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Wood Recruitment to Streams

Mendocino Coast, California

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TEN MILE AND NOYO RIVER WOOD RECRUITMENT STUDIES: CONCLUSIONS

- Historical logging-related woody debris accounted for 49% of all wood storage in 17 km (11 mi.) of study reaches.

- Wood recruitment to streams is dominated by non forest mortality sources (i.e., bank erosion and streamside landsliding): 64% in Ten Mile and 85% in the Noyo River basins.

- Ninety percent of wood recruitment (by volume) occurs within 14 m (46') and 8 m (26') of stream edges respectively in Ten Mile and Noyo watersheds.

- Average wood jam age ranged between 30 and 40 years; average wood jam spacing ranged between 50 and 100 m. Wood transport (over the lifetime of wood in streams) is predicted to range between 150 and 1300 m depending on stream size. In headwater systems, only the lower 200 meters of channel are predicted to contribute wood to larger fish-bearing channels (transported wood should be only several meters long).

- Significant spatial variability of wood storage indicates that continuous channel surveys of 4,000 to 10,000 m or more (2.6 to 6+ mi) are necessary to estimate a reliable average value of wood loading. Natural variability in wood recruitment and storage over these length scales suggests that establishing regional targets for the purpose of conducting compliance monitoring for wood is questionable in the naturally dynamic and spatially heterogeneous riparian environments.

- Implications for sediment budgets and TMDLs:

Ten Mile Watershed

Field-based estimates of erosion by soil creep and streamside landsliding in the wood budget are 750% higher than those sediment sources estimated in the EPA Ten Mile "desk top" sediment budget and associated TMDL. This suggests that the Ten Mile TMDL has underestimated "background" sediment production by approximately 500% and overestimated the recent timber harvest contribution to sediment yields by approximately 300%. The implication is that the sediment budget and TMDL are not sufficiently accurate to base "allocated loads" or other quantitative measures of compliance for resource management.

Noyo River Watershed

Field-based estimates of soil creep are significantly greater (~500%) compared to the EPA Noyo River "desk top" sediment budget and TMDL. Consequently, the EPA TMDL may have underestimated background sediment yields by approximately 250% suggesting that the sediment budget and TMDL may not be sufficiently accurate to establish quantitative thresholds for monitoring or other related activities.

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1. What is a Wood Budget and What Information Does it Provide?

A wood budget is the woody debris equivalent of a sediment budget. Wood budgets make quantitative estimates of wood recruitment, wood storage, distances to sources of wood, wood decay (or loss), and wood transport. Wood budgets also are used to make estimates of rates of forest mortality, soil creep, bank erosion, and streamside landsliding. For further information on constructing wood budgets refer to Martin and Benda (2001) and Benda et al. (2003). Wood budgets have several uses in forest management including:

1. Estimate the role of historical and present-day timber harvest activities on wood recruitment and storage.

2. Estimate the relative importance of different recruitment processes on in-stream wood abundance, specifically from mortality, bank erosion, and landsliding. This may be important since most wood recruitment models focus only on riparian tree death or forest mortality.

3. Quantify where wood is entering the stream from the riparian forest (i.e., what distances away from stream margins).

4. Estimate the transport of woody debris in streams of various sizes.

5. Quantify the range of variability in wood supply and storage to evaluate the efficacy of conducting wood monitoring studies for regulatory compliance.

6. Estimate sediment production by soil creep, bank erosion, and streamside landsliding to support construction of sediment budgets or to evaluate the accuracy of existing sediment budgets and TMDLs.

This report contains a summary of the wood budgets conducted in the Little North Fork (LNF) Noyo River watershed, and Bear Haven and Redwood Creek subbasins located in the Ten Mile watershed, both catchments located close to Fort Bragg, California. The studies were commissioned by Mr. Stephen Levesque of Campbell Timberland Management on behalf of Hawthorne Timber Company and carried out by Lee Benda and Associates, Inc. of Mt. Shasta, CA during 2002 and 2003. 17.6 km (11 mi.) of stream were surveyed in the 3 study basins (Figure 1, Table 1). Additional details on the wood recruitment studies can be found in the original reports (Campbell Timberland Management 2002, 2004).

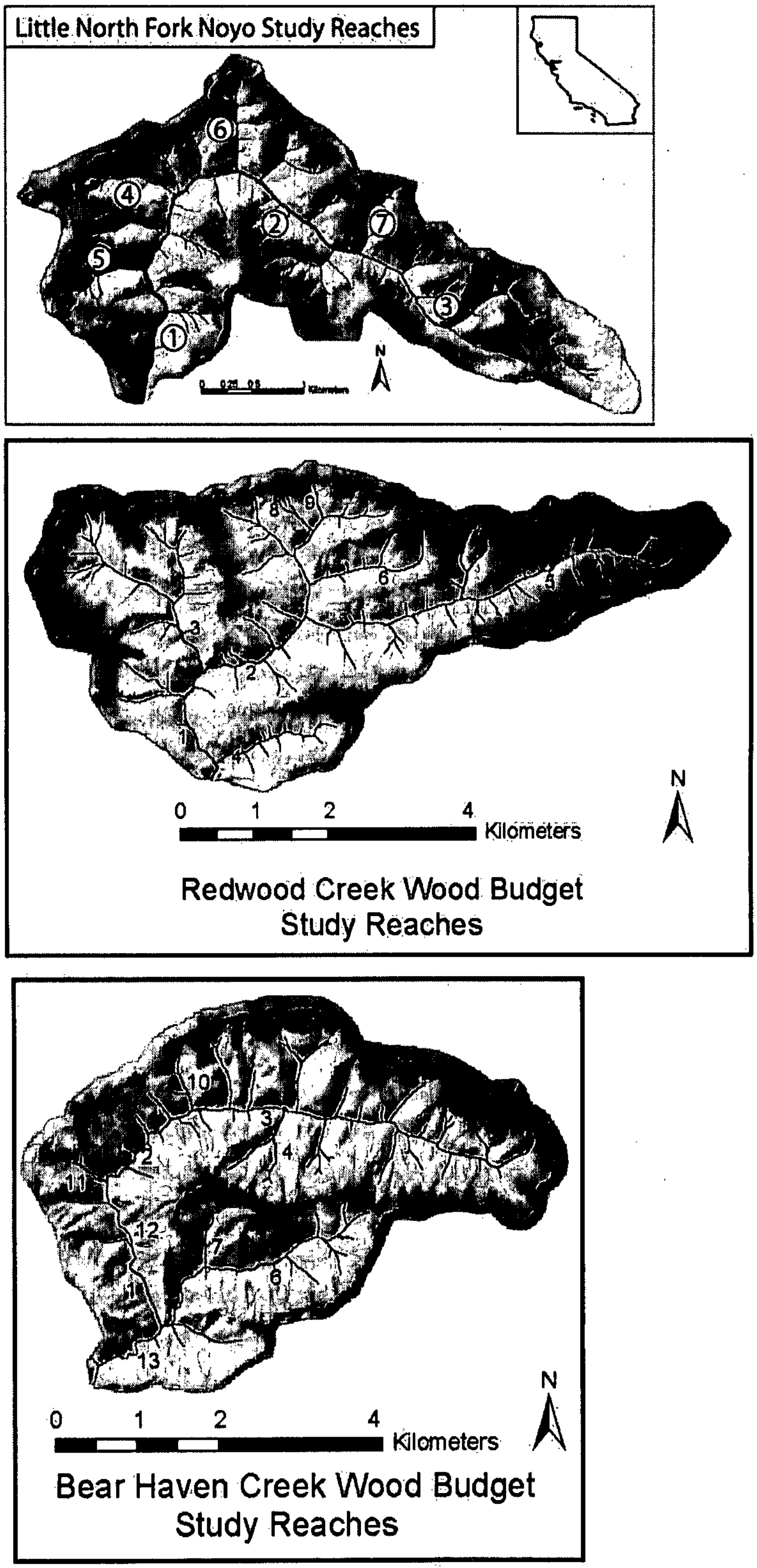

Figure 1 - Mendocino County study basins with study reaches identified by number. Refer to Table 1 for details on individual study reaches.

Table 1 - Physical characteristics of the three study sites in the Ten Mile and Little North Fork Noyo watersheds.

Reach No.	Drainage Area (km^2)	Stream Class	Reach Length (m)	Average Slope (%)	Ave Channel Width (m)	Dominant Substrate	Channel Type	Pool Former (%) Wood	Boulder	Hydraulic
LNF Noyo River										
1	9.5	I	1500	1	7.0	Gravel	PR / FP	78	17	6
2	6.9	I	2500	1	4.7	Gravel	PR / FP	77	0	23
3	1.9	I	800	2	2.5	Sand	PB / FP	70	0	30
4	0.6	II	900	7	1.8	Sand	SP / FP / PB	100	0	0
5	0.3	II	800	8	1.2	Sand	SP / FP / PB	100	0	0
6	0.5	II	700	5	1.8	Sand	SP / FP / PB	50	0	50
7	0.4	II	400	9	1.0	Sand	SP / FP / PB	100	0	0
Bear Haven Creek										
1	12.2	I	1063	1.5	6.8	gravel	R/Fp	89	11	0
2	9.7	I	500	2.2	7.5	gravel	R/Fp	75	0	25
3	2.6	II	401	4.1	2.0	gravel	R/Fp			
4	1.2	II	399	8.8	1.6	gravel	Fc	100	0	0
6	6.4	II	343	4.1	2.3	gravel	R/Fp			
7	2.3	II	499	10.4	1.6	gravel	R/Fp			
10	1.3	II	373	7.0	1.2	gravel	R/Fp	100	0	0
11	1.3	II	338	10.2	0.9	gravel	R/Fp			
Redwood Creek										
1	20.3	I	1000	1.5	9.0	gravel	R/Fp	50	43	7
2	17.4	I	1500	1.3	6.6	cobble	PR/FP	41	18	41
3	1.4	II	440	7.2	2.7	cobble	R/SP/Fc			
4	4.5	I	930	1.6	2.8	cobble	PR/FP	10		90
5	3.0	I/II	1615	5.3	3.2	cobble	SP			
6	0.5	II	600	8.3	0.9	gravel	SP			

Notes:

Fp- forced pool
Fc - forced cascade
PR - pool/riffle
R - riffle
SP - Step Pool

2. Results

2.1 What Are The Origins of Present Day In-Stream Wood?

Only a portion (26 to 66%, Table 2) of all wood pieces inventoried was associated with a recruitment process; the remainder was unidentified. In the Ten Mile watershed, in-stream wood originated from a range of processes, including historical logging (65%), bank erosion (15%), mortality (10%), landsliding (9%), and debris flows (4%). In the LNF Noyo, wood originated from historical logging (33%), bank erosion (38%), mortality (4%), streamside landsliding (8%), and debris flows (16%). Field measurements revealed high spatial variability in total wood storage and wood recruitment along the cumulative 17.6 km of channels surveyed in all three basins (Figure 2).

Table 2 - Comparison of wood budget parameters for LNF Noyo River, Bear Haven Creek, and Redwood Creek.

Attribute	LNF Noyo	Bear Haven	Redwood
Wood Storage (m^3/100m)			
range	2 - 95	47 - 67	0.9 - 48
mean	18	22	18
% Pieces identfied by Source	26	66	56
% Logging Related (by volume)	19	55	76
Source Distance (feet)			
60%	2	16	10
80%	2	40	49
Wood Recruitment (m^3/km/yr)			
Mortality	0.3 (15%)	0.4 (44%)	0.2 (29%)
Bank Erosion	1.6 (74%)	0.4 (44%)	0.3 (46%)
Landslide	0.2 (12%)	0.13 (14%)	0.17 (25%
Forest Biomass (m^3/Ha)			
Conifer	485	301	504
Deciduous	30	32	34
Mean Wood Transport Dist. (meters)	442	155	464

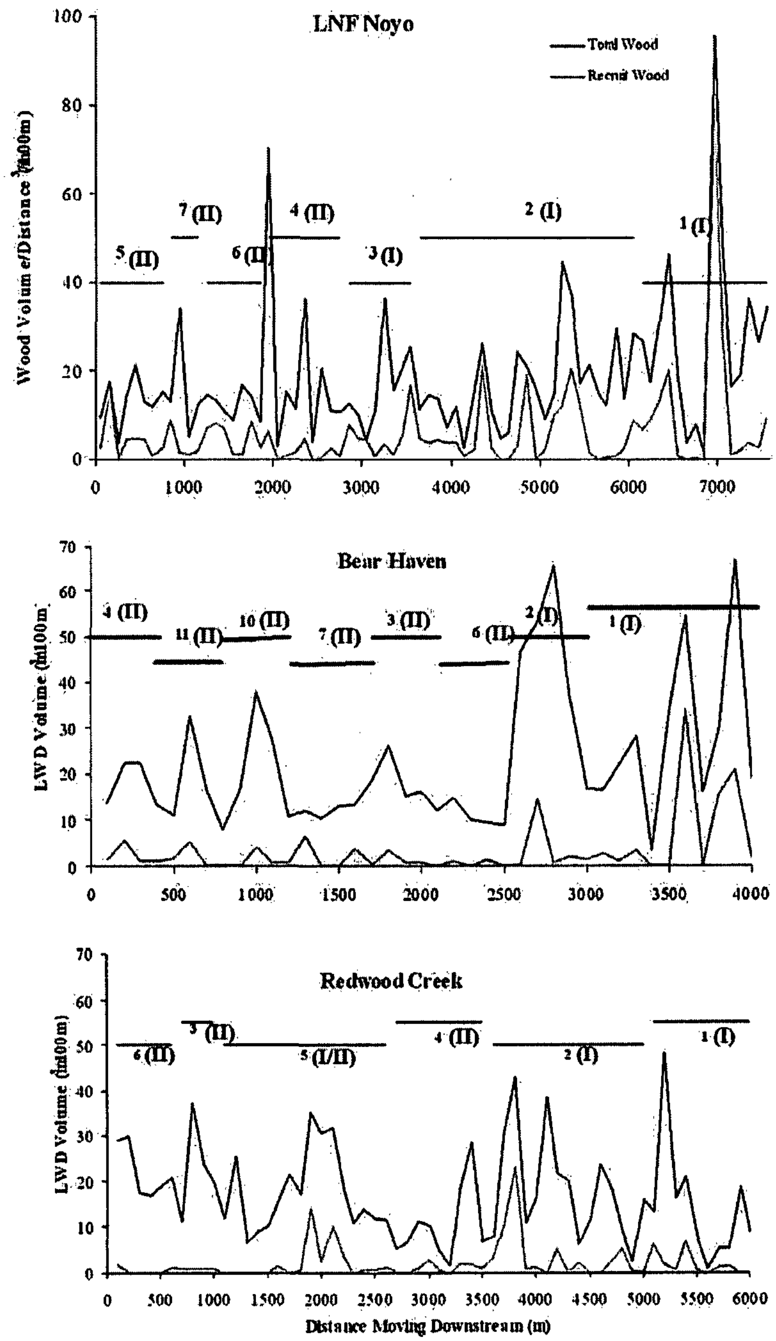

Figure 2 - Spatial variation in total and recruited wood storage volume by distance. Numbers near horizontal lines denote study reaches that are plotted from smallest to largest drainage area (i.e., distance moving downstream). (I) and (II) next to numbered study reached denote stream class.

Although harvest of riparian forests that eliminates trees can reduce wood loading to streams, introduction of slash to streams (particularly large material from the original harvest of old growth trees) can significantly contribute to wood loading for decades. This is the case in small to intermediate size streams in the Mendocino Coast area of California.

2.2 By What Processes Is Wood Recruited to Streams?

Variation in wood storage in streams is driven predominantly by spatial differences in wood recruitment rates (volume/length/time) from bank erosion, streamside landsliding, and mortality (Figure 3). In the Ten Mile watershed wood recruitment is governed by bank erosion (44%), mortality (36%), and streamside landsliding (20%); recruitment from debris flows could not be estimated because of lack of age constraints on debris flow frequency. In the LNF Fork Noyo wood recruitment is governed by bank erosion (73%), mortality (15%), and streamside landsliding (12%). Non-mortality sources of wood recruitment (i.e., bank erosion and streamside landsliding) dominated in both basins (64% in Ten Mile and 85% in the LNF Noyo). These are significant findings considering that most wood recruitment models (Bragg et al. 2000, Welty et al. 2002) consider wood inputs by forest mortality alone; the exception is a wood recruitment model that predicts wood inputs by forest fire, chronic forest mortality, bank erosion, streamside landsliding, and debris flows (Benda and Sias 2003, U. S. F. S. 2002). Hence, when managing riparian zones for wood recruitment it may be more important to consider the processes of bank erosion and streamside landsliding than forest mortality.

2.3 Where In The Riparian Zone Does Wood Originate From?

The distances from wood sources (location of standing trees) to channels (i.e., referred to as "source distances") are variable because of the spatial variability in wood recruitment processes (Table 2, Figure 4). When data are combined for all study reaches, 90% of wood enters the channel from within 14 m (46') in the Ten Mile basin and from within 8 m (26') in the LNF Noyo watershed (Figure 4). For individual reaches, the source distance is highly influenced by the dominant recruitment mechanisms. For example, in reaches where bank erosion is the dominant recruitment process, source distances are less than the theoretical prediction from mortality alone (Figure 4) and typically less than several meters (6'-9'). These results have implications for the design of riparian forest buffer strips. For instance, in many areas where bank erosion dominates wood recruitment, buffer strips designed solely for wood recruitment can be considerably less wide than the average tree height. On the other hand, in areas where streamside landsliding is the dominant wood recruitment agent, buffer strips and streamside landslide protection zones may be greater than a tree height. Consequently, design of buffer strips can be tailored to site specific conditions based on local hillslope and stream bank topography.

2.4 Where Is Fluvial Transport of Wood Significant?

The mean wood transport distance of wood over the life time of pieces was predicted using measured parameters including debris jam age, jam spacing, and the proportion of channel blocked by jams (Benda and Sias 2003). In all three basins wood transport is predicted to vary from less than 100 m in the smallest channels (drainage area of 1 - 2 km^2) up to 1300 m in streams having drainage areas of 2 to 20 km^2 (Figure 5). In addition the predicted transport distances increased with increasing channel size and drainage area (Figure 5). Predicted wood transport suggests that in small, headwater streams that have drainage areas less than about 1 – 2 km², wood located in approximately the first 200 meters upstream from the confluence contributes to the wood storage of larger, fish-bearing streams over periods of decades (although the transported wood should be only several meters long). Because of the predicted short travel distances of wood, the majority of headwater streams will have little wood in transport. In larger, fish-bearing streams wood transport is much more significant.

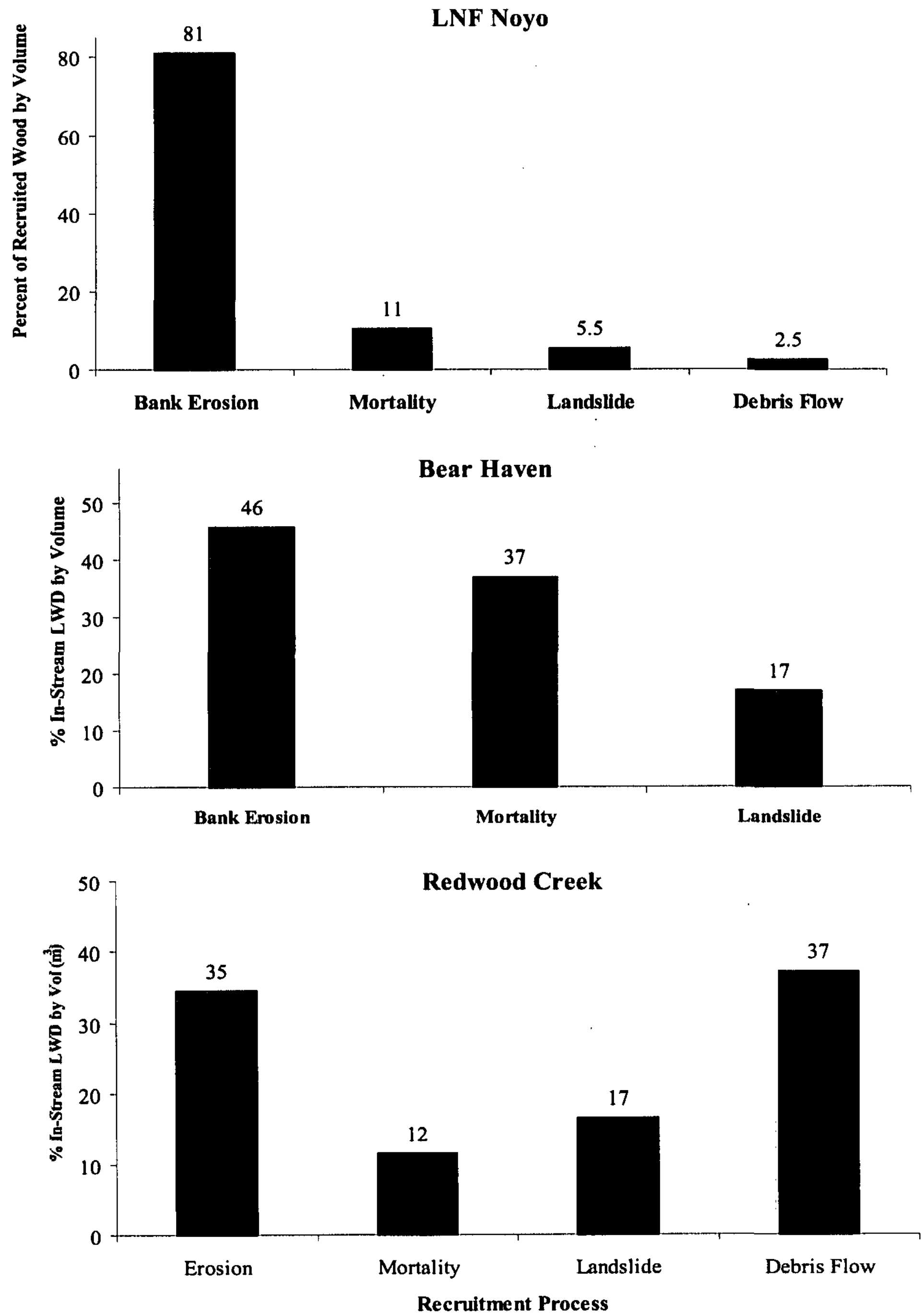

Figure 3 - Percent of in-stream recruited wood by process.

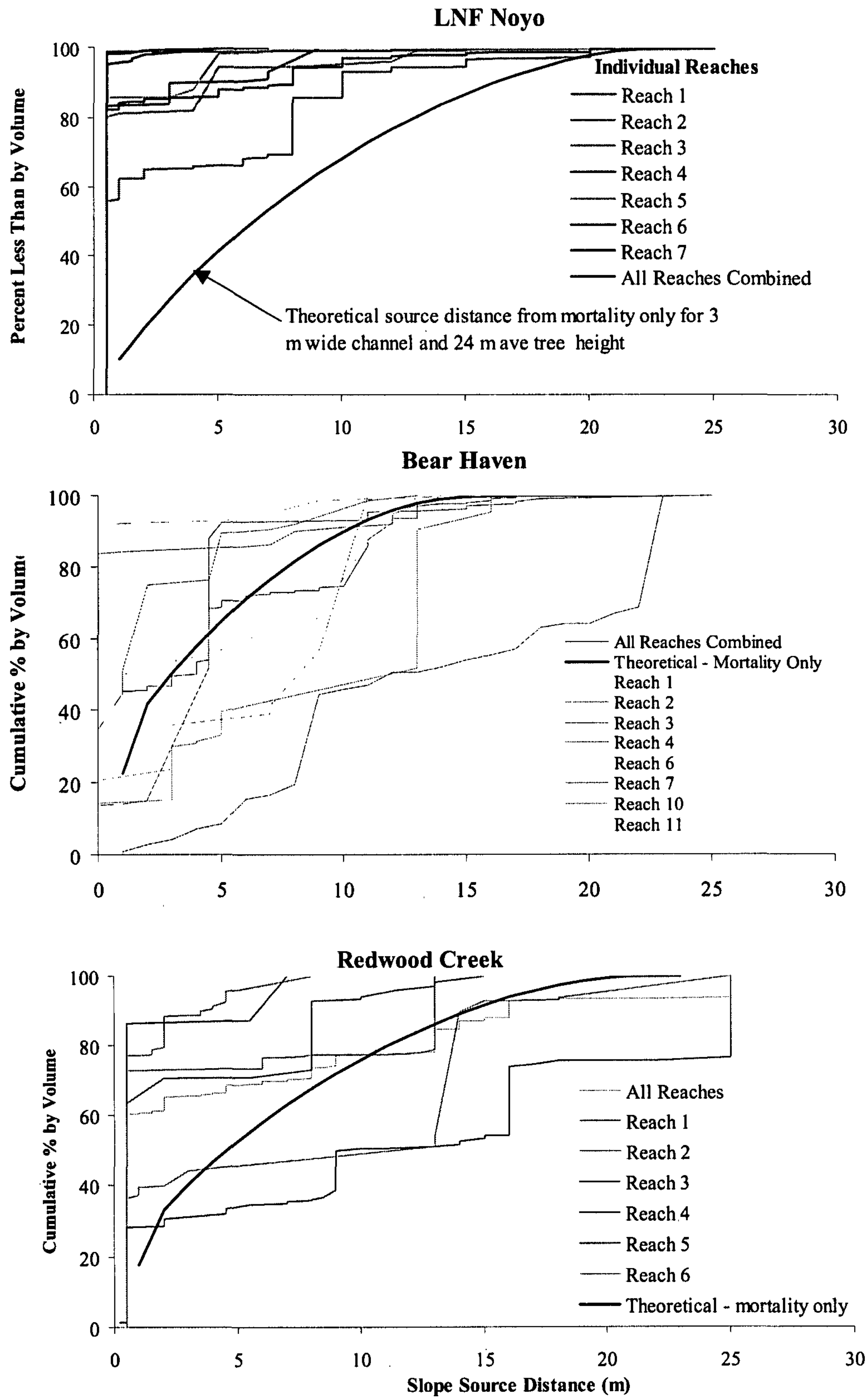

Figure 4 - Slope distance from stream edge to source of wood for individual reaches, all reaches combined, and theoretical prediction for mortality only.

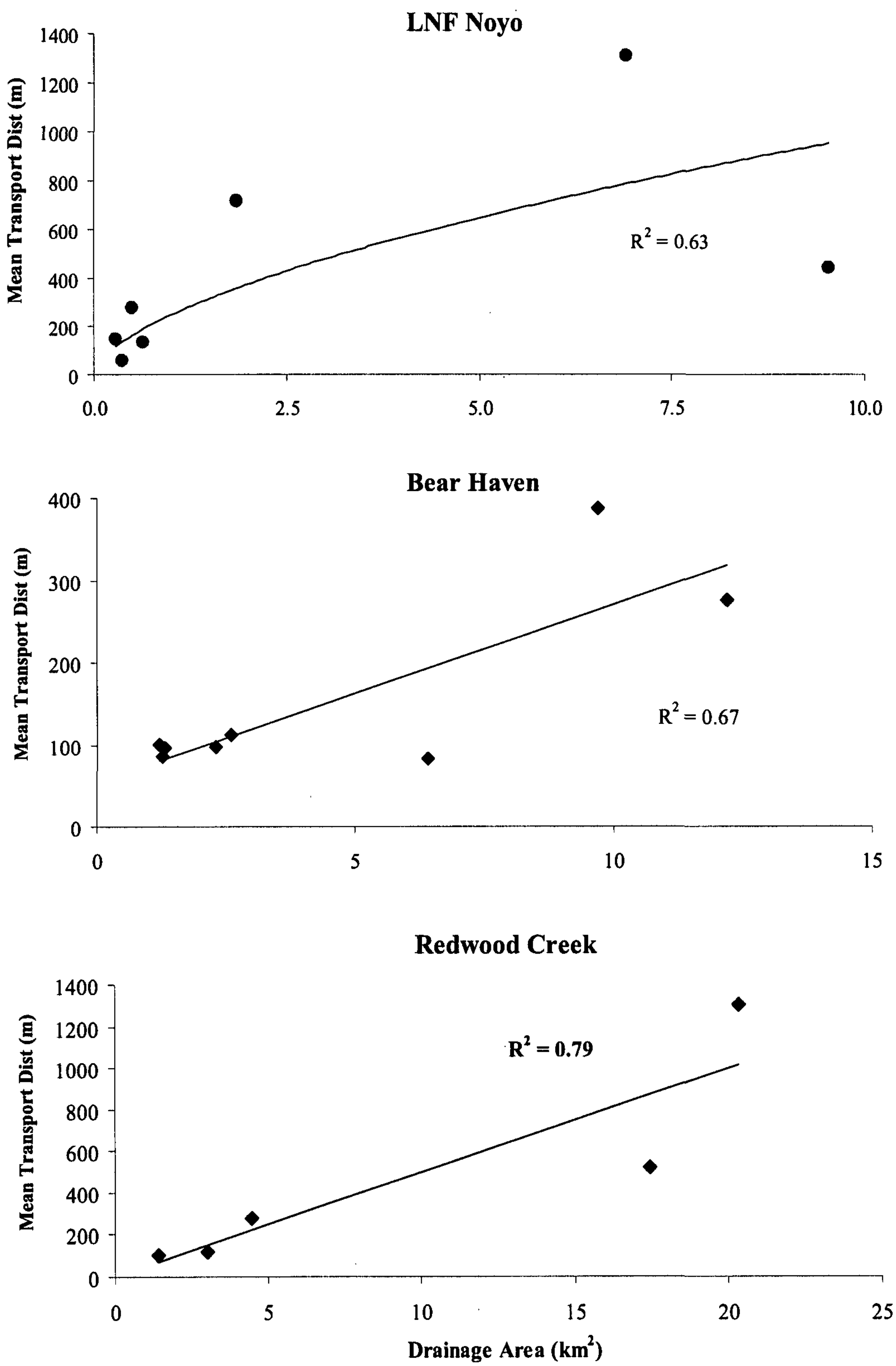

Figure 5 - Predicted wood transport distances.

3. Other Implications for Forest Management

3.1 High Spatial and Temporal Variability in Wood Recruitment May Complicate Monitoring Studies

There is increasing interest in setting targets for wood storage and conducting monitoring studies in California, however, there are no current monitoring guidelines or inventory protocols that consider spatial and temporal variability in wood recruitment. Given the observed spatial variability in wood volumes in streams, a pertinent question is: over what distance of channel should a wood inventory be conducted to estimate a reliable mean value? A plot of the cumulative spatial average of total and recruited wood storage per 100 m reaches (Figure 6) suggests that where spatial variation in wood storage is high (e.g. LNF Noyo), storage values do not converge on a stable mean value over the entire survey length (7.6 km). In contrast, in basins where spatial variability of wood storage is lower (e.g. Redwood Creek) stable mean values of total wood storage converged at approximately 4 km of continuous surveys. Depending on the degree of variability driven by differences in bank erosion, landsliding, forest mortality, and logging history, it might be infeasible to obtain accurate mean values of wood storage. In addition, the history of storms and floods will strongly influence variability in wood storage, particularly since the majority of wood recruitment originates from disturbance-related processes such as storms and floods (i.e., from bank erosion and streamside landslides). These complexities suggest that establishing regional targets for wood loading and conducting compliance monitoring to verify them is questionable in the naturally dynamic and spatially heterogeneous stream environments in northern California.

3.2 Field-Based Estimates of Soil Creep and Bank Erosion Are Used to Evaluate Accuracy of TMDLs

Ten Mile Watershed

The Ten Mile TMDL (EPA 2000) based on a "desk top and preliminary" sediment budget (GMA 2000) estimated that bank erosion and streamside landsliding produced 77 t km^{-2} yr^{-1} of sediment and it concluded that forest management over the last decade was responsible for 56% of all sediment delivery to streams. In contrast, the sediment production from soil creep (i.e., bank erosion) and streamside landsliding derived from the wood budget was 600 t km^{-2} yr^{-1}. This is, on average, 750% higher than the 77 t km^{-2} yr^{-1} in the Ten Mile TMDL and suggests that over the last decade forest management has contributed 18% of all sediment production, rather than 56%. Furthermore if the higher estimated bank erosion rate is used in the sediment budget (4 cm yr^{-1} rather than 1.9 cm yr^{-1}), then forest management contributions over the last decade would be closer to 10%. These results point out the very approximate nature of sediment budgeting particularly for EPA - TMDLs that do not rely heavily on field data (i.e., "desk top budgets"). Consequently, estimates of sediment production contained in a sediment budget should be used cautiously for developing quantitative estimates for "allowable loads" or other compliance indices.

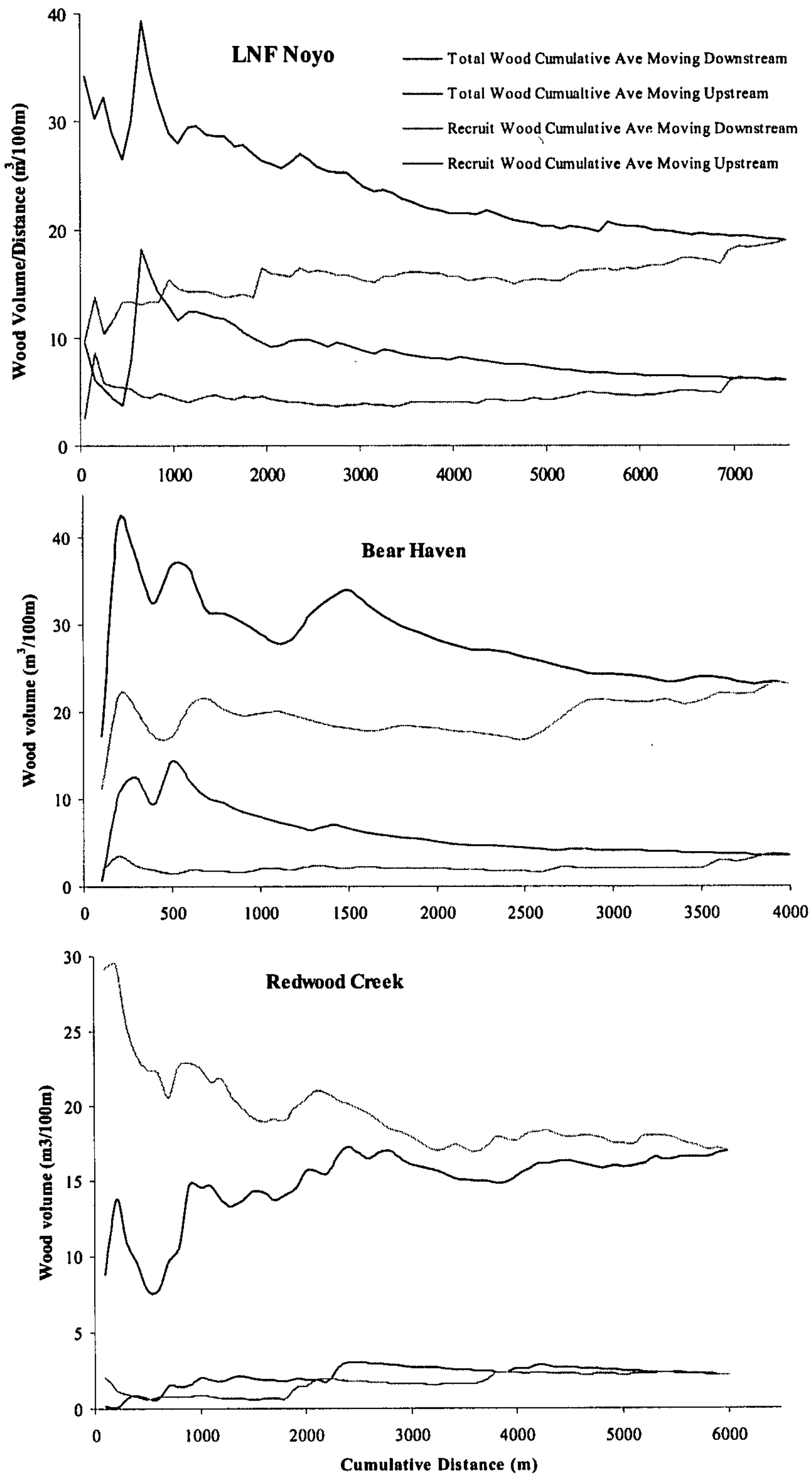

Figure 6 - Cumulative average of total wood storage and recruited wood. Reach data are plotted from largest to smallest streams (i.e., moving upstream) and from smallest to largest streams (i.e., moving downstream).

Noyo River Watershed

Average bank erosion rates for fish bearing streams in the LNF Noyo River basin was estimated to be 7 cm yr^{-1}, a rate that likely reflects continuing incision and lateral migration of the channel because of past logging that either filled channels with sediment or otherwise altered their hydraulic geometry. A bank erosion sediment flux for 3rd and higher order channels of 410 t km^{-2} yr^{-1} was calculated for the LNF Noyo. The rate of 410 t km^{-2} yr^{-1} for fluvial bank erosion is inconsistent with the estimated bank erosion sediment input rate of 77 tons km^{-2} yr^{-1} contained within the Noyo River EPA TMDL (1999) based on the "desk top" sediment budget of GMA (1999). This suggests that the EPA TMDL for the Noyo River may have underestimated the bank erosion component of the sediment budget by approximately 500% and consequently the "background" sediment yield by 250%. The likelihood of underestimating erosion rates (because of the "desk top" approach) in the EPA sediment budget in the Noyo River was acknowledged by developers of the sediment budget (GMA 1999).

It appears that lingering effects of past logging activities may dominate present day erosion and sediment yield in the Noyo system (as well as in other watersheds along the California coast), a situation that cannot be significantly altered by present day forestry activities. The apparent underestimation of the bank erosion component and hence the background sediment loading contained within the EPA TMDL for the Noyo River suggests that the use of quantitative values (from the TMDL) should be treated with significant caution and potentially not be used for establishing quantitative thresholds for monitoring, etc. The conclusion that sediment input or sediment yield rates in the Noyo River sediment budget are significantly underestimated was also reached by Koehler et al. (2002) who speculated that in the Noyo River "*remobilized historic sediment* [...due to large volumes of sediment delivered to channels in response to past logging activities...] *appears to increase suspended sediment load and may be a significant, unrecognized sediment source.*"

References

Benda, L. and Sias, J. 2003. A quantitative framework for evaluating the wood budget. Journal of Forest Ecology and Management 172 (1): 1-16.

Benda, L., D. Miller, J. Sias, D. Martin, B. Bilby, C. Veldhuisen, and T. Dunne. 2003. Wood Recruitment Processes and Wood Budgeting. Pages 49 - 73 *in* S. V. Gregory, K. Boyer, and A. M. Gurnell, editors. The Ecology and Management of Wood in World Rivers. American Fisheries Society.

Bragg, D. C., L. Kershner, and D. W. Roberts. 2000. Modeling large woody debris recruitment for small streams of the central Rocky Mountains. U. S. Department of Agriculture, Rocky Mountain Research Station, Fort Collins, CO. General Technical Report RMRS-GTR-55.

Campbell Timberland Management. 2002. Bear Haven and Redwood Creek wood and sediment budgets, Mendocino County, California. Unpublished report prepared by Lee Benda and Associates.

Campbell Timberland Management. 2004. Little North Fork Noyo River wood budget, Mendocino County, California. Unpublished report prepared by Lee Benda and Associates.

Environmental Protection Agency (EPA). 1999. Noyo River Total Maximum Daily Load for Sediment, Region IX.

Environmental Protection Agency (EPA). 2000. Tenmile River Total Maximum Daily Load for Sediment, Region IX.

Graham Matthews and Associates (GMA). 1999. Sediment source analysis and preliminary sediment budget for the Noyo River, Mendocino County, CA.

Graham Matthews and Associates (GMA). 2000. Sediment source analysis and preliminary sediment budget for the Tenmile River, Mendocino County, CA.

Koehler, R., Kelson, K., Matthews, G., Kang, K., and Barrow, A. 2002. The role of stored historic sediment in short-term sediment production, South Fork Noyo River, Jackson State Demonstration Forest, California. Abstract 98th Annual GSA meeting, Cordilleran Section, May 13-15, 2002.

Martin, D. and Benda, L. 2001. Patterns of in-stream wood recruitment and transport at the watershed scale. Transactions of the American Fisheries Society 130: 940-958.

McDade, M.H., Swanson, F.J, Mckee, W.A., Franklin, J.F., and Van Sickle, J. 1990. Source distances for coarse wood entering small streams in western Oregon and Washington, Canadian Journal of Forest Research. 20: 326-330.

U.S. Forest Service. 2002. Landscape Dynamics and Forest Management: Educational CD-ROM. General Technical Report, RMRS-GTR-101CD, USDA, Rocky Mountain Research Station.

Welty, J., Beechie, T., Sullivan, K., Hyink, T., Bilby, R.E., Andrus, C. W., and Pess, G. 2002. Riparian aquatic interaction simulator (RAIS): A model of riparian forest dynamics for the generation of large woody debris and shade. Forest Ecology and Management 162 (2-3): 299-318.