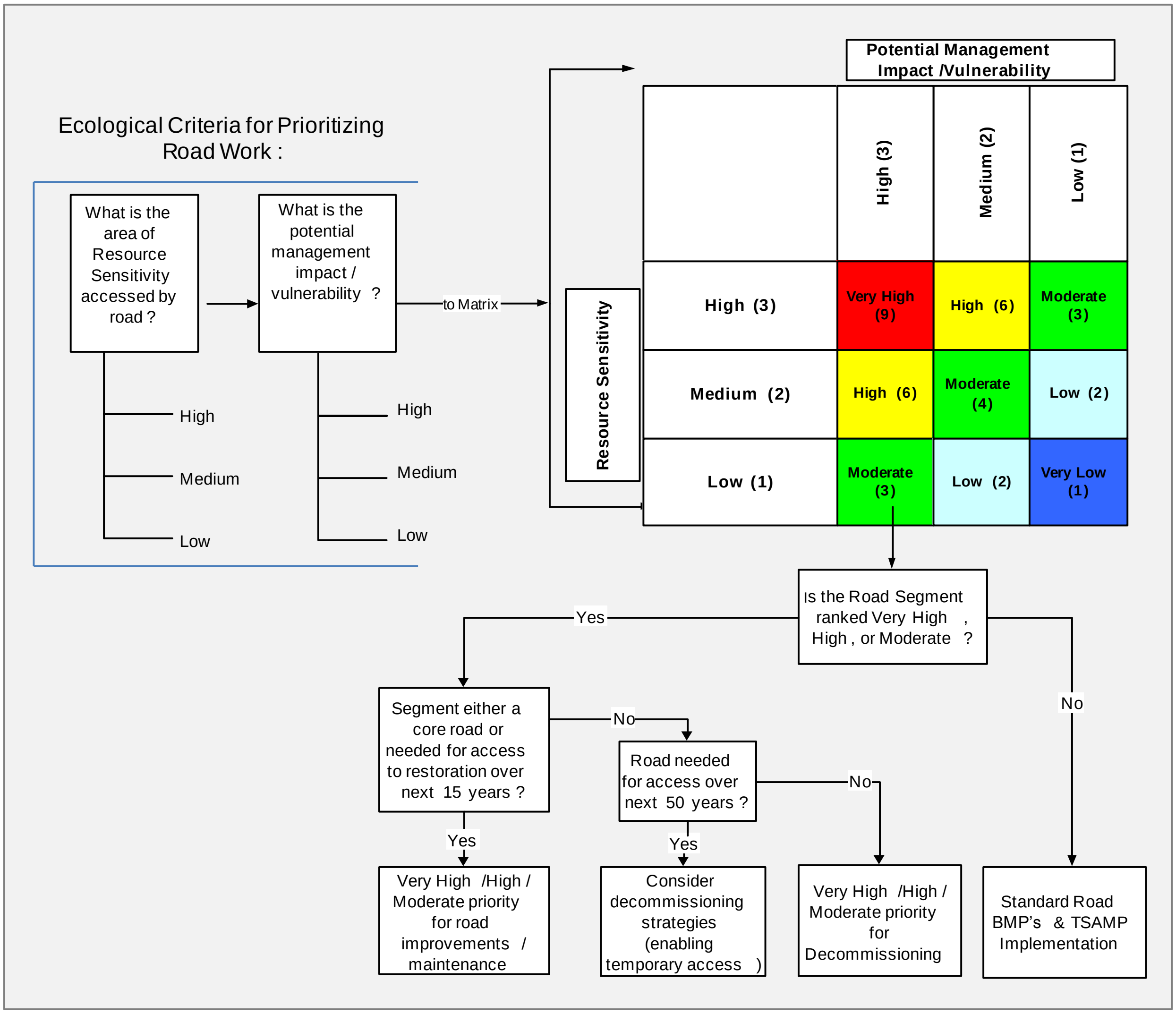


Figure 4. Diagram of ranking system used prioritizing road management for Cedar River watershed.

EXAMPLE 4 - Sub-watershed: *Ellsworth Creek*

Ellsworth Creek is a 5000 acre watershed owned solely by The Nature Conservancy (the Conservancy). The Ellsworth Creek watershed nests within the larger Naselle River watershed and is part of the Conservancy's 8,200 acre Ellsworth Creek Preserve. The Conservancy purchased the land in 1999 from numerous private landowners, thus consolidating ownership within the watershed. The Ellsworth Creek watershed contains a 300 acre patch of old-growth forest, holds approximately 22 miles of fish-bearing stream, and had 62 miles of road upon purchase by the Conservancy (several miles have since been removed). The Conservancy's primary goals for the watershed include: (1) restore ecologically functional estuarine, freshwater, and upland forest habitats that support species and ecological processes representative of those found within unmanaged late-successional forest landscapes of the Pacific Northwest coast; (2) develop and implement restoration strategies that accomplish ecological goals in a cost effective manner; (3) maximize opportunities for learning how coastal forest landscapes respond to restoration treatments; and (4) manage the preserve with exemplary stewardship that earns respect and builds productive relationships within the local community and amongst resource management partners. Thus, long-term stewardship, restoration, and research/monitoring needs dictate road management within the watershed. A complete road inventory was conducted upon purchase of the lands and roads were ranked according to geologic stability, risk to old-growth forest habitat, and risk to aquatic systems. Roads that disconnected old-growth habitat or were considered to be an "imminent high risk" for triggering landslides and debris flows that would deliver material directly to the stream network were immediately scheduled for decommissioning. Due the previous mixed ownership condition of the watershed, many roads had been "duplicated" to reach similar areas on opposite sides of the property line and/or had been built in unsuitable locations due to property lines and access rights. Upon consolidation of the property, Conservancy staff assessed roads for redundancy and for opportunities to re-align the road network. In some cases, building small segments (<0.5 miles) of new road in more stable locations permitted removal of several miles of unstable, high risk roads. While single ownership made this possible at Ellsworth Creek, it illustrates that looking and working across property lines may, in some cases, offer opportunities to reduce the amount of roads on the landscape, share road management costs, and minimize ecological impacts of roads.

Road Management Options and Strategies

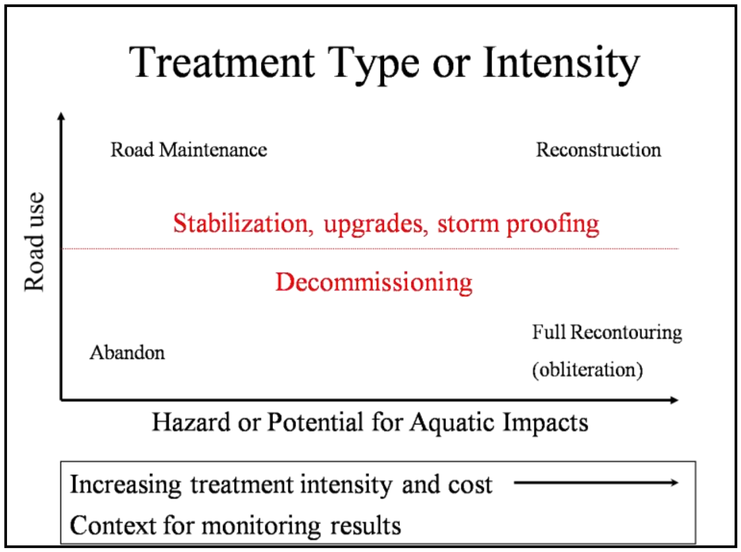


Figure 5. Diagram of treatment options (*Figure courtesy of: Bill Shelmerdine, Olympic National Forest)*

Once road management goals and prioritization are defined, treatments can be designed and implemented. These treatments can vary from storm proofing upgrades, to full road obliteration/recontouring (see Figure 5). Road abandonment is not technically a 'treatment' and is only an option when the outcome would be the same as road decommissioning (no future threat to aquatic systems). Specific techniques for most treatments are highly technical and require people knowledgeable not only with road engineering and equipment operation but also in the local site conditions, including geology and hydrology, and the biological systems likely to be impacted. Thus, discussion of specific techniques is beyond the scope of this paper, but information can generally be obtained from experienced road engineers and contractors in consultation with resource specialists (e.g., earth scientists, hydrologists, biologists) and from references provided in the "Technical Notes" of this paper. This section instead provides a broad overview of considerations, tips, and strategies for road upgrades and decommissioning that can increase the positive impact of comprehensive road management on watershed restoration efforts.

Road Upgrades

As the examples above illustrate, the fiscal, operational, and social constraints that bind road management decisions denote a critical reality: even if all "unnecessary roads" are removed, many roads in most watersheds, including some "high risk" roads, will likely be maintained for future management and societal needs. Thus, road upgrades are a vital component for most watershed restoration programs. There are several reasons why road upgrading should be included in watershed restoration plans, including: (a) open, maintained roads are the most common category of roads in a watershed and often generate and deliver large volumes of sediment to streams; (b) many maintained

Road upgrading and maintenance are vital, but often overlooked and underfunded, components of watershed restoration

For example, approximately 40% of the typical forest road network on inventoried National Forest Lands in the Pacific Northwest has been found to be hydrologically connected to the streams. Upgrading roads to reduce this connection can result in significant reductions of fine sediment delivery to streams (Weaver, 2009).

roads were built decades ago to now-outdated standards and have weak points that are susceptible to failure; (c) most culverted stream crossings have undersized pipes and many have a diversion potential - an especially risky problem if flood events become more frequent/severe with climate change; and (d) many maintained forest roads have high levels of hydrologic connectivity and associated fine sediment delivery. Consequently, common sediment control objectives for road upgrading include: (a) reduced slope failure potential and magnitude; (b) reduced road-related sediment delivery; (c) reduced cost of storm damage repair; and (d) reduced time that roads are "out of service" after storms (i.e., fewer and smaller washouts and road failures). A forward-looking inventory, such as that previously described, is also essential for identification, quantification and prioritization of road upgrade sites.

Five treatment mantras for road upgrading:

1. **Treat sites of <u>current</u> and <u>future</u> sediment delivery**. Just because it was a site of erosion in the past, does not mean it still is (the risk may now be gone). Don't treat sites of past erosion unless they have potential to erode and deliver sediment in the future.
2. **Differentiate between erosion and delivery**. Even if a site is eroding, it may not be delivering sediment to a stream channel; if the primary goal is to protect and improve aquatic conditions, and if it's not *delivering* sediment, then it should not be a top priority for treatment.
3. **Treat the cause, not the symptom.** For example, do not simply apply treatments to an active gully in an attempt to control erosion; instead, determine the source of the water that is causing the gullying, and then cutoff or disperse that source to eliminate the cause.
4. **If you don't change anything, it's just going to happen again.** For example, cleaning a culvert is a short-term solution, but is not addressing the cause of the culvert plugging. The culvert may be too small or there may be too many organic materials routing to the culvert; solutions may include enlarging the culvert, adding a flared inlet, or installing a debris barrier.
5. **Prevent erosion before you have to try to control it. It is usually easier, less expensive and more effective to prevent a failure from occurring than it is to stop a failure once it has started. Many failures occur too rapidly to be controlled.** Thus, **i**nstalling a debris barrier to prevent culvert plugging is much cheaper and more effective than repairing a blown out road or trying to mitigate the harm that has occurred to fish and other species.

The documents listed in the "Technical Notes" section should be consulted for a more comprehensive overview of road upgrading strategies and techniques, but below are a few simple strategies that should be considered when conducting road upgrades that can help make projects more efficient and effective, including:

1. When possible, use bridges rather than culverts when fish passage is a concern.
2. Install culverts in-line with the natural channel; vertical and horizontal culvert alignment is critical to preventing culvert plugging and failure.
3. Emergency overflow culverts can be installed higher in the fill in deep, high risk stream crossings. This can help relieve ponded water if the main culvert plugs and thus prevent washout or diversion. Sometimes the main culvert is not the appropriate size but the land owner does not want to replace it or cannot afford the cost of the needed upgrade.

4. Consider installing debris barriers at culverts that are prone to plugging. Even with emergency overflow culverts, most culverts fail due to plugging by organic material and sediment, not because flood water exceeded their capacity (even during the 100-year flood). However, these MUST be installed properly or even greater problems may arise!
5. Consider use of accessories that can increase the function of culverts and reduce risk of failure (e.g., drop inlet/settling basin, trash rack, flared or beveled inlet, etc.). Again, proper installation is critical!
6. Use critical dips at culverted stream crossings to eliminate the risk of stream diversion. These should be located at or near the down-road hingeline of the fill to reduce failure magnitude and can be extremely effective in reducing failure magnitude and damage even when culverts plug.
7. Armored fill crossings can also be used at culverted stream crossings to reduce failure potential and erosion.
8. Treat unstable fillslopes ("sidecast") *only* if it's going to deliver to streams. It may have a long way to go before it gets to stream and if it will not impact the stream, the costly treatment may not be warranted. Unstable road and landing fillslopes are often caused by "sidecasting" onto steep slopes (taking material from roadway and pushing it onto the downslope hillside during road construction or maintenance). This unstable fill material combined with redirection of flows can lead to debris flows and usually requires treatment via direct excavation of the unstable materials.
9. Cutbank erosion should be assessed for its threat to water quality and aquatic resources before treating. It is often a lower priority, but cutbank can plug ditches and trigger cascading downslope effects (e.g., gullies and fillslope failures).

Road Decommissioning: Working with the Contractor

Successful road decommissioning projects depend upon high quality ground work, generally undertaken by a skilled, private contractor. Thus, for the project to be successful, it must start with clear, open communication between the site manager and the contractor that establishes a comprehensive relationship based on a mutual understanding of project goals and objectives. In developing the goals and objectives, it can often be helpful to prepare a model or visual description of existing conditions versus desired conditions to ensure that the contractor and site manager have the same vision for the project prior to beginning work. A detailed road log of treatments then provides the contractor with an understanding of the details of the project scope and how that vision can be achieved. Involving the contractor in this way helps to ensure that the contractor feels ownership over the results and is more likely to do a complete and thorough job. When sufficient details are not given to contractor, or they are unaware of the goals and purpose of the project, ecological resources could be placed at greater risk.

The best contractors gain a basic understand the geomorphic processes involved, the geology of the area, and the science behind the project. It is important that the contractor have the opportunity to become familiar with site-specific conditions prior to beginning work and be allowed to work with the project manager to adjust the work plan accordingly. Many site conditions can only be seen by walking the ground and the streams (i.e., information that will *not* be represented in inventory) and many site conditions will only become apparent when excavations are underway. The contractors should know where seeps and springs are so they do not cause instability later and they should also know where "stream crossings" *should* be (i.e., not all stream crossings on roads are located where they should be. If natural hillslope drainage points are not reconnected, they can lead to on-site or downslope problems later).

Highly skilled and well-trained equipment operators are also essential for a successful project, both for implementation as well as project safety. Equipment operators must be properly trained in road decommissioning and have experience working in steep, hazardous conditions. They *must* know the capabilities and limitations of the equipment on specific terrain, including what it can do, where it can go, and how to get it out. Experience running the same equipment on non road-decommissioning projects or less severe terrain does not translate. Importantly, equipment operators, especially the excavator operator, must be able to envision the end product of their work and be able to think several steps ahead in their earth moving activities. They must also possess an intrinsic understanding of those working around them. Inexperienced operators can be dangerous and expensive; if safety is not top priority, things can go very wrong, even resulting in injury or death. In the end, a well-trained crew can reduce costs due to their efficiency, attention to safety and a lower level of required supervision.

Contracting tips for successful projects

1. Allow contractors to familiarize themselves with the site and local conditions.
2. Involve contractors early in the process (e.g., planning phase) if at all possible.
3. Develop a clear, concise contract that articulates goals, objectives, and a work plan that is mutually understood and agreeable to both the site manager and the contractor.
4. Be sure the work plan provides clear instructions and guidelines for contract administration but also allows flexibility to adjust work if unexpected changes in conditions occur.
5. Be sure to include specific instructions for invasive species control, if needed (e.g., washing and cleaning of equipment).
6. Ensure that both the contractor *and* ground personnel are familiar with the goals/objectives as well as limits and details of individual work items.
7. Provide frequent oversight of on-going project work using technically experienced and competent contract managers/supervisors.

Road Decommissioning: A few "Best Management Practices"

In addition to the many recommendations already discussed, there are a few additional tips that are generally good to follow for most road decommissioning projects, including:

- Closing or abandoning roads is ***not*** "decommissioning." Simply closing a road by gating it or installing a barrier does not eliminate risk of road failure or chronic sediment inputs. Roads must be hydrologically disconnected from streams and points of potential failure must be eliminated. If resources are scarce, the road should be maintained properly until resources to decommission it correctly are available. Some protective measures (e.g., emergency culverts, trash barriers) may be installed to lessen risks or problems until it can be decommissioned, but simply closing a road and walking away from it is not acceptable management.

- Cascading failures can occur on roads in some steep watersheds. For example, on the Clearwater National Forest (Idaho), many cutslope failures led to fillslope failures which then resulted in landslides that impacted the stream system. In Rogue River/Siskiyou National Forest (Oregon), severe storms in 1996, plugged culverts caused stream diversions and triggered debris torrents that in turn caused major stream diversions that created immense gullies in the lower watershed. Road decommissioning can be performed in a number of different ways and intensities, from minor treatments to full road obliteration and slope recontouring. No one decommissioning methodology is correct in all situations, but the most effective method is one that accounts for the expected post-decommissioning erosion threats as well as the cost-effectiveness of the proposed treatments.
- Practice conservation of resources (e.g., save salvaged rock to use for future projects; use buried logs and on-site organic debris to mulch bare slopes; integrate with fuels reduction treatments and use removed fuel material to mulch bare ground)
- Successful revegetation and restoration of site productivity generally requires ripping of the road surface to decompact the soil; hence, don't just remove stream crossings, but also rip the road surface and provide for dispersed road surface drainage by outsloping or cross road drain construction.
- Revegetating sites and minimizing weed invasion are common problems encountered. Some techniques for addressing these issues include:
    - Plan and budget accordingly for revegetation and weed management.
    - Minimize disturbance of existing vegetation on stream banks and hillsides; it is less area that has to revegetate and fewer opportunities for invasive species to populate.
    - Use excavated plants for restoration of ground slopes (e.g., ripped road surface, stream banks). These species are inoculated with mycelium from the area and are best suited to the soil and site conditions; thus they have the best chance for survival.
    - Mulch bare soils with locally derived trees, slash, limbs, brush and native, locally-derived organic debris. In addition, or alternatively, spray site with compost (*good idea in theory but often logistically difficult; also compost often has non-native seed contaminants).* Plant trees, if needed, to provide for a well dispersed future forest.
    - If local materials are scarce, cover site with weed-free straw or duff (slash, organic materials) to stabilize soil and allow natural seeding and/or plant with a weed-free seed mix (*note that even "weed-free" straw and seed mix is often contaminated with weeds)*. Planting with annuals or other "desirable non-natives" that quickly capture the site, stabilize soil, and are then out-competed by native vegetation is a relatively new technique that is still being evaluated.
    - If a weed problem arises, evaluate the risk that is posed before rushing to treat it. Many non-native species will die back as trees grow and shade increases. In some severe cases (e.g., knap-weed), a pre- and post-treatment herbicide application followed by quick planting of conifers may be necessary.

Road Management: Making it Happen

While the treatment types and technical specifications are often similar among ownership types, the costs, social considerations, and funding options often differ. These factors can often constrain management options, but they can also catalyze innovative funding strategies and partnerships.

Costs

Public land managers must often conduct lengthy and generally costly environmental impact assessments of road-related activities in compliance with federal and state environmental protection laws (e.g., National Environmental Protection Act; State Environmental Protection Act). While private landowners may be exempt from these types of public reviews, they generally must comply with all legal requirements of federal and state laws that govern forest management, water quality, listed species, and cultural or other sensitive resources. Some states (e.g., Washington) have forest practice regulations that require plans for road maintenance and abandonment on private lands. Other road management costs (e.g., development of rock sources for roads, contractor licensing requirements) can also often differ between private and public lands depending upon regulatory frameworks and social environment.

Social considerations

Road management on public and private lands is similar in that it needs to incorporate the input of landowners in close proximity to the road work or people who will be impacted by the work (e.g., recreationists, affected neighboring landowners, etc). Generally, on public lands, public meetings that include an open, transparent analysis that discloses all reasons for the prescribed management can help to win public support for projects. Landowner and community education programs can also help increase support for road management projects by educating people on road issues, road-related risks, and benefits incurred through different road management options. On private lands, the social element can be easier or more challenging, depending on the owner's reputation in the community and their willingness to take actions that minimize impacts to neighbors. Private landowners also often have to contend with easements, either by neighboring landowners, public land managers, or public utility companies.

Funding

Funding is always a challenge, regardless of ownership type. Road management on federal lands, including planning, upgrading and decommissioning, has become more financially feasible in recent years due to the passage of the Legacy Roads and Trails Remediation Initiative (United States Congress 2008). Funds appropriated through this initiative are designed to reduce impacts of forest roads and trails on drinking water and habitat for threatened, endangered, and sensitive fish species. For 2010, this initiative is funded at $90 million. While this is a significant improvement over the past when such funding was scarce, the serious backlog of road storm-proofing, road decommissioning and road maintenance on federal lands will require many years of funding at or above current levels to make significant advances. Funding road management on state-owned and private lands can be even more challenging. Grant sources are available, but these often have funding caps that limit project size (e.g., single culvert removals) or that restrict eligible projects to certain project types (e.g., fish passage), geographic areas or species-specific habitats (e.g., only watersheds containing coho salmon). Funding for comprehensive road planning and large-scale projects (e.g., road re-alignment, road storm-proofing or full road decommissioning or obliteration) is generally limited. Increasing and developing financial incentives and public and private funding sources for work on private lands will be critical to advancing watershed restoration in the future; private coastal forestlands contain some of the most biologically productive salmonid rivers and streams in the Pacific Northwest. Ideas for these incentives include: federal/state/county tax reform; conservation easements; stewardship certification and marketing; and cost share programs.

Partnerships

Funding limitations combined with the need to address road management across all ownerships in a watershed have prompted growth of private/public/tribal partnerships in road management projects. These partnerships can provide a suite of benefits including building trust and cooperation (especially if collaborative efforts start on mutually agreed upon “high priority” projects), fostering long-term stewardship among land owners that is critical for long-term restoration success, and opening doors to innovative funding opportunities, such as cost-sharing partnerships (e.g., use of road engineers from public lands and rock materials from private land). Successful partnerships often allow stakeholders to access more diverse pools of funds and resources while accomplishing mutually agreed upon ecological goals. The two examples below illustrate benefits of these partnerships.

EXAMPLE 1: ***The Nature Conservancy and the U.S. Fish and Wildlife Service***

The Nature Conservancy (the Conservancy) is partnering with the U.S. Fish and Wildlife Service (USFWS) to remove approximately 29 miles of road in the South Willapa Bay Conservation Area (SWBCA) by 2016. SWBCA is a 15,000 acre area comprised of the Conservancy’s Ellsworth Creek Preserve and USFWS’s Willapa National Wildlife Refuge. The area is managed for restoration and conservation under a joint forest management plan developed by the Conservancy. The partnership has strengthened both parties’ ability to compete and acquire grant and appropriations funding. They are also using funds, acquired by the Conservancy, to train USFWS equipment crews in road decommissioning. These properly trained crews are now helping to decommission several miles of road across the joint properties.

EXAMPLE 2: ***Clearwater National Forest and the Nez Perce Tribe***

Partnership between the Clearwater National Forest (CNF) in northern Idaho and the Nez Perce Tribe began in the late 1990s as the beginnings of the Nez Perce Tribe (NPT) Watershed Division coincided with the acceleration of the CNF Watershed Restoration/Road Obliteration program. The CNF and NPT are full partners in all phases of road-decommissioning projects, including planning and prioritization, road surveys, contract preparation and design, contract administration and inspection, and monitoring, with a cost share on all projects of approximately 50/50. This partnership has opened many doors for funding opportunities and partnerships with several diverse agencies and organizations, including Bonneville Power Administration, National Forest Foundation, Wildlands CPR, National Fish and Wildlife Foundation, and stewardship contractors. Together, the CNF and NPT have partnered on many road management projects ranging from road decommissioning to noxious weed inventory, prevention, and treatment, to monitoring and they have jointly removed over 600 miles of roads on the CNF since the partnership began.

Questions that Remain

A lot of research has evaluated the effectiveness of road-decommissioning, particularly for conservation of aquatic resources, over the past decade. Many studies have demonstrated positive ecological benefits of road decommissioning including decreased sedimentation and erosion (e.g., Madej 2001, Switalski et al. 2004, Cook and Dresser 2007). However, the direct biological impacts of road decommissioning on fish and other aquatic organisms, both short-term and long-term, have not yet been thoroughly explored. The effect of road decommissioning for many terrestrial ecosystems and species also remains an area where considerable uncertainty remains. Finally, new emerging questions regarding the role that road decommissioning can play in carbon sequestration through re-vegetation of roads and increased retention of soil carbon resulting from reduced landslides and soil erosion (Madej et al. 2010) warrant attention. More research is needed on carbon budgets for road decommissioning and possible ecological interactions (e.g., fire) that may offset some of these benefits. As more road decommissioning projects are implemented, seizing the opportunity to conduct experiments and incorporate biological monitoring will be important in providing information that will help managers evaluate costs and benefits associated with road decommissioning.

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