

Erosion at Decommissioned Road-Stream Crossings: Case Studies from Three Northern California Watersheds

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Abstract

Post-treatment erosion was observed for 41 decommissioned road stream crossings in three northern California watersheds. Sites were purposefully selected in order to characterize the nature and range of post-treatment erosional responses. Sites with the highest visible erosion were selected in order to better understand the dominant process and incorporate any lessons learned into future projects. Sites were also intentionally selected where post-treatment erosion appeared to be negligible, or excavation techniques were judged to have been fully effective at removing erodible material. In these cases, our objectives and methods remained identical, but we wanted to examine the conditions that led to the apparent negligible erosion.

Results are consistent with other findings in the region. Erosion volumes ranged from 1.5 m³ to 60 m³, or, 0.1 percent to 4.5 percent of the initial volume excavated during treatment. Erosion averaged 11 m³ per site or 0.4 percent of excavated volume in the Headwaters Forest Reserve and 21 m³ per site or 2.4 percent of excavated volume in Lacks Creek. Repeat monitoring of a sub-set of sites in the Headwaters Forest Reserve over subsequent years, indicates that 99 percent of post-treatment erosion occurs in the first year following treatment. Channel incision is the dominant process of sediment production from treated sites, accounting for 80 percent of observed erosion. In response, woody debris has been incorporated into recently excavated crossings with the intent of providing armor and roughness elements to reduce channel incision. At those sites where post-treatment erosion is apparently minimal, incision remains the dominant process of sediment generation and can exceed 20 m³. In some cases, excavation techniques were judged to be largely effective at removing erodible material, however, interstitial material stored between larger, more immobile clasts can produce surprisingly large erosion volumes as this material is winnowed away during higher flows.

Key words: erosion, road decommissioning, watershed restoration, sediment

Introduction

Removal of logging roads is an established method for reducing ongoing and potential sediment delivery to aquatic habitat sensitive to sediment inputs (for example, Madej 2001, PWA 2005). Across the redwood region of northern California, road removal programs implemented by a variety of landowners have resulted in substantial reductions in potential sediment delivery. For example, in the Redwood Creek watershed, for the period 1998 to 2000, road treatments have reduced the quantities of potentially deliverable road-related sediment by 58 percent

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in the lower portion of the watershed on National Park lands, and 18 percent in the upper two-thirds of the watershed³.

Several efforts in the northern redwood region have documented erosion following road decommissioning at road-stream crossings (*table 1*). Most of these studies have shown that channel incision is the dominant form of erosion to occur, followed by side slope failures and surface erosion. All of these studies have documented post-treatment erosion, with the bulk of the erosion occurring in the first winter following treatment (*table 1*).

The intent of this study is to examine post-treatment erosion at road-stream crossings to inform managers, project supervisors and equipment operators on project effectiveness. Site selection was intended to develop a series of case studies to explore the range of responses experienced at decommissioned crossings. In this paper, our specific objectives are to:

- 1) Describe the principal erosional processes at work.
- 2) Quantify erosion volumes in the years following treatment.
- 3) Assess the temporal distribution of erosion.
- 4) Quantify erosion quantities at sites where best management practices appeared to be met, but erosion was still evident.
- 5) Contemplate measures to reduce erosion from future treatment sites.

We compare our findings from BLM-managed lands to studies conducted elsewhere in the northern redwood region and offer suggestions for future investigative work.

Study sites

The Bureau of Land Management (BLM) manages land in the Redwood Creek, Elk River and Salmon Creek watersheds. Redwood Creek and Elk River watersheds are listed as sediment impaired under the Clean Water Act 303(d) listing process. The areas contain an extensive network of older logging roads. In addition, all three watersheds provide habitat for federally listed salmon and steelhead populations.

Headwaters Forest Reserve

The Headwaters Forest Reserve (Reserve) is located in the headwaters of Salmon Creek and the South Fork Elk River, both tributaries to Humboldt Bay in Humboldt County, California. The Reserve was established in 1999 (BLM-CDFG 2004) and encompasses 30 km² of mixed redwood and Douglas fir forest. Approximately 12.5 km² of the Reserve is old growth redwood forest with little road construction. Approximately 85 km of roads were constructed throughout the Reserve from the 1950s through the 1990s. Many of these roads were constructed along streams or geologic contacts where a natural bench was present.

A previous road assessment identified approximately 50 km of road in the South Fork Elk River watershed (PWA 2004). The assessment identified nearly 83,000 m³ of potentially deliverable road sediment. Of this, approximately 58,000 m³ was identified from 242 stream crossings (PWA 2004).

³ G. Bundros, Geologist, Redwood National and State Parks. June, 2011; personal communication.

Table 1—*Summary of studies investigating erosion at decommissioned road-stream crossings in northwest California.*

Author(s)	Location	# sites	Average erosion (m³)	% of excavated volume^a	Comments
Klein (1987)	Redwood Creek, Humboldt County	24	26.6	n/a	
Madej (2001)	Redwood Creek, Humboldt County	207	50	4.8	Incision and assoc. bank erosion most common
Klein (2003)	Upper Mattole River, Humboldt/Mendocino Counties	18	11.9	n/a	Channel incision 88% of observed erosion
PWA (2005)	Northern California	614	26	5	Incision greatest # of sites, surface erosion greatest volume
Cook and Dresser (2007)	Six Rivers National Forest	262	21	4.5	40% incision 60% bank failure
Keppeler and others (2007)	Caspar Creek, Mendocino County	25	24.6	4	83% of erosion after first winter
Maurin (2008)	Smith River, Del Norte County and Redwood Creek, Humboldt County	16	6.8	n/a	Noted need for further work on woody debris
PWA (2008)	Redwood Creek, Humboldt County	16	8.8	0.9	
Klein (2009)	Lost Man Creek, Humboldt County	30	14.7	0.4	15% of additional erosion following initial winter
Wilson (2008)	Headwaters Forest Reserve, Humboldt County	8	5.4	n/a	Incision 98% of observed erosion

^a Expressed as total eroded volume as a proportion of excavated volume. See Klein (2003) for discussion on various means of displaying erosion results.

Road removal efforts began in the Reserve in 1999, focused on those road segments with the greatest potential to deliver sediment. Over the period 1999 through 2010, 34 km of road have been decommissioned in the Reserve encompassing both the Salmon Creek and South Fork Elk River watersheds.

Lacks Creek

Lacks Creek watershed is a 50 km² tributary to Redwood Creek in Humboldt County, California. The BLM manages approximately 60 percent of the watershed

with the remainder in private ranch lands. Road assessment efforts have identified approximately 150 km of roads in the watershed with the potential to deliver approximately 150,000 m³ of material (Bundros et al. 2004). Over the period 2007 through 2010, 13.6 km of road have been decommissioned and 26.3 km have been upgraded along the 101 km of road on BLM lands in the watershed.

Methods

Site selection

Sites were selected in order to provide a series of “case studies” to inform managers, project supervisors and equipment operators on the range of erosional conditions experienced following crossing removal. Site selection was based on our intent of capturing instances of larger erosional responses in the hopes of avoiding such occurrences in the future. Sites were visited following the first winter after treatment. In the Reserve, a sub-set of sites were re-occupied to assess erosion in subsequent years.

Erosional processes

We considered three types of erosion during our site visits: channel incision, bank failure, and rill/gully erosion along channel sideslopes. In practice, we recognized that some bank failures were likely triggered by channel incision. Regardless, we recorded these as bank failures. At each site, we recorded eroded volume. No attempt was made to quantify what proportion of the eroded volume was delivered to the channel network.

Tapes and marked depth sticks were used to record linear dimensions of eroded features. Where erosion patterns were relatively uniform, such as channel incision throughout the crossing, we measured width at three to six cross sections through the site and depth at three to seven points along each cross section. Values were averaged for each cross section and multiplied by the length of the feature. Where numerous or complex erosional features were present, we divided the site into two or more separate erosional features and calculated erosional volumes. Individual erosion features < 0.5 m³ were not recorded.

Results

Forty two sites were assessed for erosion following treatment (*table 2*). At the Reserve sites, we revisited 19 sites from 2 to 10 years following our initial visit to determine the extent of any additional erosion.

Table 2—*Erosional responses from 41 decommissioned crossings on BLM-managed lands.*

Location	# sites	Average erosion (m ³)	% incision	% erosion occurring first year	% excavated volume ^a	Average drainage area (ha)	Average channel slope (%)
Lacks Creek	13	21	89	n/a	2.4	16.5	33.7
Headwaters Forest Reserve	28	10.8	68	99	0.4	20.7	25.5

^aExpressed as total eroded volume as a proportion of excavated volume. See Klein (2003) for discussion on various means of displaying erosion results.

Discussion

Erosional volumes

Our results are consistent with others in the region. Average erosion across the 10 studies reviewed and summarized in *table 1* was 19.5 m³ compared with the 21 m³ and 11 m³ observed in Lacks Creek and the Reserve, respectively. Expressed as a proportion of excavated volume, values also reflect the greater erosion in Lacks Creek. Readers are encouraged to refer to Klein (2003) for a discussion of various ways of expressing eroded volumes in context of either the site or watershed-scale sediment budgets. In short, we chose to express our erosion volumes in the context of excavated volumes due to reporting requirements and a lack of watershed-wide sediment budget data which would enable us to report the erosion volumes in the context of watershed-wide sediment sources.

We observed relatively large erosion volumes from sites where all appropriate treatment methods had been employed. Finished side slopes, channel slope and width through the site were appropriate for the setting. At one site in Lacks Creek, 54 m³ of channel incision occurred. This was the largest site by drainage area (168 ha). The channel developed on this terrain flows over boulders in excess of two meters diameter. Winnowing of remnant fill material from amongst the boulders and consequent incision upstream was the source of the eroded sediment. However, in our judgment, further excavation was not possible given the equipment on site. Any further reductions in potentially erodible volume would have come with great time and expense to dissect the material out from the boulder interstices.

We also note that a seemingly small incision notch over a long crossing can produce eroded volumes on the order of 2 to 6 m³. While “under excavation” is often cited as a reason for channel incision, our findings suggest that some amount of channel incision is unavoidable at many sites.

Temporal distribution of erosion

In the Reserve, we revisited 19 sites a second time 2 to 5 years after treatment. Five of the sites were visited a third time. Only four sites showed evidence of subsequent erosion and the erosion observed was <1 m³. Our results indicate that 99 percent of the post-treatment erosion occurs in the first winter following treatment. However, during our site visits in the Reserve, we noted that heavy re-growth in the years following treatment may have concealed some instances of subsequent erosion. However, we are confident that any larger erosional features (>5 m³) would likely have been detected. This is consistent with others who noted the bulk of erosion occurring in the first winter season (*table 1*).

The role of woody debris in erosion rates

In response to our findings, we have begun placing woody debris in the channel to arrest, or at least minimize channel incision. The effectiveness of wood placement on post-treatment erosion has not been systematically studied. Maurin (2008), working in Lost Man Creek, concluded that more work was needed on woody debris

placement strategies. His small sample size precluded any conclusions on the effectiveness of various placement strategies. Our initial observations suggest that wood placement may be least effective on areas of extensively sheared bedrock such as occurs in the Incoherent Unit of Coyote Creek. In these areas, channel incision leaves the wood ineffectively perched above the channel bed. In other areas, however, the placement of logs nearly perpendicular to the channel appears to create a series of storage compartments that effectively traps sediment eroded from upstream. We agree with Maurin (2008) that more work is needed in this area to determine the best strategies for incorporating woody debris into excavated stream crossings.

Conclusions

Our observations of erosion following the decommissioning of road-stream crossings add to a growing data set of regional observations. Both the volumes and style of erosion are consistent with others' observations in northwest California. Our results suggest that post-treatment erosion likely cannot be avoided and that channel incision is the dominant erosional response. Areas warranting further examination are treatment of crossings in areas of highly sheared bedrock and the best use of woody debris in these and other sites.

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