Lower 48 States

358) Abbe, T.B., and D.R. Montgomery. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. Regulated Rivers: Research & Management. 12: 201-221. (A, D)

Author abstract: Field surveys document the accumulation of large woody debris (LWD) into structurally distinctive jam types in the alluvial channel of the Queets River on the Olympic Peninsula of northwest Washington. Calculations, field observations and historical evidence show that these jams can form stable structures controlling local channel hydraulics and providing refugia for riparian forest development over decades and possibly centuries. Distinctive spatial patters of LWD, pools, bars and forested islands form in association with particular jam types. The deposition of 'key member' logs initiates the formation of stable bar apex and meander jams that alter the local flow hydraulics and thereby the spatial characteristics of scour and deposition leading to pool and bar formation. Historical evidence and the age structure of forest patches documents the temporal development of alluvial topography associated with these jam types. Bar apex jams, for example, are associated with a crescentic pool, an upstream arcuate bar and a downstream central bar that is the focus of forest patch development. Experimental and empirical studies in hydraulic engineering accurately predict channel scour associated with jams. Individual jams can be remarkably stable, providing long-term bank protection that creates local refugia for mature forest patches within a valley floor environment characterized by rapid channel migration and frequent disturbance. Processes controlling the formation, structure and stability of naturally occurring LWD jams are fundamental to the dynamics of forest river ecosystems and provide insights into the design of both habitat restoration structures and ecosystem-based watershed management.

359) Abbe, T.B., and D.R. Montgomery. 2003. Patterns and processes of wood debris accumulation in the Queets River basin, Washington. Geomorphology. 51: 81-107. (A, D)

Author abstract: Field surveys in the 724-km^2 Queets river basin on the west slope of the Olympic Mountains in NW Washington reveal basin-wide patterns of distinctive wood debris (WD) accumulations that arise from different mechanisms of WD recruitment, hydraulic geometry, and physical characteristics of WD. Individual pieces of WD in an accumulation or jam can be separated into key, racked, and loose members. Ten types of WD accumulations are identified based on the mode of recruitment and the orientation of key, racked, and loose debris relative to the channel axis. Although some types of WD accumulation have few geomorphic effects, others form stable in-stream structures that influence alluvial morphology at both subreach- and reach-length scales ranging from less than 1 to greater than 10 channel widths. In the Queets river, stable accumulations of WD directly influence channel anabranching, planform geometry, flood plain topography, and establishment of long-term riparian refugia for old-growth forest development. The classification of wood debris accumulations in the Queets river basin is based on physical observations that offer a template potentially applicable to other forested mountain regions.

360) Abe, K., and R.R. Ziemer. 1991. Effect of tree roots on a shear zone: Modeling reinforced shear stress. Canadian Journal of Forest Research. 21: 1012-1019. (K)

Author abstract: Tree roots provide important soil reinforcement that improves the stability of hillslopes. After trees are cut and roots begin to decay, the frequency of slope failures can increase. To more fully understand the mechanics of how tree roots reinforce soil, fine sandy soil containing pine roots was placed in a large shear box in horizontal layers and sheared across a vertical plane. The shapes of the deformed roots in the sheared soil were explained satisfactorily by an equation that had been developed to model the deformed shape of artificial reinforcement elements, such as wood dowels, parachute cord, Bungy cord, and aluminum rods. Root deformation in sheared soil is influenced by the diameter and concentration of roots. A model is proposed that uses root strain to estimate the shear stress of soil reinforced by roots. The shear resistance measured from the shear tests compared quite well with the model simulation.

361) Acker, S.A., S.V. Gregory, G. Lienkaemper, W.A. McKee, F.J. Swanson, and S.D. Miller. 2003. Composition, complexity, and tree mortality in riparian forest in the central western Cascades of Oregon. Forest Ecology and Management. 173: 293-308. (D)

Author abstract: Riparian forest contribute to the diversity and function of both terrestrial and aquatic ecosystems. To assess some of these contributions, we compared tree composition, stand complexity, and temporal patterns of tree mortality on permanent plots in seven mature and old-growth stand representing upland forest and forests along low- and mid-order streams in the Western Cascade Range of Oregon. We also assessed recruitment of large wood into stream channels due to tree mortality, both by direct measurement and by estimation from tree mortality and location data. Stand differed in composition due to both stream order and successional stage. Stands on mid-order streams had high abundance of hardwood trees and/or *Thuja plicata.* Stand complexity (variability in tree diameters, tree life-froms diversity, and tree species diversity), was high in stand on mid-order streams and in the upland, old-growth stand. Tree mortality was exceptionally high in six of the seven stands in 1996, the year in which the largest flood during the study occurred. However, only in the one stand on an unconstrained reach of a mid-order stream was mortality primarily due to flooding. Estimated recruitment of wood was much higher from the stand on the unconstrained reach than from the other stand on mid-order streams, suggestions that unconstrained reaches may be important for efforts to maintain or restore large wood in streams.

362) Amaranthus, M.P., R.M. Rice, N.R. Barr, and R.R. Ziemer. 1985. Logging and forest roads related to increased debris slides in southwestern Oregon. Journal of Forestry. 83: 229-233. (K)

Author abstract: Debris slides over a 20-year period were inventoried on 137,500 acres of forested land in the Klamath Mountains of southwest Oregon. Frequency during the study period was about one slide every 4.3 years on each 1,000 acres-an erosion rate of about 1/2 yd^3 per acre per year. Erosion rates on roads and landings were 100 times those on undisturbed areas, while erosion on harvested areas was seven times that of undisturbed areas. Three quarters of the slides were found on slopes steeper than 70 percent and half were on the lower third of slopes. The

study area was subdivided into nine geomorphological erosion response units which exhibited profound differences in natural erosion rates and responses to disturbance. The results serve as a guide to appraising slide risk associated with planned timber harvests or mad construction on forested slopes.

363) Bash, J., C. Berman, and S. Bolton. 2001. Effects of turbidity and suspended solids on salmonids. Center For Streamside Studies, University of Washington, Seattle. 74pp. (I)

Author abstract: Human activities in Northwestern watersheds, including logging, grazing, agriculture, mining, road building, urbanization, and commercial construction contribute to periodic pulses or chronic levels of suspended sediment in streams. Suspended sediment is associated with negative effects on the spawning, growth, and reproduction of salmonids. Effects on salmonids will differ based on their developmental stage. Suspended sediments may affect salmonids by altering their physiology, behavior, and habitat, all of which may lead to physiological stress and reduced survival rates. A sizable body of data (laboratory and field-based) has been gathered in North America focusing on the relationship between turbidity, total suspended sediments, and salmonid health. The controlled environment of laboratory studies tends to give clearer results than field studies.

Understanding the relationship between turbidity measurements, suspended sediments, and their effects on salmonids at various life stages will assist agencies implementing transportation projects to devise techniques to reduce temporary and chronic erosion and sedimentation associated with these activities. There are three primary ways in which sediment in the water column is measured: turbidity, total suspended solids, and water clarity. While these measures are frequently correlated with one another, the strength of correlation may vary widely between samples from different monitoring sites and between different watersheds. Turbidity is currently in widespread use by resource managers, partially due to the ease of taking turbidity measurements. In addition, current state regulations addressing suspended sediment are usually NTU-based. The disadvantage of turbidity is that it is only an indicator of suspended sediment effects, rather than a direct measure, and may not accurately reflect the effect on salmonids.

Protection of Washington State's salmonids requires that transportation officials consider the effect of suspended sediments released into streams during transportation projects. Many state and provincial criteria are based on a threshold of exceedance for background levels of turbidity. However, determining natural background levels of turbidity is a difficult endeavor. Turbidity measures may be affected by 1) differing physical processes between watersheds including geologic, hydrologic and hydraulic conditions; 2) legacy issues (activities historically conducted in the watershed); and 3) problems with instrumentation and repeatability of turbidity measurements. Altered systems may not provide accurate baseline conditions.

The inconsistent correlation between turbidity measurements and mass of suspended solids, as well as the difficulty in achieving repeatability using turbidimeters contributes to concerns that turbidity may not be a consistent and reliable tool determining the effects of suspended solids on salmonids. Other factors, such as life stage, time of year, size and angularity of sediment, availability of off-channel and tributary habitat, and composition of sediment may be more telling in determining the effect of sediment on salmonids in Northwestern rivers.

Although salmonids are found in naturally turbid river systems in the Northwest, this does not necessarily mean that salmonids in general can tolerate increases over time of suspended

sediments. An understanding of sediment size, shape, and composition, salmonid species and life history stages, cumulative and synergistic stressor effects, and overall habitat complexity and availability in a watershed is required.

For short-term construction projects, operators will need to measure background turbidities on a case by case basis to determine if they are exceeding regulations. However, transportation projects may also produce long-term, chronic effects. Shortterm pulses will presumably have a different effect on salmonids than chronic exposure.

To adequately protect salmonids during their freshwater residence, TSS data on physiological, behavioral, and habitat effects should be viewed in a layer context incorporating both the spatial geometry of suitable habitat and the temporal changes associated with life history, year class, and climate variability. Spatial and temporal considerations provide the foundation to decipher legacy effects as well as cumulative and synergistic effects on salmonid protection and recovery.

364) Bates, K., B. Barnard, B. Heiner, J.P. Klavas, and P.D. Powers. 2003. Design of road culverts for fish passage. Washington Department of Fish and Wildlife. Aquatic Habitat Guidelines Series. 111pp. (K)

Author abstract (Author Introduction): *Design of Road Culverts for Fish Passage* serves as a guide for property owners and engineers who are designing permanent road-crossing culverts to facilitate upstream fish migration. It provides guidance for projects involving new culvert construction as well as retrofitting or replacing existing culverts. The designer will need to have working knowledge of hydraulic engineering, hydrology and soils/structural engineering to accomplish an appropriate design.

Formal fish ladders may be required as a retrofit at some culvert sites to provide passage. The design of fish ladders is beyond the scope of this guideline, though there is a brief description of some basic design concepts included here. An engineer with expertise in fish passage should be consulted for additional assistance for the design of fish ladders.

Design of Road Culverts for Fish Passage lays out the consecutive design steps most likely to be required in a culvert project. A form describing the data is needed for the design and its evaluation is provided in Appendix F, Summary Forms for Fish-Passage Design Data. Explanations and definitions of terms describing channel hydrology and data requirements can also be found in Appendix F.

Before using this guideline, great care should be taken to determine whether a culvert is a suitable solution for providing fish passage at the particular site in question. Indeed, environmental circumstances other than fish passage may make it impossible to obtain a permit to install a culvert. The Washington Department of Fish and Wildlife prefers construction of a bridge over installation of a culvert in order to minimize risk of impacts to fish and habitat. Wherever a roadway crosses a stream, it creates some level of risk to fish passage, water quality, or specific aquatic or riparian habitats. Generally, the risks increase the more the roadway confines and constricts the channel and floodplain. Any and all alternatives should be investigated to minimize the number of sites where a roadway crosses a stream, including designing road alignments to avoid crossings, consolidating crossings and using temporary crossing structures for short-term needs.

365) Baxter, C.V., and F.R. Hauer. 2000. Geomorphology, hyporheic exchange, and selection of spawning habitat by bull trout (*Salvelinus confluentus*). Canadian Journal of Fisheries and Aquatic Sciences. 57: 1470-1481. (B, G)

Author abstract: The distribution and abundance of bull trout (*Salvelinus confluentus*) spawning were affected by geomorphology and hyporheic groundwater - stream water exchange across multiple spatial scales in streams of the Swan River basin, northwestern Montana. Among spawning tributary streams, the abundance of bull trout redds increased with increased area of alluvial valley segments that were longitudinally confined by geomorphic knickpoints. Among all valley segment types, bull trout redds were primarily found in these bounded alluvial valley segments, which possessed complex patterns of hyporheic exchange and extensive upwelling zones. Bull trout used stream reaches for spawning that were strongly influenced by upwelling. However, within these selected reaches, bull trout redds were primarily located in transitional bedforms that possessed strong localized downwelling and high intragravel flow rates. The changing relationship of spawning habitat selection, in which bull trout selected upwelling zones at one spatial scale and downwelling zones at another spatial scale, emphasizes the importance of considering multiple spatial scales within a hierarchical geomorphic context when considering the ecology of this species or plans for bull trout conservation and restoration.

366) Baxter, C.V., Frissell, C.A. and F.R. Hauer. 1999. Geomorphology, logging roads, and the distribution of bull trout spawning in a forested river basin: Implications for management and conservation. Transactions of the American Fisheries Society. 128: 854-867. (B)

Author abstract: The Swan Basin in Montana is considered a stronghold of regional significance for the bull trout *Salvelinus confluentus*, a native char whose populations are fragmented and declining throughout its range. We used correlation analysis to examine spatial and temporal variation of bull trout redd count data (1982-1995) relative to geomorphic and land-use factors among nine principal spawning tributaries of the Swan River. Bull trout redd numbers were positively correlated with the extent of alluvial valley segments bounded by knickpoints and negatively correlated with the density of logging roads in spawning tributary catchments. The density of logging roads in spawning tributary catchments was not significantly correlated with geomorphic factors. Temporal trends among the principal spawning streams were variable. In four of the nine principal spawning streams, redd numbers increased significantly during the survey period, and in the remaining streams, redd numbers showed no significant change. Changes in redd numbers with time were negatively correlated with catchment road density and positively correlated with the extent of bounded alluvial valley segments. The significance of bounded alluvial valley segments to bull trout spawning habitat may be related to groundwater-surface water exchange occurring within these segments. Our results emphasize the importance of valley geomorphology to bull trout, and our results suggest that prior land use may have adversely affected bull trout populations in the Swan Basin. Protection of critical spawning tributary catchments from additional road building and associated land-use disturbances will likely be necessary for the maintenance of viable bull trout populations in the Swan Basin. Geomorphic context and land-use status of spawning tributaries are important considerations for future monitoring and management of this species.

367) Benda, L., C. Veldhuisen, and J. Black. 2003. Debris flows as agents of morphological heterogeneity at low-order confluences, Olympic Mountains, Washington. Geological Society of America Bulletin. 115: 1110-1121. (A, D)

Author abstract: Effects of tributary junctions on longitudinal patterns of riverine heterogeneity are relevant to both fluvial geomorphology and riverine ecology. We surveyed 10 km of small- to moderate-sized mountain channels in the Olympic Peninsula, Washington, to investigate how low-order confluences prone to debris flow deposition directly and indirectly influenced channel and valley morphology. In the Olympic Mountains, debris flows scour sediment and organic material from steep first- and second-order channels and create deposits (debris fans) at tributary junctions in higher-order streams. In lower-energy depositional environments there were statistically significant relationships among debris fans at low-order confluences and gravel substrate, wide channels, and numbers of logs and large pools. Effects of debris fans on channel morphology extended upstream and downstream of fan perimeters, indicating the importance of indirect (offsite) effects of debris flows. Consequently, certain aspects of channel morphology (e.g., pool density, substrate texture, and channel widths) were nonuniformly distributed, reflecting the role of network topology and disturbance history on the spatial scale of morphological heterogeneity. Moreover, heterogeneity of channel morphology increased in proximity to low-order confluences prone to debris flows. In contrast, confluence effects in higher-energy depositional environments were limited. Our field data and information from seven other studies indicate how variation in debris flow volume and composition, stream energy, and valley width at the point of deposition influence the relationship between low-order confluences and channel morphology.

368) Benda, L.E., P. Bigelow, and T.M. Worsley. 2002. Recruitment of wood to streams in old-growth and second-growth redwood forests, northern California, U.S.A. Canadian Journal of Forest Research. 32: 1460-1477. (D)

Electronic abstract: From an ecological perspective, one aim of forest management is to supply wood to streams to protect and enhance aquatic habitats. An analysis was made of the mass balance of in-stream wood along 9 km of channels in old-growth and 50-year-old second-growth redwood (*Sequoia sempervirens* (D. Don) Endl.) forests in northern California, U.S.A. High volumes of wood storage in streams in old-growth forests were due primarily to streamside landsliding and bank erosion. Logging-related debris and high forest mortality rates in conifer and deciduous forests contributed to high wood storage in second-growth forests. Volumes of in-stream wood in second-growth forests were similar to volumes in one old-growth system and less than another. Diameters of wood were significantly greater in older forests. Wood recruitment from forest mortality in old-growth forests was low compared with second-growth sites, driven by differences in conifer mortality rates of approximately 0.04 and 0.9%·year $^{-1}$, respectively. Contrasting old-growth redwood mortality with values reported for unmanaged Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests in Washington State (0.5%·year $^{-1}$) and unmanaged Sitka spruce (*Picea stichensis* (Bong.) Carrière) forests in southeastern Alaska (1.2%·year $^{-1}$) point to a strong latitudinal gradient of forest mortality reflected in tree size. The mass balance analysis of in-stream wood also allowed an estimation of bank erosion along large channels and soil creep along small, steep streams.

369) Berg, N.H., D. Azuma, and A. Carlson. 2002. Effects of wildfire on in-channel woody debris in the eastern Sierra Nevada, California. In: Proceedings of the Symposium on the Ecology and Management of Dead Wood in Western Forests, 2-4 November 1999, Reno, Nevada. W.F. Laudenslayer, Jr., P.J. Shea, B.E. Valentine, C.P. Weatherspoon, and T.E. Lisle, Technical Coordinators. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-181. Pages 49-63. (D)

Author abstract: Management of in-channel woody debris after wildfire is controversial. Post-fire increases in stream discharges can cause more frequent downstream flooding. The resulting heightened transport and accumulation of debris can wash out bridges and cause other damage. In-channel debris is sometimes removed or cut into smaller pieces to expedite flushing through the system and to avoid debris jam formation. Biotic values of debris for fish cover, pool formation, sediment storage, and food sources for invertebrates and microorganisms are lost or reduced, however, when debris is removed or cut up. Information on debris dynamics after wildfire in the Sierra Nevada is scant. Changes in debris frequency, mobility, volume, aggregation, and carbon loading after a 1994 wildfire in the eastern Sierra Nevada were quantified by before and after comparative measurements at Badenaugh Creek in northern California, and by comparing selected attributes to a nearby "reference" stream. Fifty-seven percent of wood volume, and 25 percent of the pieces, were consumed by the fire. The fire reduced aquatic carbon loading from about 2½ to 1½ times terrestrial loading after the fire. Although more pieces moved 1 year after the fire at Badenaugh Creek than in the control stream, the size and number of debris jams both immediately and 1 year after the fire were appreciably reduced from pre-fire levels, probably because fewer pieces were available to form aggregates. Decisions on the disposition of post-fire debris must consider the interaction between fire intensity, channel width, and the size of the remaining wood. If few pieces of channel-spanning length remain after a fire, they may pose relatively little downstream danger.

370) Bethlahmy, N. 1975. A Colorado episode: Beetle epidemic, ghost forests, more stream flow. Northwest Science. 49: 95-105. (G)

Electronic abstract: When a small watershed is clearcut, it temporarily yields more water. The implication is that water yield and land use are closely related. This interdependence is illustrated for two large watersheds in Colorado where barkbeetles destroyed the living timber trees. Substantially greater yields are still evident 25 years after the epidemic because significant elements of the watersheds have not reverted to their former status—dead trees still occupy the land, and have not been replaced by live trees. The variable hydrologic effects of the epidemic in the studied watersheds reflect differences in their exposures.

371) Bilby, R.E., and G.E. Likens. 1980. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology. 61: 1107-1113. (C, D, E, I)

Author abstract: Removal of all organic debris dams from a 175-m stretch of second-order stream at the Hubbard Brook Experimental Forest in New Hampshire led to a dramatic increase in the export of organic carbon from this ecosystem. Out of dissolved organic carbon (<0.50 μm)

increased 18%. Fine particular organic carbon (0.50 μm-1 mm) export increased 632% and coarse particulate organic matter (>1 mm) export increased 138%.

Measurement of the standing stock of coarse particulate organic matter on streambeds of the Hubbard Brook Valley revealed that organic debris dams were very important in accumulating this material. In first-order streams, debris dams contain nearly 75% of the standing stock of organic matter. The proportion of organic matter held by dams drops to 58% in second-order streams and to 20% in third-order streams.

Organic debris dams, therefore, are extremely important components of the small streams ecosystem. They retain organic matter within the system, thereby allowing it to be processed into finer size fractions in headwater tributaries rather than transported downstream in a coarse particulate form.

372) Bilby, R.E., and P.A. Bisson. 1998. Function and distribution of large woody debris. In: River Ecology and Management: Lessons From the Pacific Coastal Regions. S. Kantor, Editor. Springer-Verlag, Washington, D.C. Pages 324-346. (C, D)

Electronic abstract: Wood is more abundant in streams in the Pacific coastal ecoregions than in streams anywhere else in North America. Abundance of large woody debris decreases with increasing channel size, but sizes of pieces increases with channel size. Input of large wood to stream channels occurs as a result of chronic bank cutting, windthrow, stem suppression, and catastrophic occurrences, such as debris torrents, floods, and fires. Large woody debris is removed from stream channels by leaching, microbial decomposition, fragmentation by invertebrates, physical fragmentation, and downstream transport. The relative importance of these processes differs with stream size. Particulate organic matter accumulated by large woody debris is an important food source for many stream-dwelling invertebrates. Addition of wood to channels causes increased abundance of macroinvertebrates and changes species composition.

373) Bilby, R.E., B.R. Fransen, and P.A. Bisson. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: Evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences. 53: 164–173. (C, E)

Author abstract: Epilithic organic matter, all aquatic macroinvertebrates except shredders, and fish were significantly enriched with ^{15}N and ^{13}C in streams (western Washington state, .S.A.) where spawning coho salmon (*Oncorhynchus kisutch*) were present. Riparian vegetation adjacent to salmon-bearing streams and shredding macroinvertebrates were enriched with 15N but not ^{13}C. The highest levels of enrichment of the stream biota with the heavier isotopes occurred in the early spring, shortly after carcasses had decomposed. Following spawning, age-0 coho salmon exhibited a doubling in rate of growth. Age-0 cutthroat trout in a nearby stream without salmon exhibited no change in growth rate during the winter. Salmon-derived organic matter was incorporated into the stream biota through direct consumption of eggs, carcasses, and fry and by sorption onto the streambed substrate of dissolved organic matter released by decomposing carcasses. Autotrophic uptake was not an important avenue of incorporation. The proportion of nitrogen contributed by spawning salmon varied among trophic categories, ranging from about 17% in collector-gatherers to more than 30% in juvenile coho salmon. Carbon contributed by

spawning salmon ranged from 0% in the foliage of riparian plants and shredders to 34% in juvenile coho salmon.

374) Bilby, R.E., E.W. Beach, B.R. Fransen, and J.K. Walter. 2003. Transfer of nutrients from spawning salmon to riparian vegetation in western Washington. Transactions of the American Fisheries Society. 132: 733-745. (E)

Author abstract: The extent to which nutrients from Pacific salmon are transported to riparian areas may be influenced by differences in spawning behavior among species. Chum salmon *Oncorhynchus keta*, pink salmon *O. gorbuscha*, and sockeye salmon *O. nerka* typically spawn in dense aggregations, while species like steelhead *O. mykiss* and Coho salmon *O. kisutch* spawn at lower densities. The contribution of nutrients to riparian vegetation was compared at two watersheds in western Washington, Griffin Creek (used by coho salmon) and Kennedy Creek (used by chum salmon). Salmonberry *Rubus spectabilis* foliage was collected at the channel edge above and below barriers to spawning salmon and at 20, 50, and 100 m upslope from the stream and analyzed for nitrogen stable isotope ratio ($d^{15}N$, an indicator of salmon-derived nitrogen), total nitrogen (N), and phosphorus (P) content. Cover, plant density, and the species richness of shrub and understory vegetation were compared between sites with and without salmon. The $d^{15}N$ values in salmonberry leaves were higher at sites with salmon than at corresponding distances from the channel at sites without salmon at Kennedy Creek but not Griffin Creek. Salmonberry foliage adjacent to salmon spawning reaches possessed significantly higher levels of total N and P in both watersheds. Nitrogen content was positively associated with $d^{15}N$ values at the Kennedy Creek sites but not at the Griffin Creek sites. At Kennedy Creek, shrub species diversity and understory plant density and species diversity were higher at sites with salmon than at sites without salmon. These results suggest that areas bordering streams utilized by high-density-spawning species like chum salmon receive a substantial nutrient contribution from the fish and that this subsidy influences the vegetation. We did not see clear evidence for a similar nutrient contribution from coho salmon.

375) Binkley, D., and T.C. Brown. 1993. Management impacts on water quality of forests and rangelands. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-239. 114pp. (I)

Author abstract (Author Overview): This report compiles information about the effects of management practices on water quality in forests and rangelands. Chapter 1 summarizes water quality concerns on all types of lands. It discusses categories of water quality degradation, land area sources of degradation, processes and activities that cause such degradation, and recent trends in water quality in the United States. Chapter 1 places water quality problems on forests and rangelands in the context of the broader concern. In most cases, forest and rangeland management activities are relatively minor contributors of water quality degradation.

Chapters 2 through 9 focus on physical, chemical, and biological aspects of the forest and rangeland water quality. Chapter 2 reviews basic forest and rangeland hydrology and water quality processes, and it ends with a brief description of where we obtained the water quality data for this report. Chapters 3 through 8 review the state of knowledge about the effects of land management actions on water quality of forests and rangelands in 6 regions of North America. Each of these regional chapters focuses on results at experimental watersheds within the region.

Each chapter ends with a short summary; a table summarizing the findings at the region's experimental watersheds is in the Appendix. Chapter 9 provides a synthesis of the 6 regional chapters. This synthesis concludes that suspended sediment, especially in areas of sensitive soils and slopes, is the major water quality concern. Best management practices (defined in Chapter 10) generally minimize suspended sediment concentrations.

The scope of Chapters 3 through 9 is limited in two ways. First, the focus is on the effects of land management practices, such as harvesting and grazing, and not on the generally less important effects of acid precipitation on forest and rangeland water quality. Second, our emphasis is water quality, not erosion, so we do not review the many studies that have measured only on-land soil movement.

Chapter 10 describes the federal laws and state programs that are intended to control or monitor forest and rangeland management practices affecting water quality. The state programs are summarized in a table based on recent interviews with state personnel. Examples of state efforts are given. Then we discuss the rationale for basing nonpoint source pollution control on specification and use of best management practices. Carefully designed best management practices are encouraged, but cost effectiveness is also emphasized.

The final chapter reviews available information about the economic efficiency of nonpoint source pollution programs on forestlands. While the costs of implementing best management practices are fairly well understood in some locations, the benefits of their application are poorly documented. Better studies are needed to determine the efficiency of best management practices.

376) Bonin, H.L., R.P. Griffiths, and B.A. Caldwell. 2000. Nutrient and microbiological characteristics of fine benthic organic matter in mountain streams. Journal of the North American Benthological Society. 19: 235-249. (C, E)

Author abstract: Fine benthic organic matter (FBOM) was collected over a 10-mo period from 14 1st-order streams in the Cascade Mountains of western Oregon to investigate 1) relationships between FBOM substrate quality and microbial activity, 2) links between organic matter sources and FBOM substrate quality, and 3) how FBOM is influenced by riparian vegetation, elevation, and season. Streams drained forests in 3 successional age classes: old-growth forest dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*), and young regenerating stands, either 10 y old with a large riparian herbaceous component, or 30 y old and surrounded by deciduous trees such as red alder (*Alnus rubra*).

Seasonal trends showed a major autumn depression in carbon: nitrogen ratios (C:N) and an increase in microbial activities, a likely result of increased leaf inputs after an early fall storm. Decreases in C:N, total C, total N, and organic P were correlated with reciprocal increases in respiration, β–glucosidase and phosphatase activities, and acetylene reduction, all of which are relative indicators of microbial activity. Lower C:N and higher denitrification potentials, respiration rates, β–glucosidase and phosphatase activities, and mineralizable N were observed in young stands compared to old growth, suggesting higher quality FBOM and faster decomposition rates in young stands. An exception to this trend was acetylene reduction, which was greater in FBOM from old-growth streams. Significantly lower C:N at high elevations (1220–1280 m) versus low elevations (580–800 m) suggested the presence of more herbaceous vegetation and alder in high-elevation riparian zones. Lower total N and total C, and elevated denitrification potentials, acetylene reduction, respiration rates, and phosphatase activity at low elevations (580–800 m) suggested greater decomposition rates at low elevations. Organic P was

3.6 and 2.2 mg P/g organic matter at high and low elevations, respectively, a significant difference probably resulting from the young geologic age of parent material at high elevations. Data from this study suggest a potential link, mediated by shifts in FBOM, between headwater forest management and dynamics of stream food webs.

377) Braudrick, C.A., and G.E. Grant. 2001. Transport and deposition of large woody debris in streams: A flume experiment. Geomorphology. 41: 263-283. (A, D, G)

Author abstract: Large woody debris (LWD) is an integral component of forested streams of the Pacific Northwest and elsewhere, yet little is known about how far wood is transported and where it is deposited in streams. In this paper, we report the results of flume experiments that examine interactions among hydraulics, channel geometry, transport distance and deposition of floating wood. These experiments were carried out in a 1.22-m-wide×9.14-m-long gravel bed flume using wooden dowels of various sizes as surrogate logs. Channel planforms were either self-formed or created by hand, and ranged from meanders to alternate bars. Floating pieces tended to orient with long axes parallel to flow in the center of the channel. Pieces were deposited where channel depth was less than buoyant depth, typically at the head of mid-channel bars, in shallow zones where flow expanded, and on the outside of bends. We hypothesize that the distance logs travel may be a function of the channel's debris roughness, a dimensionless index incorporating ratios of piece length and diameter to channel width, depth and sinuosity. Travel distance decreased as the ratio of piece length to both channel width and radius of curvature increased, but the relative importance of these variables changed with channel planform. Large pieces can move further than our debris roughness models predict if greater than 50% of the active channel area is deeper than the buoyant depth of the piece, or if momentum is high enough to carry pieces across shallows. Our debris roughness model allows first-order prediction of the amount of wood transport under various channel geometries.

378) Brookshire, E.N.J, and K.A. Dwire. 2003. Controls on patterns of coarse organic particle retention in headwater streams. Journal of the North American Benthological Society. 22: 17-34. (A, C, D, E, G)

Author abstract: Organic matter retention is an integral ecosystem process affecting C and nutrient dynamics and biota in streams. Influences of discharge (Q), reach-scale channel form, and riparian vegetation on coarse particulate organic matter (CPOM) retention were analyzed in 2 headwater streams in northeastern Oregon. *Ginko biloba* leaves were released in coniferous forest reaches and downstream floodplain meadow reaches during spring high flow and summer baseflow. Transitional reaches were also analyzed during summer baseflow. Paper strips, simulating sedge blade retention, were released in meadow reaches during high flow. Mean transport distances (S_p) were calculated as the inverse of the longitudinal loss rate (k) of leaves in transport. The metrics S_p, width-specific discharge (Q_w = Q/stream width), and the mass transfer coefficient ($v_{dep} = Q_w/S_p$) were used to investigate retention. Values of S_p (0.9–97 m) were 2 to 11 times longer during high flow than baseflow. Mean S_p in forest reaches (29.3 m) was significantly shorter than in meadow reaches (68.9 m) during high flow but not during baseflow. Standardizing k for the scaling effects of Q by analyzing the relationship between Q_w and S_p, in which the slope equaled the inverse of mean v_{dep} of all *Ginkgo* releases, indicated times when v_{dep} was higher or lower than predicted by Q. Values of S_p were driven largely by Q, yet most

experiments in which values of v_{dep} exceeded those predicted by Q_w occurred during high flow. Values of v_{dep} (0.3–32 mm/s) across experiments were generally inversely related to S_p but did not differ between forest and meadow reaches during high flow. Unlike meadow reaches, mean v_{dep} in forest reaches was higher during high flow (5.2 mm/s) than baseflow (1.1 mm/s). Values of v_{dep} were positively related to large wood volume and negatively related to the extent of floodplain inundation during high flow. Yet, in the meadow reach that had lower relative channel constraint, paper strips were transported farther onto the floodplain as Q rose, resulting in long-term (~1.5 mo) retention. Despite downstream increases in Q, there were no differences in mean baseflow S_p or v_{dep} among reaches in either stream, indicating some longitudinal compensation in retention. Alternating associations between retention metrics and structural elements of the stream channels between flow periods suggests dynamic reach-scale hydrologic-retention thresholds in response to changes in Q. Analysis of v_{dep} across experiments indicated that channel morphology, stream wood, and riparian vegetation are major controls on CPOM retention.

379) Brown, G.W. 1969. Predicting temperatures of small streams. Water Resources Research. 5: 68-75. (J)

Author abstract: Hourly temperatures of small streams can be accurately predicted using an energy balance. Micrometeorological measurements are required to assess the environment of the small stream accurately. The temperature-prediction technique was tested on three streams in Oregon. On inshaded stretches, net all-wave radiation is the predominant energy source during the day; evaporation and convection account for less than 10% of the total energy exchange. Conduction of heat into the stream bottom is an important energy balance component on shallow streams having a bedrock bottom. Up to 25% of the energy absorbed by such a stream may be transferred into the bed. Hourly temperature changes of 0-16° F were predicted to within 1° F more than 90% of the time. This technique permits foresters to control water temperature through manipulation of stream-side vegetation.

380) Burns, J.W. 1970. Spawning bed sedimentation studies in northern California streams. California Fish and Game. 56: 253-270. (B, I)

Author abstract: Changes in the size composition of spawning bed materials in six coastal streams were monitored for 3 years to determine the effects of logging on the habitat of silver salmon (*Oncorhynchus kisutch*) and trout (*Salmo gairdnerii gairdnerii* and *S. clarkii clarkii*). Four test streams were sampled before, during and after logging. Two streams in unlogged watersheds and the undisturbed upstream section of one test stream served as controls. A variety of stream types in second-growth and old-growth forests was selected for observation.

Spawning bed composition in the four test streams changed after logging, roughly in proportion to the amount of streambank disturbance. The heaviest sedimentation occurred when bulldozers operated in narrow stream channels having pebble bottoms. In a larger stream with a cobble and boulder bottom, bulldozer operations in the channel did not increase sedimentation greatly. Sustained logging and road construction kept sediment levels high in one stream for several years. Sedimentation was greatest during periods of road construction near streams and removal of debris from streams, confirming the need for special measures to minimize erosion

during such operations. Control streams changed little in spawning bed composition during the 3 years.

381) Burns, J.W. 1972. Some effects of logging and associated road construction on northern California streams. Transactions of the American Fisheries Society. 101: 1-17. (B, C, F, I)

Author abstract: The effects of logging and associated road construction on four California trout and salmon streams were investigated from 1966 through 1969. This study included measurements of streambed sedimentation, water quality, fish food abundance, and stream nursery capacity. Logging was found to be compatible with anadromous fish production when adequate attention was given to stream protection and channel clearance. The carrying capacities for juvenile salmonids of some stream sections were increased when high temperatures, low dissolved oxygen concentrations, and adverse sedimentation did not accompany the logging. Extensive use of bulldozers on steep slopes for road building and in stream channels during debris removal caused excessive streambed sedimentation in narrow streams. Sustained logging prolonged adverse conditions in one stream and delayed stream recovery. Other aspects of logging on anadromous fish production on the Pacific Coast are discussed.

382) Cafferata, P.H., and T.E. Spittler. 1998. Logging impacts of the 1970's vs. the 1990's in the Caspar Creek Watershed. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-168. Pages 103-115. (K)

Author abstract: The Caspar Creek watershed study provides resource professionals with information regarding the impacts of timber operations conducted under varying forest practices on sensitive aquatic habitats. In the South Fork watershed, roads were constructed near watercourse channels in the 1960's, and the watershed was selectively logged using tractors during the early 1970's. Subwatersheds in the North Fork were clearcut from 1985 to 1991 using predominantly cable yarding and roads located high on ridges. Numerous landslides were documented after road construction and logging in the South Fork owing to inadequate road, skid trail, and landing design, placement, and construction. In contrast, the size and number of landslides after timber operations in the North Fork to date have been similar in logged and unlogged units. Considerably more hillslope erosion and sediment yield have also been documented after logging operations in the South Fork, when compared to the North Fork. An analysis of the storm events associated with documented landslides showed that high 3-day or 10-day precipitation totals in combination with moderately high 1-day amounts have been more important than very high 1-day totals alone in triggering debris sliding at Caspar Creek. Storm sequences meeting the criteria required for causing documented landslides were found to have occurred in all phases of the 36-year study, with the greatest number occurring in water year 1998. Numerous large landslides associated with the road system in the South Fork occurred in early 1998, indicating that "legacy" roads continue to be significant sources of sediment decades after they were constructed.

383) Cannon, S.H., R.M. Kirkham, and M. Parise. 2001. Wildfire-related debris-flow initiation processes, Storm King Mountain, Colorado. Geomorphology. 39: 171-188. (K)

Author abstract: A torrential rainstorm on September 1, 1994 at the recently burned hillslopes of Storm King Mountain, CO, resulted in the generation of debris flows from every burned drainage basin. Maps (1:5000 scale) of bedrock and surficial materials and of the debris-flow paths, coupled with a 10-m Digital Elevation Model (DEM) of topography, are used to evaluate the processes that generated fire-related debris flows in this setting. These evaluations form the basis for a descriptive model for fire-related debris-flow initiation.

The prominent paths left by the debris flows originated in 0- and 1st-order hollows or channels. Discrete soil-slip scars do not occur at the heads of these paths. Although 58 soil-slip scars were mapped on hillslopes in the burned basins, material derived from these soil slips accounted for only about 7% of the total volume of material deposited at canyon mouths. This fact, combined with observations of significant erosion of hillslope materials, suggests that a runoff-dominated process of progressive sediment entrainment by surface runoff, rather than infiltration-triggered failure of discrete soil slips, was the primary mechanism of debris-flow initiation. A paucity of channel incision, along with observations of extensive hillslope erosion, indicates that a significant proportion of material in the debris flows was derived from the hillslopes, with a smaller contribution from the channels.

Because of the importance of runoff-dominated rather than infiltration-dominated processes in the generation of these fire-related debris flows, the runoff-contributing area that extends upslope from the point of debris-flow initiation to the drainage divide, and its gradient, becomes a critical constraint in debris-flow initiation. Slope-area thresholds for fire-related debris-flow initiation from Storm King Mountain are defined by functions of the form $A_{cr}(\tan\theta)^3=S$, where A_{cr} is the critical area extending upslope from the initiation location to the drainage divide, and $\tan\theta$ is its gradient. The thresholds vary with different materials.

384) Cederholm, C.J., and L.M. Reid. 1987. Impact of forest management on coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater River, Washington: A project summary. In: Streamside Management: Forestry and Fishery Interactions. Proceedings of a symposium held at University of Washington, 12-14 February 1986, Seattle. E.O. Salo and T.W. Cundy, Editors. Institute of Forest Resources, Seattle, Washington, Contribution No. 57. Pages 373-398. (B, D, I)

Author abstract: In 1972, declining coho salmon production and visible forestry impacts on coho habitats prompted the initiation of an ongoing fisheries research project in the Clearwater River basin of the Olympic Peninsula. Heavy fishery catches have resulted in a general underseeding of the basin, as demonstrated by stocking experiments and inventories of potential habitat. Because of the resulting lack of a reservoir of surplus juveniles, the number of smolts produced is more sensitive to natural and forestry-related impacts.

Forestry-related mortality in the Clearwater basin is primarily due to an increased sediment load and to alterations in the riparian environment that reduce refuge habitat during winter storms. Increased sediment loads come primarily from landslides and surface erosion on heavily used logging roads, while reductions in winter refuge capacity are caused by stream blockages or by destruction of the refuge habitat.

Field and laboratory experiments demonstrate that (1) survival of eggs and alevins decreases as the percentage of fine sediments in spawning gravels increases, (2) suspended sediments cause stress to juveniles during summer, (3) disruption or blockage of small winter refuge channels can

reduce smolt survival, (4) aggradation of coarse sediments can cause loss of summer rearing habitats, and (5) streambed stability may be locally reduced by removal of large woody debris.

Since the depressed state of Clearwater River coho stocks has resulted from the combined effects of overfishing and forestry-caused habitat degradation, an integrated approach to natural resource management is needed that includes recognition of both the independent and combined impacts of the fishery and forestry industries. Within a drainage basin, resource management programs must provide for the protection of the full range of habitat types used by the fish.

385) Cederholm C.J., L.M. Reid, and E.O. Salo. 1980. Cumulative effects of logging road sediment on salmonid populations in the clearwater river, Jefferson County, Washington. Presented at the conference: Salmon-Spawning Gravel: A Renewable Resource in the Pacific Northwest?, 6-7 October, 1980, Seattle, Washington. 41pp. (B, I)

Author abstract: The nature of sediment production from logging roads and the effect of the resulting sediment on salmonid spawning success in the Clearwater River drainage have been studied for eight years. The study includes intensive and extensive analyses of field situations, supplemented by several controlled experiments. It was found that significant amounts (15-25 percent) of fine sediments (less than 0.85 mm diameter material) are accumulating in spawning gravels of some heavily roaded tributary basins. This accumulation is highest in basins where the road area exceeds 2.5 percent of the basin area. Tributaries of relatively steep gradient are less likely to accumulate high levels of fines. The survival of salmonid eggs to emergence is inversely correlated with percent fines when the percentage of fines exceeds the natural levels of 10 percent. There is a rapid decrease in survival to emergence for each 1 percent increase in fines over natural levels. The presence of 2.5 km/km^2 of gravel-surfaced roads undergoing an average distribution of road uses is found to be responsible for producing sediment at 2.6-4.3 times the natural rate in a drainage basin. Sixty percent of the road-related sediment production is caused by landslides while erosion on road surfaces accounts for an additional 18-26 percent. If fine sediment alone is considered, production from road surfaces and landslides is nearly equal. The tributaries of the Clearwater River may be underseeded for coho salmon due to heavy harvest rates in the commercial and sport fisheries. This underseeded condition becomes significant when the efficiency of the spawning environment.

386) Cederholm, C.J., R.E. Bilby, P.A. Bisson, T.W. Bumstead, B.R. Fransen, W.J. Scarlett, and J.W. Ward. 1997. Response of juvenile coho salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management. 17: 947-963. (A, D, G)

Author abstract: *Many* fish habitats have been altered in Pacific Northwest streams and rivers over the past century by a variety of land use practices, including forestry, urbanization, agriculture, and channelization. There are research and management needs for evaluation of the effectiveness of rehabilitation projects intended to enhance stream fish habitat recovery. The response of populations of juvenile coho salmon *Oncorhynchus kisutch* and steelhead *0. mykiss* to addition of large woody debris (LWD) was tested in North Fork Porter Creek (NFPC), a small coastal tributary of the Chehalis River, Washington. The NFPC was divided into three 500-m study sections; two sections were altered with two approaches (engineered and logger's choice)

to adding LWD, and the third was kept as a reference site. Immediately after LWD addition, the abundance of LWD pieces was 7.9 times greater than the pretreatment level in the engineered site and 2.7 times greater in the logger's choice site; abundance was unchanged in the reference site. Subsequent winter storms brought additional LWD into all three study sites. In the years that followed, the amount of pool surface area increased significantly in both the engineered and logger's choice sites, while it decreased slightly in the reference site. After LWD addition, winter populations of juvenile coho salmon increased significantly in the engineered and logger's choice sites, while they remained the same in the reference site. There were no significant differences in the coho salmon populations during spring and autumn within the reference, engineered, or logger's choice sites. The coho salmon smolt yield from the engineered and logger's choice sites also increased significantly after LWD addition, while it decreased slightly in the reference site. After LWD addition, the reference site and the engineered site both exhibited increases in age-0 steelhead populations; however, the population in the logger's choice site did not change. There was no difference in age-l steelhead abundance among sites, or before and after enhancement during any season. Winter populations of juvenile coho salmon and age-0 steelhead were related inversely to maximum and mean winter discharge.

387) Cenderelli, D.A., and J.S. Kite. 1998. Geomorphic effects of large debris flows on channel morphology at North Fork Mountain, eastern West Virginia, USA. Earth Surface Processes and Landforms. 23: 1-19. (A, I)

Author abstract: Extreme rainfall in June 1949 and November 1985 triggered numerous large debris flows on the steep slopes of North Fork Mountain, eastern West Virginia. Detailed mapping at four sites and field observations of several others indicate that the debris flows began in steep hillslope hollows, propagated downslope through the channel system, eroded channel sediment, produced complex distributions of deposits in lower gradient channels, and delivered sediment to floodwaters beyond the debris-flow termini. Based on the distribution of deposits and eroded surfaces, up to four zones were identified with each debris flow: an upper failure zone, a middle transport/erosion zone, a lower deposition zone, and a sediment-laden floodwater zone immediately downstream from the debris-flow terminus. Geomorphic effects of the debris flows in these zones are spatially variable. The initiation of debris flows in the failure zones and passage through the transport/erosion zones are characterized by degradation; 2300 to 17 000 m^3 of sediment was eroded from these zones. The total volume of channel erosion in the transport/erosion zones was 1.3 to 1.5 times greater than the total volume of sediment that initially failed, indicating that the debris flows were effective erosion agents as they traveled through the transport/erosion zones. The overall response in the deposition zones was aggradation. However, up to 43 per cent of the sediment delivered to these zones was eroded by floodwaters from joining tributaries immediately after debris-flow deposition. This sediment was incorporated into floodwaters downstream from the debris-flow termini causing considerable erosion and deposition in these channels.

388) Clinton, S.M., R.T. Edwards, and R.J. Naiman. 2002. Forest –river interaction: Influence on hyporheic dissolved organic carbon concentrations in a floodplain terrace. Journal of the American Water Resources Association. 83: 619-631. (C, E, I)

Author abstract: In large floodplain river, hyporheic (subsurface) flow paths transfer nutrients from productive riparian terraces to oligotrophic off-channel habitats. Because dissolved organic carbon (DOC) fuels microbial processes and hyporheic microorganisms represent the first stage of retention and transformation of these nutrients, understanding DOC flux can provide information on the constraints of microbial metabolism in the hyporheic zone of rivers. We monitored hydrology, physicochemical indicators, and dissolved organic carbon (DOC) dynamics during low and high discharge periods in the hyporheic zone of a riparian terrace on the Queets River, Washington, to understand what processes control the supply of carbon to subsurface microbial communities. As discharge increased, terrace hyporheic flowpaths changed from parallel to focused, and the location of surface water inputs to the terrace shifted from the terrace edge to head. Overall, DOC concentrations decreased along hyporheic flowpaths; however, concentrations at points along the flowpath varied with position along the head gradient and age of the overlying vegetation. We estimated that there is insufficient DOC in advecting surface water to support hyporheic microbial metabolism in this riparian terrace. These trends indicate that there are additional carbon sources to the subsurface water, and we conclude that DOC is leaching from overlying riparian soils within the forest patches. Thus, subsurface DOC concentrations reflect a balance between surface water inputs, metabolic uptake, and allochthonous inputs from forest soils.

389) Cole, M.B., K.R. Russell, and T.J. Mabee. 2003. Relation of headwater macroinvertebrate communities to in-stream and adjacent stand characteristics in managed second-growth forests of the Oregon Coast Range mountains. Canadian Journal of Forest Research. 33: 1433-1443. (C, I)

Author abstract: Although headwater streams constitute a significant portion of stream length within watersheds, their aquatic fauna, contributions to regional biodiversity, and responses to forest management have been understudied. Macro invertebrate communities, physical habitat, and water chemistry were sampled from 40 headwater streams in managed forests in the Oregon Coast Range mountains. We characterized functional and structural attributes of macroinvertebrate communities in relation to physical, chemical, and biological gradients. Substrate composition, specific conductance, and riparian forest age showed the strongest correlations with resultant ordination patterns in macroinvertebrate community composition. Among individual metrics of community structure and composition, total macro invertebrate density and dominance by three taxa showed the strongest correlations with forest age. No community measures were related to densities of torrent salamanders (*Rhyacotriton kezeri*) or crayfish (*Pacifastacus leniusculus*), suggesting these potential predators had little influence on overall macro invertebrate community structure. Rare taxa were sampled from several reaches, including *Rhyacophila* probably *viquaea* for which little information is available, and an *Eobrachycentrus* sp., previously known to occur only in the Cascade mountains. Headwater streams within these managed forests of northwestern Oregon appear to be taxa rich, continue to support taxa limited to headwater streams, and harbor taxa about which little is known.

390) Crenshaw, C.L., H.M. Valett, and J.L. Tank. 2002. Effects of coarse particulate organic matter on fungal biomass and invertebrate density in the subsurface of a headwater stream. Journal of the North American Benthological Society. 21: 28-42. (C, G)

Author abstract: Links between groundwater invertebrates and their potential food resources were examined using biofilm development on fine wood. Little is known about biofilm development and organic matter content of lateral subsurface (i.e., parafluvial) environments and hyporheic habitats (upwelling and downwelling zones). Eighteen experimental baskets containing river rocks were paired by treatment in which 1 basket was supplemented with wood (six 7.2 cm × 12 cm strips of oak wood veneer). Nine pairs of baskets were buried 12 to 15 cm below the surface in Gallina Creek, a 1st-order mountain stream in northern New Mexico in late summer 1997. Three pairs were buried beneath the stream bank (i.e., parafluvial zone) and 6 pairs were buried in the hyporheic zone. Baskets were distributed along upwelling and downwelling reaches to assess the potential hydrologic influence of subsurface–surface exchange. Open baskets of wood veneer were placed on the streambed surface to compare fungal biomass on the surface with the subsurface. Wood in both hyporheic and parafluvial baskets was colonized by fungi, but fungal biomass was significantly greater on wood in surface water than in hyporheic and parafluvial zones. In addition, fungal biomass on hyporheic wood was significantly greater than on parafluvial wood. A similar pattern (i.e., surface > hyporheic > parafluvial) was observed for dissolved oxygen. In contrast, concentrations of retained particulate organic matter were significantly higher in the parafluvial than the hyporheic zone. Invertebrate densities were significantly greater in baskets supplemented with wood and were greater in the hyporheic zone than in the parafluvial zone. Our data suggest that wood and associated microbial biofilms represent an important food resource for interstitial invertebrate communities.

391) Cross, J. 2002. Measuring the impact of harvest intensity on riparian forest functionality in terms of shade production and large woody debris recruitment potential: Two models. M.S. Thesis, University of Washington, Seattle. (D, H)

Compiler abstract: The author developed two mathematical models: (1) a deterministic model for shade production, and (2) a probabilistic model for large woody debris (LWD) recruitment into streams. These models allowed for comparisons of harvest intensity effects between various management scenarios.

The shade model included the following variables: inventory composition, latitude, declination, buffer width, buffer slope, stream width, stream reach, stream gradient, and stream azimuth. Model results indicated that harvest intensity affects shade production. The author stressed that inferences and predictions about stream temperature changes based on results of the shade model can not be made because stream temperatures are dependent not only on direct solar insolation, but also on ambient air temperature, groundwater influx, substrate composition, discharge rate, and channel morphology.

The LWD model included the following variables: Inventory composition, buffer width, and buffer length (i.e. stream reach). The results of the LWD recruitment model showed that marginal recruitment diminishes as distance from the stream increases.

The results of this research indicated that managing buffers for maximum tree height would provide the most flexibility to managers to control shade production and LWD recruitment potential.

392) Curran, J.H., and E.E. Wohl. 2003. Large woody debris and flow resistance in step-pool channels, Cascade Range, Washington. Geomorphology. 51: 141-157. (A, D, G)

Author abstract: Total flow resistance, measured as Darcy–Weisbach f, in 20 step-pool channels with large woody debris (LWD) in Washington, ranged from 5 to 380 during summer low flows. Step risers in the study streams consist of either (1) large and relatively immobile woody debris, bedrock, or roots that form fixed, or "forced," steps, or (2) smaller and relatively mobile wood or clasts, or a mixture of both, arranged across the channel by the stream. Flow resistance in step-pool channels may be partitioned into grain, form, and spill resistance. Grain resistance is calculated as a function of particle size, and form resistance is calculated as large woody debris drag. Combined, grain and form resistance account for less than 10% of the total flow resistance. We initially assumed that the substantial remaining portion is spill resistance attributable to steps. However, measured step characteristics could not explain between-reach variations in flow resistance. This suggests that other factors may be significant; the coefficient of variation of the hydraulic radius explained 43% of the variation in friction factors between streams, for example. Large woody debris generates form resistance on step treads and spill resistance at step risers. Because the form resistance of step-pool channels is relatively minor compared to spill resistance and because wood in steps accentuates spill resistance by increasing step height, we suggest that wood in step risers influences channel hydraulics more than wood elsewhere in the channel. Hence, the distribution and function, not just abundance, of large woody debris is critical in steep, step-pool channels.

393) Damian, F. 2003. Cross-drain placement to reduce sediment delivery from forest roads to streams. M.S. Thesis, University of Washington, Seattle. (I)

Author abstract: Ditch relief culverts can reduce road sediment delivery to streams by allowing infiltration and sediment filtering across the forest floor. Below the last ditch relief culvert, all the sediment routed by the ditch will be delivered directly to the stream. The last ditch relief culvert should be as close to the stream crossing as possible. If the ditch relief culvert is too close to the stream however, then there is little potential for sediment filtering. This tradeoff between minimizing the amount of water delivered directly to the stream and maximizing the distance for outflow filtration poses a question of where the last ditch relief culvert should be placed.

A model has been developed which allows a designer to place ditch relief culverts at various locations and subsequently evaluate their impact on sediment delivery to streams. The main feature of the model is its immediate feedback to the forest engineer in visual as well as quantitative form. It allows the designer to dynamically assess the sediment impacts associated with each culvert as it is placed on the road network. Sediment delivery and routing algorithms are based on accepted methodologies. Current as well as planned roads can be evaluated and the potential for improvements documented in a quantifiable and repeatable way.

The model was tested on a portion of the Tahoma State Forest, situated south of Mt. Rainier. Two existing road systems with 28 and 39 stream crossings and 82 and 86 cross drain culverts respectively, were analyzed. Interactively relocating 20 and 35 of the cross drains resulted in a three quarter reduction in sediment delivered to the stream system. The last culvert was usually placed about 100 - 200 ft of a stream according to local conditions, challenging one of the regulatory recommendations to place a cross drain within 100 ft of a stream crossing. Forest

engineers and regulators now have a design tool to assess effectiveness of a cross drain system rather then simply relying on culvert spacing and count.

394) Daniels, M.D., and B.L. Rhoads. 2003. Influence of a large woody debris obstruction on three-dimensional flow structure in a meander bend. Geomorphology. 51: 159-173. (A, D, F, G)

Author abstract: A field experiment has been conducted to assess the influence of large woody debris (LWD) obstruction on three-dimensional flow through a meander bend of a small stream in east central Illinois. Previous studies in unobstructed meander bends have shown that flow through a curved channel should develop a coherent three-dimensional structure characterized by large-scale helical motion. Many meander bends are complicated by naturally occurring persistent obstacles, such as LWD, that have the potential to profoundly disrupt flow structure. The results of this study show that the LWD obstruction systematically influences the three-dimensionality of flow through the bend, particularly the position of the high-velocity core and the development of helicity. The high-velocity core is positioned in the center of the channel upstream of and near the bend apex, but as flow approaches the LWD, it is steered toward the inner bank by the obstruction. Evolving helicity in the upstream portion of the bend is amplified by abrupt turning of the flow induced by the LWD. As the flow moves past the LWD, helicity diminishes rapidly and may even reverse its pattern of rotation. The net effect of the LWD obstruction is to reduce near-bank velocities along the outer bank downstream of the bend apex––a critical locus for bank erosion in meander bends. Given the persistence of the LWD obstruction, it probably has an important local influence on bend migration and evolution.

395) Darby, S.E., D. Gessler, and C.R. Thorne. 2000. Computer program for stability analysis of steep, cohesive riverbanks. Earth Surface Processes and Landforms. 25: 175-190. (F)

Author abstract: The ability to predict the stability of eroding riverbanks is a prerequisite for modelling alluvial channel width adjustment and a requirement for predicting bank erosion rates and sediment yield associated with bank erosion. Mass-wasting of bank materials under gravity occurs through a variety of specific mechanisms, with a separate analysis required for each type of failure. This paper presents a computer program for the analysis of the stability of steep, cohesive riverbanks with respect to planar-type failures. Planar-type failures are common along stream channels destabilized by severe bed degradation. Existing stability analyses for planar-type failures have a number of limitations that affect their physical basis and predictive ability. The computer program presented here is based on an analysis developed by Darby and Thorne. The software takes account of the geotechnical characteristics of the bank materials, the shape of the bank profile, and the relative elevations of the groundwater and surface water to estimate stability with respect to mass failure along a planar-type failure surface. Results can be displayed either in terms of a factor of safety (ratio of resisting to driving forces), or probability of failure. The computer analysis is able to determine the relative amounts of bed degradation and bank-toe erosion required to destabilize an initially stable bank. Data for the analysis are supplied in the form of either HEC-2 hydrographic survey data files or user-supplied bank profile data, in conjunction with user-supplied geotechnical parameter values. Some examples, using data from

the Upper Missouri River in Montana, are used to demonstrate potential applications of the software.

396) del Rosario, R.B., and V.H. Resh. 2000. Invertebrates in intermittent and perennial streams: Is the hyporheic zone a refuge from drying? Journal of the North American Benthological Society. 19: 680-696. (A, C)

Author abstract: Two northern Californian streams, an intermittent and a perennial, with similar climate, geology, vegetation, and land use were compared to examine the effects of seasonal drying on surface and hyporheic invertebrate assemblages. Aquatic insects composed 95% and 94% of the surface fauna in the intermittent and perennial streams, respectively, and were dominated by chironomids and caddisflies (e.g., *Apatania, Neothremma, Parthina*). Noninsects composed 73% and 59% of the hyporheic fauna in the intermittent and perennial streams, respectively, and were dominated by archiannelids and harpacticoid and cyclopoid copepods. Faunal overlap between the intermittent and perennial streams was high (Jaccard coefficient 0.88 for surface fauna and 0.82 for hyporheic fauna). The intermittent stream surface fauna had lower total densities, taxon richness, and species diversity compared to that of the perennial stream; the hyporheic fauna in the intermittent stream had lower densities, similar richness, but higher species diversity.

We used a Before-After-Control-Impact (BACI) design to test the hypothesis that the hyporheic zone serves as a refuge for surface invertebrates when surface flow ceases. If the hyporheic zone serves as a refuge, then hyporheic densities during the dry period should increase in the intermittent stream relative to the perennial stream. However, during the drying process, populations of temporary hyporheic resident invertebrates remained unchanged (*Sweltsa*) or decreased (*Baetis, Parthina,* Ceratopogonidae), but densities of the permanent hyporheic resident (Archiannelida) increased. This result suggests that the hyporheic zone was not a refuge from drying for surface invertebrates inhabiting this intermittent stream.

397) Dent, C.L., N.B. Grimm, and S.G. Fisher. 2001. Multiscale effects of surface-subsurface exchange on stream water nutrient concentrations. Journal of the North American Benthological Society. 20: 162-181. (E, G, I)

Author abstract: Stream–riparian ecosystems are landscapes composed of dynamic interacting terrestrial and aquatic patches. Patch composition and configuration affects both the form of transported materials and the amount of nutrient retention and export. We describe spatial patterns of nutrients in the surface water of an arid-land stream using surveys conducted at 3 different scales, ranging from 30 m to 10 km in extent and from 1 m to 25 m in grain. We then relate these patterns to connections with subsurface patches at channel subunit, channel unit, and reach scales. Our objectives were to compare spatial variation in nutrients across scales, to determine the causes of downstream changes in nutrient concentration in terms of intervening patches, and to investigate whether subsurface patches at different scales behaved similarly in terms of net nutrient processing.

Nutrients varied spatially at all scales sampled. The highest variation was observed in nitrate-N (NO_3-N) in the survey with the smallest grain (CV = 161%) and the lowest was observed in soluble reactive P (SRP) in the same survey (CV = 17%). We hypothesized that downstream changes in nutrient concentrations were caused by upwelling of high-nutrient water from the

subsurface. To test this hypothesis, we identified locations of hydrologic inputs to surface water from the subsurface using geomorphic features of the stream such as gravel bar edges (channel subunit scale), riffle-run transitions (channel unit scale), and permanent groundwater sources (reach scale). As surface water passed over these locations, nutrient concentrations generally increased, particularly during late succession when subsurface patches acted as sources of NO_3-N at all 3 scales and as sources of SRP at the channel unit and reach scales. A hierarchical approach allowed us to decompose effects of subsurface upwellings at different scales and to consider interactions between them. Processes occurring in subsurface patches influenced surface water nutrient patterns at scales from a few meters to several kilometers.

398) Dettmers, J.M., D.H. Wahl, D.A. Soluk, and S. Gutreuter. 2001. Life in the fast lane: Fish and foodweb structure in the main channel of large rivers. Journal of the North American Benthological Society. 20: 255-265. (A, C, E)

Author abstract: We studied the main channel of the lower Illinois River and of the Mississippi River just upstream and downstream of its confluence with the Illinois River to describe the abundance, composition, and/or seasonal appearance of components of the main-channel community. Abundance of fishes in the main channel was high, especially adults. Most adult fishes were present in the main channel for either 3 or 4 seasons/y, indicating that fishes regularly reside in the main channel. We documented abundant zooplankton and benthic invertebrates in the main channel, and the presence of these food types in the diets of channel catfish and freshwater drum. All trophic levels were well represented in the main channel, indicating that the main channel supports a unique food web. The main channel also serves as an important energetic link with other riverine habitats (e.g., floodplains, secondary channels, backwater lakes) because of the mobility of resident fishes and because of the varied energy sources supplying this food web. It may be more realistic to view energy flow in large-river systems as a combination of 3 existing concepts, the river continuum concept (downstream transport), the flood pulse concept (lateral transport to the floodplain), and the riverine productivity model (autochthonous production). We urge additional research to quantify the links between the main channel and other habitat types in large rivers because of the apparent importance of main-channel processes in the overall structure and function of large-river ecosystems.

399) Dietrich, W.E., R. Real de Asua, J. Coyle, B. Orr, and M. Trso. 1998. A validation study of the shallow slope stability model, SHALSTAB, in forested lands of Northern California. Written by the Department of Geology and Geophysics, University of California, Berkeley and Stillwater Ecosystem, Watershed & Riverine Sciences, Berkeley, California. 59pp. (K)

Author abstract: SHALSTAB is a coupled, steady-state runoff and infinite-slope stability model which can be used to map the relative potential for shallow landsliding across a landscape. The model is based on the assumptions that shallow surface runoff dictates the pore pressure field and that steady state runoff mimics the spatial pattern of soil pore pressures during transient storms. SHALSTAB can be used as a parameter free model in which the ratio of the effective precipitation to soil transmissivity (q/T) is calculated and used to assign relative landslide hazard: sites with the lowest q/T for instability are expected to be the least stable areas in the

landscape. The value of q/T depends on just two variables: (1) drainage area per width of subsurface flow, and (2) local slope, both of which can be easily evaluated using a digital terrain model (DTM). Because the model is parameter-free, it can be easily used in a validation mode, which allows the model to be rejected if its predictions do not match the observed pattern of landsliding. Furthermore, this means that exactly the same model is used on all landscapes, llowing comparisons of relative slope stability among varying landscapes. SHALSTAB is becoming widely used in the Pacific Northwest as a way of using digital elevation data to delineate potential slope stability over large areas.

The results of model testing conducted in the California Coast Ranges of coastal Mendocino and Humboldt counties are reported here. Aerial photographs taken in 1978 arid 1996 were used to map the location and size of all observable shallow landslides for seven watersheds ranging in size from 4.8 to 143 km^2. A total of 844 in-unit failures (i.e.. landslides occurring within timber harvesting units that were not associated with roads) and 354 road-related failures were mapped in the total study area of 281.2 km^2. Landslides ranged in size from 36 to 17,045 m^2, with a median area being about 500 m^2. Elevation contours from United States Geological Survey (USGS) 7.5 minute quadrangle maps were digitized and used to create a 10-m grid that provided the digital terrain framework for the model. Mapped landslides were digitized onto this digital surface. For every 10-m grid cell a value of q/T was determined and for each landslide, which typically covered five or more cells, the cell within the landslide with the lowest q/T value was selected to represent the potential instability of the landslide.

To test the model, we developed a procedure for randomly placing landslides of similar size to those that were mapped onto the digital terrain model. We then compared the distribution of modeled landslides with that of the observed landslides. If the model is successful, the observed (mapped) landslides should be much more common in the least stable areas than randomly generated landslides. In addition, the observed density of landslides (number of landslides per unit area) should be greatest for those areas predicted to be least stable. For each of the seven watersheds tested, the results indicated that SHALSTAB successfully met both of these criteria. Comparison of the seven watersheds using the 1978 landslide data also indicated that the number of landslides mapped per unit area of the watershed increased with the proportion of the watershed assigned to the higher instability categories. These results appear to support the use of SHALSTAB as a landscape-scale screening tool for identifying those watersheds with the greatest potential for shallow landsliding.

On average for each of the 7 watersheds, about 46 percent of the observed landslides and 56 percent of the landslide volume occurred in the two lowest slope stability categories (chronically unstable and $\log(q/T)<-3.1$), which represents on average 8% of the drainage area (ranging from 1 to 23% for the seven watersheds). An average for each of the watersheds of about 58 percent of the observed landslides and 72 percent by volume occurred on grid cells with $\log(q/T) <-2.8$, which represents on average 13% of trie drainage area (ranging from 3 to 31 percent). Inclusion of the inner gorge area (mapped by California Division of Mines and Geology) with the first two categories as part of the high hazard delineation significantly improved model performance, but includes a larger area of the watershed.

Data from this study were compared with similar results from two study sites near Coos Bay in the Oregon Coast Range. Here all landslides were mapped in the field. Occurrence of landslides was strongly skewed to low log(q/T) categories and the proportion of the drainage area that would be mapped as high hazard in order to include a specific proportion of all the landslides was slightly higher than that found in the less steep northern California study areas.

For one of the study sites, high resolution airborne laser altimetry was available which permitted analysis to be performed on 2-m grids rather than the 10-m grids used in this validation study. Of the 35 mapped landslides. 94 percent fell in the least stable (chronic) SHALSTAB category. Application of airborne laser altimetry technology to slope stability modeling in forest lands in California should lead to a greatly improved model performance, with two primary management benefits: (1) more accurate prediction of areas susceptible to shallow landsliding (i.e., a greater percentage of observed landslides would occur in the high instability areas), and (2) a smaller proportion of the land area would be assigned to high instability categories.

To date, L-P has been running SHALSTAB with 10-m grid data and has been classifying areas with log (q/T) of <-3.1 or chronic instability as high hazard areas. The current prescription for high hazard areas is no harvest without review, which requires geotechnical review before any timber harvesting or road construction is allowed. Inner gorge areas are also treated as high hazard. The data clearly support using at least a log (q/T) of< -3.1 and the chronic sites to determine high hazard areas. This study was designed to test the basic validity of the model, and not to determine the most appropriate threshold to use in defining high hazard areas. Based on our results, raising the high hazard threshold to < -2.8 would significantly increase the number and volume of landslides that occur in the high hazard area but would also increase the area that would be classed as high hazard. A case can not be easily made, however, for moving the threshold to <-2.5 because by this value the model on average is not significantly better than random, and the area that would be placed as high hazard would be as much as 37 percent of the landscape in some watersheds. It is recommended that as part of the geotechnical review of timberland harvesting plans an effort be made to determine whether elevating the threshold to < -2.8 significantly improves detection of highly unstable areas.

400) Downs, P.W., and A. Simon. 2001. Fluvial geomorphological analysis of the recruitment of large woody debris in the Yalobusha network, central Mississippi, USA. Geomorphology. 37: 65-91. (A, D, F)

Author abstract: The management of large woody debris (LWD) should be based on a rational assessment of its recruitment rate relative to its natural decay and removal. LWD recruitment may be controlled by 'natural' episodic terrestrial factors or by in-channel geomorphological controls related to the rate of bank erosion. The geomorphological controls are hard to quantify in laterally migrating channels, but in incising channels, a conceptual model may be developed based on the density of riparian trees relative to the knickpoint migration rate and bank stability analyses that predict the post-knickpoint width of the channel. The Yalobusha river network in Central Mississippi, USA, has twice been destabilised by channel straightening for flood defence and land drainage, most recently in 1967. System-wide rejuvenation has followed through a series of upstream migrating knickpoints several metres high that have caused mass failure of streambanks and the recruitment of large volumes of trees to the channel. LWD recruitment is maximised at the transition between stage III and stage IV channels, focusing attention on 11 sites in the network. The sites are upstream of knickzones ranging between 2.2 and 5.4 m high and migrating at rates of 0–13.8 m $year^{-1}$, based on 23–30 months of monitoring. Riparian conditions in 500 m^2 plots on each bank upstream of the knickpoints range from treeless to forested, containing 0–98 trees with an average diameter at breast height of 0.18 m and average maximum height of 14.0 m. The average volume of wood on each bank is 0.02 m^3 m^{-2}. Under rapid drawdown conditions, bank stability analyses suggest that the channels will widen in

amounts ranging from 1.8 to 31.5 m. Combined with the knickpoint migration rates, riparian land losses are estimated to range from 8.0 to 433.8 m $year^{-1}$, resulting in the recruitment of almost 28 m^3 of wood (or 100 trees) annually from the 11 sites. Assuming this LWD recruitment rate, a model is developed for the in situ potential for debris dam initiation and growth, based on the ratio of tree height to channel width under current and post-knickpoint conditions, the annual delivery of 'large' trees and the annual total of LWD recruitment by volume. A longer-term model is also developed, based on 'knickpoint severity' and vegetation density in upstream and headwater riparian zones of each tributary. The 11 study sites are classified into groups with similar LWD management concerns based on these analyses. The models developed in this research provide the first precise quantification of LWD recruitment according to geomorphological controls and standing vegetation, and a rational assessment of its meaning, but further research is required to improve the accuracy of such estimates.

401) Eaton, L.S., B.A. Morgan, R.C. Kochel, and A.D. Howard. 2003. Role of debris flows in long-term landscape denudation in the central Appalachians of Virginia. Geology. 31: 339-342. (K)

Author abstract: Four major storms that triggered debris flows in the Virginia–West Virginia Appalachians provide new insights into the role of high-magnitude, low-frequency floods in long-term denudation and landscape evolution in mountainous terrain. Storm denudation in the Blue Ridge Mountain drainage basins is approximately an order of magnitude greater compared to basins located in the mountains of the Valley and Ridge province. This difference is probably the result of higher storm rainfall from the Blue Ridge storms. Radiocarbon dating of debris-flow deposits in the Blue Ridge indicates a debris-flow return interval of not more than 2–4 k.y. in mountainous river basins. This finding, combined with measurements of basin denudation, suggests that approximately half of the long-term denudation from mechanical load occurs episodically by debris-flow processes. Although floods of moderate magnitude are largely responsible for mobilizing sediment in low-gradient streams, our data suggest that high-magnitude, low-frequency events are the most significant component in delivering coarse-grained regolith from mountainous hollows and channels to the lowland floodplains.

402) Ebersole, J.L., W.J. Liss, and C.A. Frissell. 2003. Thermal heterogeneity, stream channel morphology, and salmonid abundance in northeastern Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences. 60: 1266-1280. (A, G, J)

Author abstract: Heterogeneity in stream water temperatures created by local influx of cooler subsurface waters into geomorphically complex stream channels was associated with increased abundance of rainbow trout (*Oncorhynchus mykiss*) and chinook salmon (*Oncorhynchus tshawytscha*) in northeastern Oregon. The addition of cold water patch frequency and area as explanatory variables in salmonid habitat models indicated that doubling of cold water patch frequency was associated with increases in rainbow trout and chinook salmon abundances of 31% and 59%, respectively. Doubling of cold water patch area was associated with changes of 10% in rainbow trout abundance but was not associated with chinook abundance after accounting for other habitat factors. The physiognomy, distribution, and connectivity of cold water patches, important attributes determining the effectiveness of these habitats as thermal refuges for stream fishes, were associated with channel bedform and riparian features.

Monitoring of thermal heterogeneity and salmonid populations in response to ongoing habitat restoration efforts will provide additional insights into causal relationships among these factors.

403) Egan, A.F. 1999. Forest roads: Where soil and water don't mix. Journal of Forestry. 97(8): 18-21. (I)

Author abstract: One guiding principle that will help foresters minimize the impact of roads on water quality is a seemingly obvious statement: Roads are horizontal features in a landscape characterized by vertical processes. Erosion mitigation efforts require understanding surface water momentum, planning roads to avoid surface water as much as possible, and working with the elements of the universal soil loss equation—rainfall and runoff erosivity, soil erodibility, slope length and percent slope, vegetative cover, and soil conservation practices.

404) Environmental Law Institute. 2003. Conservation thresholds for land use planners. Environmental Law Institute., Washington, D.C. 55pp. (C, D, E, F, I, J)

Compiler abstract: The Environmental Law Institute (ELI) conducted a literature search to determine if the scientific community has developed a body of knowledge that can aid national land use planners develop biological conservation thresholds. The search was limited to articles published between 1990 and 2001, commonly cited pre-1990 articles, and review papers found in the gray literature. Consideration was given only to articles with quantitative information that could be used to determine conservation thresholds for land use planning. Ecological threshold measures were identified for: buffers, habitat patch area, edge effects, and percent of suitable habitat.

The section on managing for adequate riparian buffer width includes a discussion on uniform versus variable widths. The literature review determined that a single ideal riparian buffer width suitable for all circumstances is not defensible; the survey identified recommended buffer widths varying from 1 meter to 1600 meters. Recommended buffer widths were dependent upon management objectives, with significantly wider buffers being recommended when the goal was to protect ecological functions such as maintaining species diversity, and narrower buffers being recommended when the goal was maintaining water quality functions. Based on the literature review, ELI recommends that the following minimum buffer widths for various management objectives:

- Nutrient and pollution removal—25 meters,
- Sediment removal and temperature and microclimate regulation—30 meters,
- Detrital input and bank stabilization—50 meters,
- Wildlife habitat functions—100 meters,
- Water quality and wildlife protection—100 meters.

Specific recommended minimum riparian and wetland buffer widths to maintain various water quality and wildlife functions, as found in the scientific literature, are provided in tabular and graphical form. Additional buffer design considerations that were discussed were vegetation, linear extent, and buffer protection (e.g. legal, contamination, disturbance).

405) Faustini, J.M., and J.A. Jones. 2003. Influence of large woody debris on channel morphology and dynamics in steep, boulder-rich mountain streams, western Cascades, Oregon. Geomorphology. 51: 187-205. (A, D, F, I)

Author abstract: This study used 20-year records of stream channel change and wood to test hypotheses about the long-term influence of large woody debris (LWD) on channel morphology, channel stability, and sediment dynamics in a steep, boulder-rich mountain stream. We compared two nearly adjacent reaches of third-order Mack Creek over the period 1978–1997 after virtually all wood was removed from the channel of the lower reach in 1964. We assessed the long-term legacy of wood removal using repeated cross-section surveys, streamflow data, LWD inventory data, and detailed mapping and longitudinal profile surveys. At each of 11 cross sections in the upper reach and 19 in the lower reach, we calculated areas of scour and fill in response to the two largest floods in the record. We used quasi-likelihood logistic regression models to test the proportion of each reach that experienced change between consecutive surveys over the entire record (1978–1997) as a function of flood return periods. The longitudinal profile of the site without LWD was more variable than the reach with LWD at the finest scale (~1 m) due to a greater frequency of boulder steps, but the reach with LWD was more variable at the channel unit scale. LWD-created steps 1 to 2.5 m high in the wood-rich reach accounted for nearly 30% of the total channel fall and created low-gradient upstream channel segments one to three channel widths long. As a result, both reaches have the same average slope (about 9%), but nearly three times as much of the channel in the wood-rich reach had a slope of ≤5% as in the reach without wood (20.4% of total channel length vs. 7.5% of channel length). The reach with abundant LWD was less responsive to moderate streamflow events (return period <~5 years), but it responded similarly to peak flows with a return period of about 10 to 25 years. Although the average magnitude of cross-section changes was the same during the largest flood in the record (25-year return period), the reach without LWD experienced scour and coarsening of the bed surface, whereas the reach with LWD experienced aggradation upstream of LWD features. Mack Creek may be representative of many steep mountain streams in which channel structure is strongly influenced by nonfluvial processes: a legacy of large boulders from glacial or mass movement processes and a legacy of dead wood from ecological processes. Sediment-limited mountain streams with large boulders, when deprived of LWD, appear to exhibit less morphological variation at the channel unit scale, to store less sediment, and to release it more readily than those with LWD.

406) Fischer, R.A., C.O. Martin, and J.C. Fischenich. 2000. Improving riparian buffer strips and corridors for water quality and wildlife. International Conference on Riparian Ecology and Management in Multi-Land Use Watersheds, 28-31 August 2000, Portland, Oregon. American Water Resources Association, Middleburg, Virginia. Pages 457-462. (I)

Author abstract: The management and restoration of riparian zones has received considerable attention throughout the United States. Numerous studies have shown that riparian buffer strips of sufficient width protect and improve water quality by intercepting non-point source pollutants. Buffer strips also clearly provide a diversity of other functions, including movement corridors and habitat for a large variety of organisms. However, criteria for determining proper dimensions of buffer strips for most ecological functions are not well established. Although riparian zones are being restored along thousands of streambank miles throughout the country, the ecological benefits of variable buffer strip designs (e.g., width, length, vegetation type, placement within the watershed) have not been adequately recognized. There have been few systematic attempts to

establish criteria that mesh water quality width requirements with other riparian functions. Subsequently, management prescriptions (e.g., width recommendations) are frequently based upon anecdotal information with little regard for the full range of effects these decisions may have on other riparian functions. Our objectives are to address the suitability of riparian zones to protect water quality while enhancing biodiversity, and to discuss recent strides in providing improved guidance for corridor and buffer designs based primarily on ecological criteria.

407) Florsheim, J.L., J.F. Mount, and L.T. Rutten. 2000. Effect of baselevel change on floodplain and fan development storage and ephemeral tributary channel morphology, Navarro River, California. Earth Surface Processes and Landforms. 26: 219-232. (A, I)

Author abstract: Managed baselevel lowering in tributaries that emerge from small canyons onto forested floodplains affects floodplain and fan sediment storage and small ephemeral tributary channel morphology in the Navarro River basin, Mendocino Country, California, USA. Numerous small tributaries (drainage areas up to several square kilometres) flow through culverts under Highway 128 across the forested floodplain of the Navarro River and one of its major tributaries, the North Fork. Excavation significantly deepened and widened these small tributaries upstream and downstream of culverts under the highway following the 1997 flood (recurrence interval 12 years), that inundated both the floodplain and the highway and culvert system. The excavation lowered the local baselevel of the tributary systems within the floodplain. This field study documents the effect of the lowered baselevel on floodplain and fan sediment storage and ephemeral tributary channel morphology. Excavation created defined channels in the floodplain where no channels previously existed. Additionally, the excavation and baselevel change created steps, or knickpoints, that migrated headward and incised the upstream tributary channels. Tributary incision decreases the sediment storage potential of the fan and floodplain and reduces the residence time for storage of fine sediment. A reduction in fine sediment residence time degrades downstream habitat for anadromous fish and other aquatic organisms in the Navarro River. Large wood influences floodplain and small tributary channel morphology by forming steps and increases sediment residence time by trapping sediment in forested tributary-fan-floodplain systems. Although this field investigation is specific to the Navarro River basin, our findings linking culvert maintenance excavation to geomorphic processes may be extended to other roads on forested floodplains in the Pacific Northwest or other systems with roads on floodplains.

408) Fulton, S., and B. West. 2002. Forestry impacts on water quality. In: Southern Forest Resource Assessment. D.N. Wear and J.G. Greis, Editors. USDA Forest Service, Southern Research Station, General Technical Report SRS-53. Pages 501-518. (E, G, I, J)

Author abstract:

- In the absence of controlling measures such as Best Management Practices (BMPs), silvicultural operations have the potential to significantly impact general water quality by generating nonpoint source pollution.

- From 1988 to 1998, an annual average of approximately 3,600 miles of rivers and streams were considered potentially impaired by pollution from silvicultural activities throughout the South.
- When compared with other land uses in the South, silvicultural activities are consistently found to be minor nonpoint sources of water-quality impacts (see chapter 19). Silviculture was one of the lowest "leading sources" of pollution or impairment for rivers and streams between 1988 and 1998 as reported by Southern States.
- BMPs are critical in mitigating water-quality degradation from silviculture. When appropriately implemented and maintained, BMPs are very effective in controlling nonpoint sources of pollution. They are particularly important in areas with steep topography.
- On an individual site basis, most water-quality impacts are short term (first several years after harvest), decreasing over time as vegetation regrows. However, there is very little information available on the cumulative effects of past and ongoing timber harvesting on overall watershed health.
- The major potential nonpoint source impact resulting from silvicultural activities is sediment from roads and skid trails. Other minor nonpoint-source impacts on water quality include short-term increased peak flows during storms; short-term increased base flows; short-term increased nutrient concentrations (primarily nitrogen and phosphorous); short-term increases in herbicides, fertilizers, and derivative products; and thermal pollution (increased stream temperature).

409) Furbish, D.J., and R.M. Rice. 1983. Predicting landslides related to clearcut logging, northwestern California, U.S.A. Mountain Research and Development. 3: 253-259. (I)

Author abstract: The management and restoration of riparian zones has received considerable attention throughout the United States. Numerous studies have shown that riparian buffer strips of sufficient width protect and improve water quality by intercepting non-point source pollutants. Buffer strips also clearly provide a diversity of other functions, including movement corridors and habitat for a large variety of organisms. However, criteria for determining proper dimensions of buffer strips for most ecological functions are not well established. Although riparian zones are being restored along thousands of streambank miles throughout the country, the ecological benefits of variable buffer strip designs (e.g., width, length, vegetation type, placement within the watershed) have not been adequately recognized. There have been few systematic attempts to establish criteria that mesh water quality width requirements with other riparian functions. Subsequently, management prescriptions (e.g., width recommendations) are frequently based upon anecdotal information with little regard for the full range of effects these decisions may have on other riparian functions. Our objectives are to address the suitability of riparian zones to protect water quality while enhancing biodiversity, and to discuss recent strides in providing improved guidance for corridor and buffer designs based primarily on ecological criteria.

410) Gay, G.R., H.H. Gay, W.H. Gay, H.A. Martinson, R.H. Meade, and J.A. Moody. 1998. Evolution of cutoffs across meander necks in Powder River, Montana, USA. Earth Surface Processes and Landforms. 23: 651-662. (F)

Author abstract: Over a period of several decades, gullies have been observed in various stages of forming, growing and completing the cutoff of meander necks in Powder River. During one episode of overbank flow, water flowing over the down-stream bank of the neck forms a headcut. The headcut migrates up-valley, forming a gully in its wake, until it has traversed the entire neck, cutting off the meander. The river then follows the course of the gully, which is subsequently enlarged as the river develops its new channel. The complete process usually requires several episodes of high water: in only one of the five cases described herein was a meander cutoff initiated and completed during a single large flood.

411) Geist, D.R., and D.D. Dauble. 1998. Redd site selection and spawning habitat use by fall chinook salmon: The importance of geomorphic features in large rivers. Environmental Management. 22: 655-669. (B, G)

Author abstract: Knowledge of the three-dimensional connectivity between rivers and groundwater within the hyporheic zone can be used to improve the definition of fall chinook salmon (*Oncorhynchus tshawytscha*) spawning habitat. Information exists on the microhabitat characteristics that define suitable salmon spawning habitat. However, traditional spawning habitat models that use these characteristics to predict available spawning habitat are restricted because they can not account for the heterogeneous nature of rivers. We present a conceptual spawning habitat model for fall chinook salmon that describes how geomorphic features of river channels create hydraulic processes, including hyporheic flows, that influence where salmon spawn in unconstrained reaches of large mainstem alluvial rivers. Two case studies based on empirical data from fall chinook salmon spawning areas in the Hanford Reach of the Columbia River are presented to illustrate important aspects of our conceptual model. We suggest that traditional habitat models and our conceptual model be combined to predict the limits of suitable fall chinook salmon spawning habitat. This approach can incorporate quantitative measures of river channel morphology, including general descriptors of geomorphic features at different spatial scales, in order to understand the processes influencing redd site selection and spawning habitat use. This information is needed in order to protect existing salmon spawning habitat in large rivers, as well as to recover habitat already lost.

412) Grady, J., Jr. 2001 Effects of buffer width on organic matter input to headwater streams in the western Cascade Mountains of Washington State. M.S. Thesis, University of Washington, Seattle. 46pp. (C)

Author abstract: Large-scale forest clear-cutting is often no longer considered an acceptable forest management strategy, and more environmentally focused forestry practices are being developed and implemented. As alternative forest management techniques and strategies are developed and tested, it is essential that environmental studies are conducted at the same time to ensure that the alternative practices are in fact providing significant environmental protection. The primary emphasis of this study was to determine the effects of forest harvesting on litterfall delivery to the stream channel. Responses in streams of watersheds harvested at varying degrees of disturbance were compared to nearby undisturbed streams. From September 1999 to October 2000 litterfall was collected every 2 to 4 weeks when road access was snow-free to the sites. With the knowledge of forest characteristics litterfall inputs between similar riparian forests were compared to assess the capability of buffers to simulate natural litterfall delivery to the stream

channel. No clear statistical relationship could be determined by which litterfall amounts were related to buffer widths.

413) Grant, G.E., F.J. Swanson, and M.G. Wolman. 1990. Pattern and origin of stepped-bed morphology in high-gradient streams, western Cascades, Oregon. Geological Society of America Bulletin. 102: 340-352. (A)

Author abstract: A general hierarchical framework for viewing stepped-bed morphology in high-gradient channels is presented. We emphasize channel units—bed features that are one or more channel widths in length—as a particularly important scale of variation. Field studies in two streams in the Cascade Range in Oregon indicated that pool, riffle, rapid, cascade, and step channel units had distinct bed slope ranges, with average slopes of 0.005, 0.011, 0.029, 0.055, and 0.173, respectively. Steeper units (rapids and cascades) are composed of step-pool sequences created by particles representing the 90th or larger percentile size fraction of bed material. Step spacing is inversely proportional to bed slope.

The distribution of channel units along a stream is influenced by bedrock and processes that introduce coarse sediment. Cascade and pool units dominate where landslide and debris-flow deposits constrict channel width and deliver large immobile boulders to the channel, whereas riffle and rapid units dominate in broad valley flats where deposition of finer sediment occurs. Markov chain analysis indicates that channel units occur in nonrandom two-unit sequences with the slope of the upstream unit inversely proportional to the slope of the next downstream unit. Pool-to-pool spacings average two to four channel widths, but variability in spacing is high, owing to uneven distribution of bedrock out-crops and boulder deposits within the channel.

Hydraulic reconstruction indicates that channel units form during high- magnitude, low-frequency events with recurrence intervals of about 50 yr. Comparison of channel-unit morphology to high-gradient flume experiments with heterogenous bedload mixtures indicated that unit morphogenesis is linked to factors that cause congestion of large particles during bedload transport events; these include local constrictions in channel width, immobile bed material, and abrupt fluctuations in velocity due to hydraulic jumps that promote deposition. Channel units appear to be a two-dimensional bar form found in streams where gradients exceed 2%, bedload is widely sorted, and width-to-depth ratios and sediment supply are low—conditions found in many mountain environments.

414) Grissinger, E.H. 1982. Bank erosion of cohesive materials. In: Gravel-Bed Rivers: Fluvial Processes, Engineering and Management. R.D. Hey, J.C. Bathurst, and C.R. Thorne, Editors. John Wiley & Sons, New York. Pages 273-287. (F)

Author abstract: The resistance of cohesive materials to erosion by discrete particle scour is exceedingly complex. Soil properties and their interactions determine the magnitude of the interparticle forces of cohesion that resist detachment. The soil properties also influence the physical configuration of particles at the bank material surface. The bank surface, in turn, interacts with the hydraulics of flow near the surface. Bank failure results not only from hydraulic forces but also from gravity forces. The relative significance of the two types of force is determined by properties of the bank system. In northern Mississippi the incised nature of the drainage systems produces high, steep banks that are susceptible to mass failure. Consequently, gravity forces are relatively more significant than hydraulic forces. The mechanism of bank

failure is uniquely related to the properties of the individual valley-fill stratigraphic units that make up the bank. The distribution of the stratigraphic unit in the region is the result of paleoclimatic control of Holocene depostional and erosional systems. It can there fore be predicted on the basis of paleoclimatic and sea level change data.

415) Gritzner, M.L., W.A. Marcus, R. Aspinall, and S.G. Custer. 2001. Assessing landslide potential using GIS, soil wetness modeling and topographic attributes, Payette River, Idaho. Geomorphology. 37: 149-165. (K)

Author abstract: This study utilizes GIS modeling to determine if the location of 559 landslides in the 875 km^2 catchment of the Middle Fork of the Payette River, Idaho can be predicted based on topographic attributes and a wetness index generated by the DYNWET model. Slope and elevation were significantly related to landslide occurrence at this landscape scale. Aspect was also retained as a variable for further analysis because, despite a non-significant chi-square relation to landslide occurrence, graphical analysis suggested a relation between aspect and mass wasting. Chi-square analysis indicated that plan and profile curvature, flow path length, upslope contributing area, and the DYNWET-based moisture index were not significantly related to landsliding. A Bayesian probability model based on combinations of elevation, slope, aspect, and wetness indicates that elevation exhibits the closest relation to landsliding, followed by slope; but that neither aspect nor wetness index values help in prediction. The Bayesian probability model using elevation and slope generates a map of relative landslide risk that can be used to direct activities away from mass wasting prone areas. The association between elevation and landslides is perplexing but is perhaps due to the location of logging road at specific elevations (roads could not be included in the input data for analysis because they have not been adequately mapped). The lack of explanation provided by the DYNWET wetness index was also surprising and may be due to the 30-m digital elevation model (DEM) and the soils data having resolutions too coarse to adequately portray local variations key to mass wasting. We believe the inadequacy of data to drive the models is typical of the majority of catchment scale setting. For now, the ability of researchers to effectively model landscape scale landsliding is more limited by the type, resolution, and quality of available data than by the quality of the landslide models.

416) Gucinski, H., M.J. Furniss, R.R. Ziemer, and M.H. Brookes. 2001. Forest roads: A synthesis of scientific information. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-509. 103pp. (A, B, C, D, F, G, H, I, J)

Author abstract: Effects of roads in forested ecosystems span direct physical and ecological ones (such as geomorphic and hydrologic effects), indirect and landscape level ones (such as effects on aquatic habitat, terrestrial vertebrates, and biodiversity conservation), and socioeconomic ones (such as passive-use value, economic effects on development and range management). Road effects take place in the contexts of environmental settings, their history, and the state of engineering practices, and must be evaluated in those contexts for best management approaches.

417) Hagans, D.K., W.E. Weaver, and M.A. Madej. 1986. Long term on-site and off-site effects of logging and erosion in the Redwood Creek basin, northern California. In: Papers Presented at the American Geophysical Union Meeting on Cumulative Effects, 9-13 December 1985, San Francisco, California. G. Ice, Editor. National Council of the Paper Industry, New York, New York, Technical Bulletin 490. Pages 38-66. (A, F, I)

Author abstract (Author Summary): Erosion and sedimentation studies conducted in the 720 km^2 Redwood Creek basin show that some land use practices have caused persistent geomorphic effects at the logging site, on downslope areas and in far removed stream channels. These effects include on-site increases in drainage density and channel dimensions; off-site, downslope increases in fluvial erosion rates, drainage density and stream channel dimensions; and off-site, downstream increases in the volume of stored sediment and incidence of bank erosion, as well as decreases in pool number.

Sediment budget studies and detailed mapping on 1.4 to 197 km^2 study sites reveal that fluvial erosion, mostly gullying, accounts for 30 percent to 85 percent of the yield from all sources since 1947. Up to 85 percent, or more, result from logging-caused stream diversions that create complex channel networks and increase downslope drainage density. Multiple networks may develop from one diversion and more are expected where high diversion potentials remain uncorrected. Eighty percent of all gully erosion was avoidable.

Long-term changes in channel geometry do not seem as widespread in higher (third and fourth) order tributaries due to the short residence time of introduced sediment. Except where tributary gradients are naturally low, or locally reduced behind log jams, the off-site geomorphic effects of upstream increased erosion are minimal.

Volumes of stored sediment in Redwood Creek have risen from llxl06 m^3 in 1947 to over 16xl06 m^3 in 1980. Much of this increase can be accounted for by logging-caused fluvial erosion. Landslides also add sediment, but the portion caused by land use is not easily determined. Contrary to one model, aggradation in Redwood Creek has not itself triggered substantial stream side landsliding primarily because storage areas are wide and flanked by gently hillslopes. However, as degradation has occurred over the last 20 years, long term off-site changes in channel morphology are persisting. Residence times of most stored sediment ranges from decades to centuries.

418) Haggerty, S.M., D.P. Batzer, and C.R. Jackson. 2004. Macroinvertebrate response to logging in coastal headwater streams of Washington, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 61: 529-537. (A, C, I, J)

Author abstract: We examined the effects of logging on macroinvertebrate assemblages in first-order streams of four coniferous watersheds in Washington's Coastal Mountain ranges. Each watershed contained three to four first-order streams that were placed into one of three treatment types: clear-cut logging, operational buffer-strip (2.5–21 m) logging, or uncut reference streams. Prelogging baseline data on macroinvertebrate assemblages, channel morphology, sediment composition, sediment accretion rates, and water temperatures were collected from each stream in summer 1998. Logging operations were conducted the next winter and spring. Streams were resampled in summer 1999, within 1 year of logging, and summer 2000, 1+ years after logging. Preexisting treatment differences did not exist in 1998, indicating that postharvest treatment

differences could be attributed to logging operations. In 1999, densities of macroinvertebrate collectors, densities and biomass of macroinvertebrate shredders, and accretion rates of organic sediments were greater in clear-cut and buffered streams than uncut references. These differences diminished by 2000. An increase in collecting and shredding macroinvertebrate is not a typical response to logging and may reflect the fact that logged streams became buried under slash, increasing detrital food supplies for these organisms. The narrow buffers used for this study did not prevent macroinvertebrate community changes associated with logging.

419) Hairston-Strang, A.B., and P.W. Adams. 1998. Potential large woody debris sources in riparian buffers after harvesting in Oregon, U.S.A. Forest Ecology and Management. 112: 67-77. (D)

Author abstract: Twenty-one riparian buffers on private lands in Oregon were measured after harvest using the 1994 revised Oregon Forest Practices Rules to determine their ability to contribute large woody debris (LWD) to streams for fish habitat. On average, 51% of the trees retained in riparian buffers after harvest currently would be capable of adding debris at least 20 cm diameter and 1.5 m length to the channel. Assuming 30% of trees are windthrown over 10 years and that trees fall in random direction, the riparian buffers would be expected to add an average of 0.6 trees per 100 m (1.9 trees per 1000 ft) of stream as LWD over 10 years. Analysis showed significantly greater LWD inputs ($p<0.05$) when the likelihood of more frequent windthrow on riparian terraces and of trees tending to fall downhill on steep slopes are considered. On the sites investigated and with the information available, considereing tree lean did not significantly increase expected LWD delivery. More data on windthrow rates and direction are needed to confirm the analyses. Depending on longevity, the expected frequency of LWD pieces could remain within ranges observed in undisturbed stands.

420) Harr, R.D. 1976. Forest practices and streamflow in western Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-49. 18pp. (G)

Author abstract: Forest management activities, including roadbuilding, clearcut logging, and broadcast burning, can change certain portions of the forest hydrologic cycle. Watershed studies and other hydrologic research in the Coast and western Cascade Ranges of Oregon have shown that these changes may increase annual water yield up to 62 centimeters, double minimum flows in summer, and increase fall peak flows up to 200 percent and small winter peak flows up to 45 percent in small watersheds. Changes in streamflow resulting from clearcut logging had little effect on either onsite damage to stream channels and hydraulic structures or downstream flooding when yarding caused only light disturbance of soil. By increasing the size of larger peak flows, roadbuilding and soil compaction may cause onsite damage in small, headwater basins. Increases in annual yield and minimum flows may be substantial on small watersheds that are clearcut; under sustained yield forest management, such increases are masked in large, parent watersheds by unaltered streamflow from unlogged watersheds.

421) Harvey, B.C. 1998. Influence of large woody debris on retention, immigration, and growth of coastal cutthroat trout (*Oncorhynchus clarki clarki*) in stream pools. Canadian Journal of Fisheries and Aquatic Sciences. 55: 1902-1908. (D)

Author abstract: Over 4 months and about 1 year, coastal cutthroat trout (*Oncorhynchus clarki clarki*) age-1 in Little Jones Creek, California, remained at similar rates in pools with and without large woody debris. This result was based on attempts in July and November 1995 to collect and tag all fish in 22 pools and three collections of fish from the same pools in November 1995, May 1996, and August 1996. Retention of fish appeared to be greater in pools with large woody debris in May 1996. The presence of large woody debris in pools did not influence immigration or growth of cutthroat trout. However, both immigration and growth increased downstream over the 3850-m study reach. Low retention and substantial immigration of cutthroat trout into experimental pools indicate that movement is important in the dynamics of this population. First- and second-order channels appear to be important sources of fish for the third-order study reach, while the study reach may export significant numbers of fish to downstream reaches accessible to anadromous fish.

422) Hauer, F.R., G.C. Poole, J.T. Gangemi, and C.V. Baxter. 1999. Large woody debris in bull trout (*Salvelinus confluentus*) spawning streams of logged and wilderness watersheds in northwest Montana. Canadian Journal of Fisheries and Aquatic Sciences. 56: 915-924. (A, D)

Author abstract: We measured large woody debris (LWD) in 20 known bull trout (*Salvelinus confluentus*) spawning stream reaches from logged and wilderness watersheds in northwestern Montana. Mean bankfull width of stream reaches was 14.1 m ranging from 3.9 to 36.7 m. Streams were large enough to move LWD and form aggregates. We determined the characteristics of individual pieces of LWD that were interactive with the stream channel. Large, short pieces of LWD attached to the stream bank were the most likely to be positioned perpendicular to stream flow, while large, long pieces either tended to be parallel to the flow or, when attached, were most apt to extend across the channel thalweg. Observations indicated that the majority of pools were formed as scour pools by either very large LWD pieces that were perpendicular to the stream or multipiece LWD aggregates. Among reaches in wilderness watersheds, ratios of large to small LWD, attached to unattached LWD, and with and without rootwads were relatively consistent. However, among reaches with logging in the watershed, these ratios varied substantially. These results suggest that logging can alter the complex balance of delivery, storage, and transport of LWD in northern Rocky Mountain streams, and therefore, the likely substantive change in stream habitats.

423) Heede, B.H. 1971. Characteristics and processes of soil piping in gullies. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Paper RM-68. 15pp. (K)

Author abstract: Soil piping processes and soil development were studied as a result of combined pipe and gully actions. Soils from gully side slopes with and without pipes showed a highly significant difference in exchangeable sodium percentage (ESP). Piping soils had a layer permeability 2 to 12 percent of that of soils without pipes. Both soils were fine textured. The

interior of one soil pipe was thoroughly inspected, surveyed, and photographed from inlet to outlet. Based in the survey, and chemical and mechanical analyses, it is proposed that soil pipes on the Alkali Creek watershed developed mainly from soil cracks. Other causes such as rodent holes or dead root canals are presumed possible, but were not verified. Gullies, high exchangeable sodium percentage, low gypsum content, and fine-textured soils with montmorillonite clay appear to be prerequisites to the formation of soil pipes on the study area.

ESP was significantly higher in piping soils in place than in those fallen from the gully side slopes. ESP decreased also with increasing time since fall. Natural reclamation of the fallen soils led to processes initiating gully stabilization.

424) Hess, L.J. 1969. The effects of logging road construction on insect drop into a small coastal stream. M.S. Thesis, Humboldt State College, Arcata, California. 58pp. (C)

Author abstract: Because stream fisheries are so closely associated with forested watersheds, it is necessary that the streams and forests be managed jointly under a system of multiple use. This requires a knowledge of the interrelationships between these resources to yield maximum returns from both. It is the purpose of this paper to relate logging practices to fish management by ascertaining the effect of logging road construction on the drop of insects into a stream. On the South Fork of Caspar Creek the insects falling into the stream were greatly increased after a logging road was built. A twofold increase in number and weight of insects occurred over the entire stream. In "Disturbed" areas, where the road paralleled the stream, drop insects increased three and one half times by number and one and one half times by weight over the "Insect-Control" area. In the "Highly Disturbed" areas, where the road crossed the stream, insect numbers increased by five and one half times and a threefold increase by weight over the "Insect-Control" area was noted. A more than proportionate amount of the increase occurred in those adult insects having aquatic immature stages. One such family, Chironomidae, had a greater occurrence after road construction than all insects combined before construction. This family showed the most significant change of the families studied.

425) Hession, W.C., J.E. Pizzuto, T.E. Johnson, and R.J. Horwitz. 2003. Influence of bank vegetation on channel morphology in rural and urban watersheds. Geology. 31: 147-150. (Note: a correction to this paper is found in the journal Geology, 2003, Volume 31: 832.) (A, F)

Author abstract: Stream-bank vegetation significantly influences the morphology of streams in the Piedmont region of the United States. We surveyed the morphology of 26 paired stream reaches in southeastern Pennsylvania, northern Maryland, and Delaware. One member of each pair has a forested riparian zone, whereas the other has a riparian zone composed primarily of grass. The paired reaches are nearly contiguous, so all significant channel-forming variables except riparian vegetation are held constant. The extent of urban development of the watersheds upstream of the paired reaches also varies considerably, allowing us to determine the combined influence of riparian vegetation and urbanization on channel morphology. Statistical analyses indicate that (1) channels with forested riparian zones are wider than channels with nonforested riparian zones, (2) channels in urbanized watersheds are wider than channels in nonurbanized watersheds, and (3) the effect of riparian vegetation is independent of the level of urbanization.

426) Hicks, B.J., and J.D. Hall. 2003. Rock type and channel gradient structure salmonid populations in the Oregon Coast Range. Transactions of the American Fisheries Society. 132: 468-482. (A)

Author abstract: The study objective was to investigate the response of salmonid populations to disturbance in Oregon Coast Range streams in two rock types, basalt and sandstone. Salmonid abundance was estimated in a total of 30 km of channel in 10 Oregon Coast Range streams with similar basin areas (14–20 km^2). These basins had a range of disturbance caused by timber harvest, fire, and salvage logging. Mean channel gradient in sandstone was 0.012 m/m, and pools were the dominant habitat type. Mean channel gradient in basalt (0.025 m/m) was twice that in sandstone, and riffles were the dominant habitat type. Mean percentages by length of pools, glides, and riffles were 47, 33, and 20%, respectively, in sandstone, compared with 24, 27, and 50% in basalt. Channel gradient and channel morphology appeared to account for the observed differences in salmonid abundance, which reflected the known preference of juvenile coho salmon *Oncorhynchus kisutch* for pools. Coho salmon predominated in sandstone streams, whereas steelhead *O. mykiss* and cutthroat trout *O. clarki* predominated in basalt streams. In sandstone, juvenile coho salmon were four times more abundant than age-0 trout (steelhead and cutthroat trout combined). In basalt, age-0 trout were five times more abundant than juvenile coho salmon. Steelhead and cutthroat trout aged 1 or older were more abundant in basalt streams than in sandstone. However, mean densities of all salmonids combined were not different between rock types. We failed to find a clear fish response to disturbance, but our study shows the importance of geology in the design of studies investigating the response of salmonids to timber harvest and suggests that streams in basalt and sandstone have different potential capacities for salmonid communities.

427) Hicks, M. 2002. Evaluating standards for protecting aquatic life in Washington's surface water quality standards. Preliminary review draft discussion paper. Sponsored by the Washington State Department of Ecology Watershed Program, Watershed Management Section, Olympia Washington, Publication Number 00-10-070. 197pp. (J)

Author abstract: Maintaining proper temperatures in our natural waterways is vital to the long-term health of fish and other aquatic life. This paper examines the temperature requirements of aquatic species indigenous to the State of Washington to determine if the existing state standards provide full and effective protection. It is the conclusion of the author, that the existing state temperature criteria as currently established and applied are inadequate to fully protect sensitive stream dwelling amphibians and our native char; and allows temperature regimes to be developed that have the potential to cause slight to moderate impairment of Pacific salmon, steelhead, and cutthroat trout. The existing standards also fail to adequately recognize natural warm water fish habitats that are not used by salmon or trout. It is recommended that the existing temperature standards be revised, and that replacement criteria be established that more explicitly consider and incorporate the specific life-history patterns and temperature requirements of our indigenous aquatic life communities.

Rather than specifying only summer maximum criteria as currently exists, the proposed criteria define optimal temperature regimes for both individuals and groups of key species. These optimal regimes recognize how temperature requirements change as species pass through

specific life-history stages across the seasons. Five separate temperature regimes are recommended. These regimes were developed in consideration of the direct, indirect, lethal, and sublethal effects that may interfere with the long-term health of Washington's aquatic communities. Specific considerations include the effect of temperature on increasing the incidence of disease; spawner egg quality; incubation survival; juvenile rearing; competition and genetic hybridization; adult migration; and short-term lethality. Temperature criteria recommendations include two values, a running 7-day average of the daily maximum temperatures and a limit on individual daily maximum temperatures. The average daily maximum criteria ensures that conditions remain within the overall optimal range for the preponderance of each life-history stage, while the single daily maximum limit ensures that acute lethality and does not occur.

428) Hildebrand, R.H., A.D. Lemly, C.A. Dollof, and K.L. Harpster. 1997. Effects of large woody debris placement on stream channels and benthic macroinvertebrates. Canadian Journal of Fisheries and Aquatic Sciences. 54: 931-939. (A, C, D)

Author abstract: Large woody debris (LWD) was added as an experimental stream restoration technique in two streams in southwest Virginia. Additions were designed to compare human judgment in log placements against a randomized design and an unmanipulated reach, and also to compare effectiveness in a low- and a high-gradient stream. Pool area increased 146% in the systematic placement and 32% in the random placement sections of the low-gradient stream, lending support to the notion that human judgment can be more effective than placing logs at random in low-gradient streams. Conversely, the high-gradient stream changed very little after LWD additions, suggesting that other hydraulic controls such as boulders and bedrock override LWD influences in high-gradient streams. Logs oriented as dams were responsible for all pools created by additions regardless of stream or method of placement. Multiple log combinations created only two pools, while the other seven pools were created by single LWD pieces. Total benthic macroinvertebrate abundance did not change as a result of LWD additions in either stream, but net abundances of Plecoptera, Coleoptera, Trichoptera, and Oligochaeta decreased, while Ephemeroptera increased significantly with the proportional increase in pool area in the low-gradient stream.

429) Hines, D.H., and J.M. Ambrose. 1998. Evaluation of stream temperature thresholds based on coho salmon (*Oncorhynchus kisutch*) presence and absence in managed forest lands in coastal Mendocino County, California. Georgia Pacific Corporation, Ft. Bragg, California. 14pp. plus Appendices. (J)

Author abstract: Field observations of juvenile coho salmon, *Oncorhynchus kisutch*, rearing in coastal streams of northern Mendocino County, California, were used to define stream temperature thresholds. Data were collected over a five-year period from 1993 to 1997 at 32 sites in six watersheds. Ten stream temperature metrics, incorporating maximum weekly average temperatures (MWAT), and 19 instream habitat variables other than temperature were fit to presence and absence data using logistic regression. The best model suggests that the number of days a site exceeded an MWAT of 17.6^{o}C was one of the most influential variables predicting coho salmon presence and absence. Stream temperature thresholds should therefore incorporate a time-of-exposure limit within a significant range of temperatures rather than the single MWAT

magnitude limit. Certain habitat variables, in combination, also influenced the model, suggesting a synergistic interaction among variables controlling the distribution of juvenile coho salmon. Of the habitat variables, pool depth was the most influential.

430) Hyatt, T.L., and R.J. Naiman. 2001. The residence time of large woody debris in the Queets River, Washington, USA. Ecological Applications. 11: 191-202. (D)

Author abstract: Instream large woody debris (LWD) provides several critical functions in riverine ecosystems, including sediment and nutrient retention, salmonid habitat enhancement, and stable colonization sites for incipient floodplain vegetation. In this study, the size and species composition of LWD in the Queets River, Washington, USA, were examined and compared with the size and species composition of forest trees from which they originated, in order to determine a depletion rate for LWD in the active channel. Increment cores from instream LWD were crossdated against cores from riparian conifers to estimate the year each LWD piece was recruited to the river channel. Debris pieces that were decayed or otherwise incompetent to provide cores were dated using standard ^{14}C techniques. Hardwood species (*Alnus rubra*, *Populus trichocarpa*, and *Acer macrophyllum*) were better represented among riparian forests than among instream LWD, and conifers (*Picea sitchensis*, *Tsuga heterophylla*, *Pseudotsuga menziesii*, and *Thuja plicata*) were better represented among LWD than in the adjacent riparian forest, suggesting that hardwoods were depleted from the channel faster than conifers. The depletion rate of coniferous LWD from the channel followed an exponential decay curve in which 80% of LWD pieces were <50 yr old, although some pieces have remained for up to 1400 yr. Although most wood is depleted from the channel within 50 yr, some wood is apparently buried in the floodplain and exhumed centuries later by lateral channel migration. The calculation depletion constant of 0.030 is equivalent to a half-life of ~20 yr, meaning that virtually all of the wood will have disappeared within 50 yr. This rapid depletion suggests that harvesting large conifers from the riparian zones of large streams could have adverse impacts within three to five decades.

431) Johnson, R.B. 1979. Factors that influence the stability of slopes: A literature review. Interim Report No. FHWA-RD-79-54 written by the USDI Geological Survey, Engineering Geology Branch, Denver, Colorado. Written for the US Department of Transportation, Federal Highway Administration, Office of Research and Development, Washington, D.C. 123pp. (K)

Author abstract: The U.S. Geological Service (USGS), under subcontract to the National Bureau of Standards (NBS) on FHWA contract no. FHWA-7-3-0001, performed the geologic tasks required by the contract. The portion of the project reported in this interim report is part of Phase I requiring documentation of features and conditions which influence stability of natural and manmade slopes in earth materials. The features and conditions described include discrete primary and secondary features or discontinuities such as bedding surfaces, joints, and foliations as well as less distinct anisotropies in an otherwise physically uniform mass. Discussion of secondary factors contributing to slope instability such as rainfall, slope steepness and aspect, and vegetation also is included. Triggering by earthquakes has not been included, nor have mud and debris flows and soil creep unless they have been inseparably grouped by authors with other types of mass movement. Also, rockfalls, rock glaciers, and topples were not investigated. All

other mass movement of soil and rock such as earthflows, slumps, and rock or block slide failures are considered to be varieties of landslides and are included in this report. The literature on interaction of landslide-causing factors was reviewed and is summarized.

432) Johnson, S.L., and J.A. Jones. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. Canadian Journal of Fisheries and Aquatic Sciences. 57: 30-39. (H, J)

Author abstract: Stream temperature controls the rates of many biotic and abiotic processes and is influenced by changes in streamside land use practices. We compiled historic stream temperature data and reestablished study sites in three small basins in the H.J. Andrews Experimental Forest in the western Cascades, Oregon, to reexamine the effects on and recovery of stream temperatures following removal of riparian vegetation. Maximum stream temperatures increased 7°C and occurred earlier in the summer after clear-cutting and burning in one basin and after debris flows and patch-cutting in another. Diurnal fluctuations in June increased from approximately 2 to 8°C. Stream temperatures in both basins gradually returned to preharvest levels after 15 years. The influence of the primary factor controlling stream temperatures, shortwave solar radiation, was amplified following removal of riparian vegetation, and conduction between stream water and nearby soils or substrates also appeared to be an important factor. Shifts in the timing of summer maxima and greater increases in early summer stream temperatures could impact sensitive stages of aquatic biota.

433) Johnston, J.G., Jr. 2002. Riparian canopy cover in northeastern Washington: Stream temperature response, historical reference conditions, and management effects. M.S. Thesis, University of Washington, Seattle. 104pp. (H, J)

Electronic abstract: Northeastern Washington riparian forests have undergone changes to species composition and structure as a result of land management. Understanding how timber harvest affects stream temperature, how riparian management alters stand conditions, and how riparian canopy cover was historically distributed across the landscape will aid in the selection of appropriate riparian treatments. Stream temperatures in adjacent harvested/nonharvested reach pairs were not statistically significant, but linear regression showed a statistically significant increase maximum temperature with a decrease in canopy cover. Comparing riparian stand conditions recorded in historical and current land surveys showed a decrease in fire-adapted tree species and decreased tree size. Historical distribution of riparian canopy cover on northeastern Washington streams was investigated by measuring cover shown in historical (1930s and 1940s) aerial photography. Basin area, valley bottom width, surficial geology, and flow direction exhibited the best relations with canopy cover; elevation was a poor predictor of cover. The final objective, to evaluate the influence of management on riparian cover, was assessed by using canopy cover and land management type measured from historical and current (1994 and 2000) aerial photographs. Reached affected by recent (within the past 10 years) timber harvest showed a decrease in cover between the historical and current periods. Reaches without recent active management (only fire suppression) had more cover than those in the historical condition. Results indicated that for mature, fire-suppressed stands, if no greater than about 15 percent canopy cover was removed during timber harvest, then cover levels were likely to be retained near historical levels.

434) Jones, E.B.D., III, G.S. Helfman, J.O. Harper, and P.V. Bolstad. 1999. Effects of riparian forest removal on fish assemblages in southern Appalachian streams. Conservation Biology. 13: 1454-1465. (A, B, G, I)

Electronic abstract: Deforestation of riparian zones is known to influence the numbers and kinds of organisms that inhabit adjoining streams, but little quantitative information is available on how much deforestation must occur before the biota is affected. We sampled fishes and stream habitats in 12 stream segments downstream from deforested but vegetated riparian patches 0-5.3 km long, all downslope from watersheds with at least 95% forest cover. We found an overall decrease in fish abundance with increasing length of nonforested riparian patch; sculpins, benthic minnows, and darters decreased, and sunfishes and water-column minnows increased in numbers. Introduced species were more common downstream from longer riparian patches. Habitat diversity decreased and riffles became filled with fine sediments as upstream patch length increased. Length of upstream nonforested patch and substrate particle size were much stronger predictors of fish occurrence than riparian patch width. Faunal characteristics and physical features of the stream changed in direct proportion to the gradient of riparian disturbance, but the abundance of several species underwent pronounced change at particular threshold patch lengths. These results suggest that riparian forest removal leads to shifts in the structure of stream fish assemblages due to (1) decreases in fish species that do not guard hidden eggs or that are dependent on swift, shallow water that flows over relatively sediment-free substrates, or (2) increases in fishes that guard their young in pebble or pit nests or that live in slower, deeper water. When watershed development is anticipated or planned, limited clearing of riparian trees may cause minor disturbance to the fish assemblage, but streams in even a heavily forested watershed with vegetated riparian buffers cannot tolerate disruption of riparian-zone trees over much more than 1 km in length. Riparian buffer length and area should be given stronger consideration in stream protection and restoration plans.

435) Jones, J.A., F.J. Swanson, B.C. Wemple, and K.U. Snyder. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. Conservation Biology. 14: 76-85. (D, G, I)

Author abstract: We outline a view of how road networks interact with stream networks at the landscape scale and, based on examples from recent and current research, illustrate how these interactions might affect biological and ecological processes in stream and riparian systems. At the landscape scale, certain definable geometric interactions involving peak flows (floods) and debris flows (rapid movements of soil, sediment, and large wood down steep stream channels) are influenced by the arrangement of the road network relative to the stream network. Although disturbance patches are created by peak-flow disturbances in mountain landscapes without roads, roads can alter the landscape distributions of the starting and stopping points of debris flows, and they can alter the balance between the intensity of flood peaks and the stream network's resistance to change. We examined this conceptual model of interactions between road networks and stream networks based on observations from a number of studies in the H. J. Andrews Experimental Forest, Oregon (U.S.A.) Road networks appear to affect floods and debris flows and thus modify disturbances patch dynamics in stream and riparian networks in mountain landscapes. We speculate that these changes may influence the rates and patterns of survival and

recovery of disturbed patches in stream networks, affecting ecosystem resilience, and we outline an approach for detecting such effects based on a patch dynamics perspective. A field sampling scheme for detecting the magnitude of various road effects on stream and riparian ecology could involve (1) landscape stratification of inherent stream network susceptibility to floods or debris flows, (2) overlay of road and stream networks and creation of areas with various densities of road-stream crossings, emphasizing midslope road-stream crossings, and (3) designations of expected high- and low-impact stream segments based on numbers of upstream road-stream crossings where sampling of selected biological variables would be conducted.

436) Kahler, T.H., P. Roni, and T.P. Quinn. 2001. Summer movement and growth of juvenile anadromous salmonids in small western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences. 58: 1947-1956. (K)

Author abstract: Movements of juvenile coho salmon (*Oncorhynchus kisutch*), cutthroat trout (*Oncorhynchus clarki clarki*), and steelhead trout (*Oncorhynchus mykiss*) were studied by observations and recapture of marked individuals in three western Washington streams to test the hypotheses that few fish would move, downstream movement would predominate, movers would be initially smaller and grow slower after movement than residents, and habitat quality would influence movement. Contrary to predictions, from 28 to 60% of marked fish moved at least one habitat unit, and immigration of unmarked fish also indicated considerable movement. Upstream movement predominated but the stream with the step-pool/cascade channel type had fewer upstream movers and greater distances moved downstream. Coho movers were not smaller than nonmovers, as predicted based on assumptions that movement results from competitive exclusion. Habitat units that coho left were smaller and shallower but lower in density than units where coho remained. Thus, movement is a common phenomenon rather than an aberration, and may reflect habitat choice rather than territorial eviction. Moreover, movers grew faster than nonmovers, so the "mobile fraction" of the population was not composed of competitively inferior fish but rather individuals that thrived. The phenomenon of small-scale habitat- and growth-related movements should be considered when planning and interpreting studies of juvenile salmonid ecology in streams.

437) Keim, R.F., and S.H. Schoenholtz. 1999. Functions and effectiveness of silvicultural streamside management zones in loessial bluff forests. Forest Ecology and Management. 118: 197-209. (A, I, J)

Author abstract: In the highly-erodible Deep Loess region of Mississippi, USA, we investigated functions of silvicultural Streamside Management Zones (SMZs) in protecting water quality from impacts of logging. Twelve first-order watersheds (3-13 ha) were treated in their entirety in one of the four ways: (1) Unrestricted harvest with no buffer, (2) Cable-only SMZ that allowed limited removal of logs from the buffer but no skidder traffic, (3) No-harvest SMZ that excluded all logging from the buffer, or (4) Reference that was unharvested. Logging removed 17% to 70% of hardwood sawtimber basal area in non-SMZ areas using group selection. For 15 months after logging, we monitored total suspended sediment (TSS), turbidity, temperature, pH, electrical conductivity, and dissolved oxygen. The unrestricted harvest increased TSS and the unrestricted harvest and cable-only SMZ treatments increased the temporal variability of TSS. Other water quality metrics were either unaffected by logging or effects were minor. Skidder

traffic in the unrestricted harvest increased exposure of mineral soil in the riparian area immediately after logging by 1.4 to 2.0 times that of other sediments. After one year, mineral soil exposure was similar among all treatments, and after three years, herbaceous growth reduced mineral soil exposure in the unrestricted harvest to below that of unlogged riparian zones. Three years after logging, transects of erosion stakes revealed more soil movement in riparian zones of unrestricted harvest watersheds than in riparian zones of reference watersheds, but natural processes of erosion and deposition apparently overwhelmed any effects of logging on patterns of deposition and erosion in riparian zones. We used permanent stream channel cross-sections to monitor changes in channel morphology for one year after logging, and found that channels in unrestricted harvest watersheds changed by up to twice as much as did channels in watersheds with undisturbed riparian zones. Streams in logged riparian zones showed net aggradation and streams in unlogged riparian zones showed net degradation. Results indicate that SMZs did not serve to filter sediment from overland flow, but their effectiveness in reducing TSS was probably due to exclusion of disturbance to the forest floor near the stream and to the stream itself.

438) Keim, R.F., A.E. Skaugset, and D.S. Bateman. 2002. Physical aquatic habitat II. Pools and cover affected by large woody debris in three western Oregon streams. North American Journal of Fisheries Management. 22: 151-164. (A, D)

Author abstract: Large woody debris (LWD) is important in affecting stream channel morphology and aquatic habitat. Although the greatest effects on streams of the Pacific Northwest have been by LWD from large conifers, many riparian forests in the region are dominated by red alder *Alnus rubra*. The effects of the small size and short life of LWD from red alders on channel morphology may be different from that of conifers and are poorly understood. We added LWD (primarily red alder) to three third-order streams in the Oregon Coast Range and used digital terrain models to evaluate physical habitat for salmonids over 3 years. Total residual pool volume increased in two streams, but in the one with the lowest gradient it did not change in the treated portion and even decreased in the untreated portion. In all streams, both the relative proportion and absolute amount of residual pool volume from deep pools increased from their pretreatment values. Cover from LWD in pools increased after treatment and remained high, but the absolute amount of cover was poorly predicted by the volume of LWD. Overall, the changes in stream channel morphology and habitat were consistent with the effects of LWD, and these case studies indicate that small, red alder LWD can effectively modify physical aquatic habitat.

439) Keppeler, E.T. 1986. The effects of selective logging on low flows and water yield in a coastal stream in northern California. M.S. Thesis, Humboldt State University, Arcata, California. 137pp. (G)

Author abstract: Using a low flow season defined as a function of antecedent precipitation, streamflow data for a 21 year period was analyzed to determine the effects of selective tractor harvesting of second-growth Douglas-fir and redwood forest on the volume, timing, and duration of low flows and annual water yield. Significant increases in streamflow were detected for both the annual period and the low flow season. Maximum increases were realized the year following the completion of logging. Greater relative increases were witnessed for the summer low flow period, however these increases were short-lived in comparison to the overall increase in annual water yield. Logging factors were found to be the most influential variables in describing flow

differences between the control and treated watersheds. Summer flow increases were well correlated with the percent of the watershed area logged when this variable was defined to represent revegetation effects as a function of time since logging. In contrast, the enhancement of annual yield (predominately winter flows) was well correlated to the percent of the watershed area converted to roads, landings, and skid trails (15%). The flow response to logging was found to be highly variable. Some of this variablility was correlated to antecedent precipitation conditions, although much was unexplained. It was concluded that the potential augmentation of water yields resulting from harvest in north coastal California watersheds would be of minimal value as a management option for meeting specific water demand levels.

440) Keppeler, E.T., and R.R. Ziemer. 1990. Logging effects on streamflow: Water yield and summer low flows at Caspar Creek in northwestern California. Water Resources Research. 26: 1669-1679. (G)

Author abstract: Streamflow data for a 21-year period were analyzed to determine the effects of selective tractor harvesting of second-growth Douglas fir and redwood forest on the volume, timing, and duration of low flows and annual water yield in northwestern California. The flow response to logging was highly variable. Some of this variability was correlated with antecedent precipitation conditions. Statistically significant increases in streamflow were detected for both the annual period and the low-flow season. Relative increases in water yield were greater for the summer low-flow but these summer flow increases generally disappeared within 5 years.

441) Keppeler, E.T., R.R. Ziemer, and P.H. Cafferata. 1994. Changes in soil moisture and pore pressure after harvesting a forested hillslope in northern California. In: Effects of Human-Induced Changes on Hydrologic Systems, 26-29 June 1994, Jackson Hole, Wyoming. R.A. Marston and V.R. Hasfurther, Editors. American Water Resources Association, Herndon, Virginia. Pages 205-214. (K)

Author abstract: In 1987, a 0.83-ha zero-order swale was instrumented with 58 pierometers and 25 tensiometers along several hillslope transects. Through 1993, soil moisture conditions were measured by pressure transducers connected to a digital data logger recording at 15-minute intervals. In August 1989, the 100-year-old second-growth forest in the swale was felled. Logs were removed by cable yarding and heavy logging equipment was excluded from the hillslopes. Increases in peak piezometric levels and soil moisture were observed following logging. In the shallower, unsaturated portion of the soil profile, the increase was short-lived due to the rapid resprouting of redwood stumps. At the soil-bedrock interface, increased pore pressures persisted during winter periods throughout the 4-yr post-harvest period. In addition to changes in evapotranspiration, pore pressure increases may be explained by reduced canopy interception, compaction, or the collapse of soil pipes. At the base of the swale, pipeflow accounted for virtually all of the stormflow. After logging, soil pipes continued to efficiently route surplus stormflows through an existing piping network and no slope instabilities were observed.

442) Kondolf, G.M., H. Piégay, and N. Landon. 2002. Channel response to increased and decreased bedload supply from land use change: Contrasts between two catchments. Geomorphology. 45: 35-51. (A, F, I)

Author abstract: The catchments of Pine Creek, Idaho, USA (200 km^2), and the Drôme River in the Drôme Department, France (1640 km^2), illustrate contrasting changes in land use, bedload sediment production, and channel response. Hard-rock mining began in the catchment of Pine Creek near the end of the 19th century and, together with road construction, timber harvest, and historically heavy grazing of uplands, resulted in increased tributary bedload yield. Increased bedload migrating to the channel, combined with removal of large cedar trees on the floodplain, resulted in channel instability, which propagated downstream over a period of decades. On many reaches of Pine Creek, active channel width has increased by over 50% since 1933. Over roughly the same time period, the Drôme River catchment was extensively reforested (after at least one century of denudation and heavy grazing) and numerous check dams were constructed on torrents to reduce erosion. As a result, the Drôme River has experienced a reduction in bedload sediment supply since the late 19th century. In addition, gravel has been extracted from some reaches. Consequently, the channel has degraded and gravel bars have been colonized with woody riparian vegetation. Channel widths in wide, braided reaches decreased from 1947 to 1970 by 60%.

On Pine Creek, channel instability has resulted in bank erosion (exposing contaminated mine tailings) and increased flood hazard. On the Drôme River, degradation has undermined bridges and embankments, and lowered the water table in areas dependent on groundwater for irrigation, resulting in loss of 6 million m^3 of groundwater storage since 1960. Though they differ in drainage area by nearly an order of magnitude, Pine Creek and the Drôme River provide an excellent contrast in that they represent two sides of an epicycle of alluvial sedimentation set off in each case by land disturbance. In both cases, the most recent channel changes, though in opposite directions, were viewed as negative by river managers. On Pine Creek, managers have removed (or protected from erosion) mine tailings, and have attempted to train the stream into a more stable channel, and most rock waste piles (the principal sediment sources) have recently been controlled. On the Drôme River, managers have prohibited gravel mining and adopted new policies to permit coarse sediment to migrate through the river system.

443) Kopperdahl, F.R., J.W. Burns, and G.E. Smith. 1971. Water quality of some logged and unlogged California streams. California Department of Fish and Game, Sacramento, California, Inland Fisheries Administrative Report Number 71-12. 19pp. (I, J)

Author abstract (Author Summary): Water quality was monitored in 1968 and 1969 in six coastal streams in northern California, four of which were subjected to logging and/or road building (Bummer Lake Creek, South Fork Yager Creek, Little North Fork Noyo River, and South Fork Caspar Creek), while the others remained undisturbed (Godwood Creek and North Fork Caspar Creek). The purposes of this study were to characterize the water quality of the streams, to determine if the logging and road construction drastically altered water quality, and to collect water quality data which could be tested for predicting stream carrying capacities for salmonids. Conditions were generally suitable for salmonids during and after the logging. No abnormal concentrations of dissolved oxygen, alkalinity, hardness, dissolved solids, phosphate, chloride, sulfate, nitrate, tannin and lignin, or pH were detected. Carbon dioxide was low in most streams, except in South Fork Caspar Creek when it reached 8 ppm during decomposition of logging debris in the summer of 1968. Turbidity was highest in areas where bulldozers were working in the streams. Temperatures of most streams increased after the logging, but seldom

exceeded 70 F because of the cool climate in the coastal fog belt. Alternating cut and uncut blocks on one stream, and retaining a buffer strip along another, kept temperatures low in two streams.

444) Koski, K.V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis, Oregon State University, Corvallis. 84pp. (B, I)

Author abstract: Survival of coho salmon from egg deposition to emergence was studied in three coastal streams in Oregon from September 1963 until September 1964. Adult coho salmon were captured, tagged, and measured as they entered the streams. Redds of specific females were located and the number of deposited eggs was estimated. A trap that captured the emerging fry was installed on each of these redds and the survival of emerging fry evaluated in terms of gravel composition, gravel permeability, dissolved oxygen, and gravel stability. Size of the parent female and the environmental factors were examined in relation to size and robustness of the emergent fry.

Egg deposition of the spawning coho salmon was estimated from a regression equation based on weight and egg number of coho from a nearby stream. The fry trap, constructed of nylon netting, was installed as a cap over the redd, and the edges were buried eight inches in the gravel. The concentration of dissolved oxygen in the intragravel water and the gravel permeability were sampled by means of a standpipe placed in each of the redds. Three samples of gravel were obtained from each redd and separated through a series of sieves. The volume retained by each sieve was expressed as a percentage of the total sample. Gravel erosion index stations were established in each of the streams to measure the relative amount of gravel movement.

Mean survival to emergence from 21 redds in the streams was 27. 1 percent. Fry in Deer Creek had the highest survival (54. 4 percent), followed by Needle Branch (25. 1 percent), and Flynn Creek (13. 6 percent). The number of emerging fry ranged from 0 to 2, 061. A mean of 110 days was required for the first emergence from the redds. Mean length of the emergence period for an individual redd was 30, 35. and 39 days for redds on Deer Creek, Needle Branch, and Flynn Creek, respectively. Length of the emergence period appeared to be related to the amount of fine sediments in the redd. Peak emergence from each redd occurred eight to ten days following the first emergence.

The size composition of the gravel was the only factor which showed a statistically significant correlation with survival to emergence. The percentage of fine sediments smaller than 3. 327 millimeters had the highest correlation (correlation coefficient r = -0. 69) of all size groupings tested. In each stream the percentage of fine sediments was inversely related to survival. Both gravel permeability and dissolved oxygen concentration were directly related to survival, but neither correlation coefficient (r = 0.36 and 0. *24*, respectively) was statistically significant at the five percent level, probably because of the interrelationships of several environmental factors affecting survival. Gravel movement was extensive in some areas of the streams.

Size and robustness of the emerging fry decreased throughout the emergence period in each of the redds examined. Both permeability of the gravel and weight of the female parent were directly related to the weight of the emergent fry.

445) Koski, K.V. 1992. Restoring stream habitats affected by logging activities. In: Restoring the Nation's Marine Environment. G.W. Thayer, Editor. Maryland Sea Grant College, College Park, Maryland. Pages 343-403. (A, D, F)

Author abstract: Most of the 5,225,000 km of streams in the United States have been degraded by land-use practices including agriculture, grazing, channelization and logging. Salmonids are important to the nation's economy; restoration of streams is needed to return the carrying capacity of the habitat to a previously existing level. Logging alters a hierarchy of environmental factors (water quality, energy source, physical structure, flow regime and biotic interactions) which can limit salmonid production. A fundamental concept of stream restoration is that removal of such limiting factors will increase production. Early efforts to restore streams failed because of inadequate knowledge of limiting factors, stream dynamics and an over- reliance on hatchery propogation. Increased knowledge of the structure and function of stream ecosystems and of salmonid-habitat relationships has provided the present scientific basis for effective stream restoration.

The stream's carrying capacity to produce salmonids is controlled by the structure and function of the riparian zone. The woody debris function has been most affected by logging and development. Physical structures emulating channel stability and habitat complexity created by woody debris are the focus of most restoration projects. Effective restoration programs must be holistic in scope and include procedures for restoration of the watershed, stream channel and fish resources. Program planning must include and inventory of fish and habitat in the watershed, determination of habitat requirements of the species involved, assessment of land-use activities, analysis of limiting factors and a project evaluation plan. Because restoration projects are costly and may never attain pre-existing conditions, restoration must not be done in lieu of adequate protection. The best alternative is to provide good watershed management and to maintain healthy riparian buffer zones.

446) Kraft, C.E., and D.R. Warren. 2003. Development of spatial pattern in large woody debris and debris dams in streams. Geomorphology. 51: 127-139. (D)

Author abstract: The spatial distribution of large woody debris (LWD) in streams was evaluated using Neighbor *K* statistics, following extensive wood deposition from an ice storm in the eastern Adirondack Mountains (New York). Two years after wood deposition, we surveyed individual pieces of LWD in one stream and surveyed debris dam locations in eight streams within the ice storm area. To examine the linear pattern of debris dams within a stream, we used a one-dimensional version of Ripley's *K*, a second-order statistic that evaluates the spatial pattern of points within a landscape. Both aggregated and segregated (regularly spaced) distributions of wood were identified. Individual pieces of LWD were aggregated at spatial extents ranging from 0 to 40 m and were segregated at spatial extents ranging from 80 to 100 m. In two streams, we found that debris dams were segregated at distances ranging from 100 to 300 m relative to randomly chosen locations, but debris dams showed no significant spatial pattern in six other study streams. Previous studies of wood distribution in streams have not observed segregated distribution patterns. Spatial segregation of debris dams in the study area likely occurred in response to regularly spaced stream features or processes that allow movement of individual pieces of LWD toward more stable accumulation points. Neighbor *K* statistics can be used to

identify and describe spatial pattern in large woody debris, and such patterns can be used to help evaluate and identify processes responsible for their generation.

447) La Marche, J.L., and D.P. Lettenmaier. 2000. Effects of forest roads on flood flows in the Deschutes River, Washington. Earth Surface Processes and Landforms. 26: 115-134. (G)

Author abstract: The effects of forest roads on peak flows were examined through a combination of field data collection and modelling in the extensively logged 149 km^2 catchment of the Deschutes River, Washington, USA. Based on a field survey, the connectivity of culverts to the channel network was related primarily to hillslope curvature and distance to the natural stream channel. Culvert crest stage recorders operated during winters 1996/97 and 1997/98 demonstrated that higher flows occurred in ditches draining clearcuts compared to forested areas. Contrary to expectation, road cutslope height did not seem to affect culvert peak runoff. A distributed hydrologic model was used to evaluate road effects on peak flows in nine subcatchments (2.2 to 21 km^2) of the Deschutes River as well as the Deschutes main stem. The model-predicted increases in the mean annual flood due to forest roads alone ranged from 2.2 to 9.5 per cent, and from 2.9 to 12.2 per cent for the 10 year event. These increases are roughly equivalent to slightly smaller than those predicted for harvest effects alone. Simulated road effects on peak flows were independent of forest harvest state. However, at the hillslope scale, modelled as well as field-monitored road ditch response was dependent on harvest state. Modelled road effects generally increased with flood return period, while vegetation effects decreased.

448) Lammert, M., and J.D. Allan. 1999. Assessing biotic integrity of streams: Effects of scale in measuring the influence of land use/cover and habitat structure on fish and macroinvertebrates. Environmental Management. 23: 257-270. (A, C, G)

Author abstract: Fish and macroinvertebrate assemblage composition, instream habitat features and surrounding land use were assessed in an agriculturally developed watershed to relate overall biotic condition to patterns of land use and channel structure. Six 100-m reaches were sampled on each of three first-order warm-water tributaries of the River Raisin in southeastern Michigan. Comparisons among sites and tributaries showed considerable variability in fish assemblages measured with the index of biotic integrity, macroinvertebrate assemblages characterized with several diversity indexes, and both quantitative and qualitative measurements of instream habitat structure. Land use immediate to the tributaries predicted biotic condition better than regional land use, but was less important than local habitat variables in explaining the variability observed in fish and macroinvertebrate assemblages. Fish and macroinvertebrates appeared to respond differently to landscape configuration and habitat variables as well. Fish showed a stronger relationship to flow variability and immediate land use, while macroinvertebrates correlated most strongly with dominant substrate. Although significant, the relationships between instream habitat variables and immediate land use explained only a modest amount of the variability observed. A prior study of this watershed ascribed greater predictive power to land use. In comparison to our study design, this study covered a larger area, providing greater contrast among subcatchments. Differences in outcomes suggests that the scale of investigation

influences the strength of predictive variables. Thus, we concluded that the importance of local habitat conditions is best revealed by comparisons at the within-subcatchment scale.

449) Larsen, D.P., P.R. Kaufmann, T.M. Kincaid, and N.S. Urquhart. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences. 61: 283-291. (K)

Electronic abstract: In the northwestern United States, there is considerable interest in the recovery of Pacific salmon (*Oncorhynchus* spp.) populations listed as threatened or endangered. A critical component of any salmon recovery effort is the improvement of stream habitat that supports various life stages. Two factors in concert control our ability to detect consistent change in habitat conditions that could result from significant expenditures on habitat improvement: the magnitude of spatial and temporal variation and the design of the monitoring network. We summarize the important components of variation that affect trend detection and explain how well-designed networks of 30–50 sites monitored consistently over years can detect underlying changes of 1–2% per year in a variety of key habitat characteristics within 10–20 years, or sooner, if such trends are present. We emphasize the importance of the duration of surveys for trend detection sensitivity because the power to detect trends improves substantially with the passage of years.

450) Larsen, E.W., and S.E. Greco. 2002. Modeling channel management impacts on river migration: A case study of Woodson Bridge State Recreation Area, Sacramento River, California, USA. Environmental Management. 30: 209-224. (K)

Author abstract: Understanding how hydraulic factors control alluvial river meander migration can help resource managers evaluate the long-term effects of floodplain management and bank stabilization measures. Using a numerical model based on the mechanics of flow and sediment transport in curved river channels, we predict 50 years of channel migration and suggest the planning and ecological implications of that migration for a 6.4-km reach (river miles 218-222) of the Sacramento River near the Woodson Bridge State Recreation Area, California, USA.

Using four different channel management scenarios, our channel migration simulations suggest that: (1) channel stabilization alters the future channel planform locally and downstream from the stabilization; (2) rock revetment currently on the bank upstream from the Woodson Bridge recreation area causes more erosion of the channel bank at the recreation area than if the revetment were not present; (3) relocating the channel to the west and allowing subsequent unconstrained river migration relieves the erosion pressure in the Woodson Bridge area; (4) the subsequent migration reworks (erodes along one river bank and replaces new floodplain along the other) 26.5 ha of land; and (5) the river will rework between 8.5 and 48.5 ha of land in the study reach (over the course of 50 years), depending on the bank stabilization plan used. The reworking of floodplain lands is an important riparian ecosystem function that maintains habitat heterogeneity, an essential factor for the long-term survival of several threatened and endangered animal species in the Sacramento River area.

451) Latterell, J.J., R.J. Naiman, B.R. Fransen, and P.A. Bisson. 2003. Physical constraints on trout (*Oncorhynchus* spp.) distribution in the Cascade Mountains: A comparison of logged and unlogged streams. Canadian Journal of Fisheries and Aquatic Sciences. 60: 1007-1017. (A)

Author abstract: The upstream extent of coastal cutthroat (*Oncorhynchus clarki clarki*) and rainbow (*Oncorhynchus mykiss*) trout distribution in logged and unlogged streams of the western Cascade Mountains appears to be primarily constrained by steep channel gradient and sparse pool habitat. Narrow or intermittent wetted channels are also important constraints in logged drainages. The upstream extent of trout distribution appears to be resilient to the combined impacts of historic and current forest management activities, in the absence of impassable road culverts. The probability of trout presence decreased with channel gradient and increased with pool abundance in both logged and unlogged streams, as indicated by logistic regression analysis of physical stream attributes flanking the trout distribution limit in 37 logged and 21 unlogged streams. Reductions in wetted channel width reduced the likelihood of trout presence in logged streams. Logistic regression models fit to data from logged drainages generated accurate predictions of trout presence or absence when applied to data from unlogged drainages. The pervasive extent of native trout in the channel networks of the Cascade Mountains emphasizes the ecological importance of small streams in watershed planning.

452) Lewis, J. 1998. Evaluating the impacts of logging activities on erosion and suspended sediment transport in the Caspar Creek watersheds. In: Proceedings of the Conference on Coastal Watersheds: The Casper Creek Story, 6 May 1998, Ukiah, California. R.R. Zeimer, Technical Coordinator. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-168. Pages 55-69. (F, G, I)

Author abstract: Suspended sediment has been sampled at both the North and South Fork weirs of Caspar Creek in northwestern California since 1963, and at 13 tributary locations in the North Fork since 1986. The North Fork gaging station (NFC) was used as a control to evaluate the effects of logging in the South Fork, in the 1970s, on annual sediment loads. In the most conservative treatment of the data, suspended loads increased by 212 percent over the total predicted for a 6-yr period commencing with the onset of logging. When the roles of the watersheds were reversed and the same analysis repeated to evaluate harvesting in the North Fork under California Forest Practice Rules in the 1990s, no significant increase was found at NFC in either annual suspended or bed load.

With the advent of automatic pumping samplers, we were able to sample sediment concentration much more frequently in the 1980s. This allowed storm event loads from control watersheds in the North Fork to be used in a new regression analysis for NFC. According to this more sensitive analysis, for the 7-yr period commencing with the onset of logging, the sum of the suspended storm loads at NFC was 89 percent higher than that predicted for the undisturbed condition. The much greater increase after logging in the South Fork is too great to be explained by differences in sampling methods and in water years, and appears to be the result of differences in road alignment, yarding methods, and stream protection zones.

Similar analyses of storm event loads for each of the treated subwatersheds in the North Fork suggested increased suspended loads in all but one of the tributaries, but effects were relatively

small or absent at the main stem locations. Of watersheds with less than 50 percent cut, only one showed a highly significant increase. The greater increase in sediment at NFC, compared to other main-stem stations, is largely explained by a 3,600-m^3 landslide that occurred in 1995 in a subwatershed that drains into the main stem just above NFC. Differences among tributary responses can be explained in terms of channel conditions.

Analysis of an aggregated model simultaneously fit to all of the data shows that sediment load increases are correlated with flow increases after logging. Field evidence suggests that the increased flows, accompanied by soil disruption and intense burning, accelerated erosion of unbuffered stream banks and channel headward expansion. Windthrow along buffered streams also appears to be important as a source of both woody debris and sediment. All roads in the North Fork are located on upper slopes and do not appear to be a significant source of sediment reaching the channels.

The aggregated model permitted evaluation of certain types of cumulative effects. Effects of multiple disturbances on suspended loads were approximately additive and, with one exception, downstream changes were no greater than would have been expected from the proportion of area disturbed. A tendency for main-stem channels to yield higher unit-area suspended loads was also detected, but after logging this was no longer the case in the North Fork of Caspar Creek.

453) Lewis, J.C., S.R. Mori, E.T. Keppeler, and R.R. Ziemer. 2001. Impacts of logging on storm peak flows, flow volumes and suspended sediment loads in Caspar Creek, California. In: Land Use and Watersheds: Human Influence on Hydrology and Geomorphology in Urban and Forest Areas. M.S. Wigmosta and S.J. Burges, Editors. American Geophysical Union, Washington, D.C., Water Science and Application. 2: 85-125. (G, I)

Author abstract: Models are fit to 11 years of storm peak flows, flow volumes, and suspended sediment loads on a network of 14 stream gaging stations in the North Fork Caspar Creek, a 473-ha coastal watershed bearing a second-growth forest of redwood and Douglas-fir. For the first 4 years of monitoring, the watershed was in a relatively undisturbed state, having last been logged prior to 1904, with only a county road traversing the ridgetops. Nearly half the watershed was clear-cut over a period of 3 years, and yarded primarily using uphill skyline cable systems to spur roads constructed high on the slopes. Three tributaries were maintained as controls and left undisturbed. Four years of data were collected after logging was completed. Exploratory analysis and model fitting permit characterization and quantification of the effects of watershed disturbances, watershed area, antecedent wetness, and time since disturbance on storm runoff and suspended sediment. Model interpretations provide insight into the nature of certain types of cumulative watershed effects.

454) Ligon, F., A. Rich, G. Rynearson, D. Thornburgh, and W. Trush (Scientific Review Panel). 1999. Report of the scientific review panel on California forest practice rules and salmonid habitat. Written for the Resources Agency of California and the National Marine Fisheries Service, Sacramento, California. 181pp. (K)

Author abstract (Author Overall Conclusions): The SRP concluded that the FPRs, including their implementation (the "THP process") do not ensure protection of anadromous salmonid populations. The primary deficiency of the FPRs is the lack of a watershed analysis approach

capable of assessing cumulative effects attributable to timber harvesting and other non-forestry activities on a watershed scale. As currently applied, Technical Rule Addendum No. 2 does not provide the necessary cumulative effects assessment at the appropriate temporal and spatial scales. Therefore, with regard to the SRPs mandate, the state will need to sponsor and conduct watershed analysis in all watersheds with both steelhead ESUs. Also, specific rules governing onsite operations and road maintenance need stronger enforcement and/or modification to further minimize sediment production, improve stream habitat, and guarantee unrestricted passage by migrating juvenile and adult salmonids. The SRP focused on the following rule sections; watercourse protection measures, road construction and maintenance, and winter operations limitation. Finally, the SRP reviewed Timber Harvesting Plan (THP) implementation issues, especially RPF involvement throughout the THP process as well as THP review and approval procedures, and developed recommendations for improving this process.

455) Lisle, T.E. 1982. Effects of aggradation and degradation on riffle-pool morphology in natural gravel channels, northwestern California. Water Resources Research. 18: 1643-1651. (A, B, F, G)

Author abstract: After the flood of December 1964, 12 gaging sections in northern California widened as much as 100% and aggraded as much as 4 m, and then degraded to stable levels during a period of 5 years or more. As channels aggraded, bed material became finer, and low to moderate flow through gaging sections in pools became shallower, faster, and steeper. Comparisons of longitudinal profiles also show the diminishment of pools as well as a decrease in bar relief accompanying the excessive sediment load. As gaging sections degraded, hydraulic geometries recovered to a limited degree; full recovery probably depends on channel narrowing and further depletion of sediment supply. The hydraulic changes with aggradation indicate an increase in the effectiveness of moderate discharges (less than 1- to 2-year recurrence interval, annual flood series) to transport bed load and shape the bed. Bars become smaller, pools preferentially fill, and riffles armored with relatively small gravel tend to erode headward during falling stages and form a gentler gradient. Excess sediment can thus be more readily transported out of channels when additional contributions from watersheds are usually slight.

456) Lisle, T.E. 1989. Sediment transport and resulting deposition in spawning gravels, north coastal California. Water Resources Research. 25: 1303-1319. (B, I)

Author abstract: Incubating salmonid eggs in streambeds are often threatened by deposition of fine sediment within the gravel. To relate sedimentation of spawning gravel beds to sediment transport, infiltration of fine sediment (<2 mm in diameter) into clean gravel beds, bed material size distributions, scour-fill depths, and sediment transport during 10 storm flow events were measured in three streams of north coastal California. Although suspended sediment comprised most (75-94%) of the clastic load during storm flows, bed load material (0.25-2 mm) accounted for most (70-78%) of the fine sediment accumulated in experimental gravel implanted in the streambeds. Sand trapped in the interstices of the top several centimeters formed a seal that impeded deeper deposition of very fine sand and finer material. The seal was responsible at least in part for a decrease in the rate of fine-sediment accumulation with increasing cumulative bed load transport. Areas of the streambeds commonly scoured or filled 0.1 m or more during storm flows, and thus scour and fill commonly created a sandy layer at least as thick as the seal formed by sediment infiltration. Scour could erode eggs laid in the bed and expose deeper levels of the

bed to infiltration by fine sediment, but at the same time could allow fine sediment to be winnowed away. Great temporal and spatial variation in sedimentation in these streams suggests that individual storms of moderate size pose a threat to eggs in many but not all areas selected by fish for spawning.

457) Lisle, T.E., and M.B. Napolitano. 1998. Effects of recent logging on the main channel of North Fork Caspar Creek. In: Proceedings of the Conference on Coastal Watersheds: The Caspar Creek story, 6 May 1998, Ukiah, California. R.R. Ziemer, Technical Coordinator. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-168. Pages 81-85. (A, B, D)

Author abstract: The response of the mainstem channel of North Fork Caspar Creek to recent logging is examined by time trends in bed load yield, scour and fill at resurveyed cross sections, and the volume and fine-sediment content of pools. Companion papers report that recent logging has increased streamflow during the summer and moderate winter rainfall events, and blowdowns from buffer strips have contributed more large woody debris. Changes in bed load yield were not detected despite a strong correlation between total scour and fill and annual effective discharge, perhaps because changes in stormflows were modest. The strongest responses are an increase in sediment storage and pool volume, particularly in the downstream portion of the channel along a buffer zone, where large woody debris (LWD) inputs are high. The association of high sediment storage and pool volume with large inputs of LWD is consistent with previous experiments in other watersheds. This suggests that improved habitat conditions after recent blowdowns will be followed in future decades by less favorable conditions as present LWD decays and input rates from depleted riparian sources in adjacent clearcuts and buffer zones decline.

458) Lowrance, R., L.S. Altier, J.D. Newbold, R.R. Schnabel, P.M. Groffman, J.M. Denver, D.L. Correll, J.W. Gilliam, J.L. Robinson, R.B. Brinsfield, K.W. Staver, W. Lucas, and A.H. Todd. 1997. Water quality functions of riparian forest buffers in Chesapeake Bay watersheds. Environmental Management. 21: 687-712. (I)

Author abstract: Maryland, Virginia, and Pennsylvania, USA, have agreed to reduce nutrient loadings to Chesapeake Bay by 40% by the year 2000. This requires control of nonpoint sources of nutrients, much of which comes from agriculture. Riparian forest buffer systems (RFBS) provide effective control of nonpoint source (NPS) pollution in some types of agricultural watersheds. Control of NPS pollution is dependent on the type of pollutant and the hydrologic connection between pollution sources, the RFBS, and the stream. Water quality improvements are most likely in areas of where most of the excess precipitation moves across, in, or near the root zone of the RFBS. In areas such as the Inner Coastal Plain and Piedmont watersheds with thin soils, RFBS should retain 50%–90% of the total loading of nitrate in shallow groundwater, sediment in surface runoff, and total N in both surface runoff and groundwater. Retention of phosphorus is generally much less. In regions with deeper soils and/or greater regional groundwater recharge (such as parts of the Piedmont and the Valley and Ridge), RFBS water quality improvements are probably much less. The expected levels of pollutant control by RFBS are identified for each of nine physiographic provinces of the Chesapeake Bay Watershed. Issues related to of establishment, sustainability, and management are also discussed.

459) Luce, C.H., and T.A. Black. 1999. Sediment production from forest roads in western Oregon. Water Resources Research. 35: 2561-2570. (K)

Author abstract: Prevention and estimation of soil erosion from forest roads requires an understanding of how road design and maintenance affect sediment production. Seventy-four plots were installed on forest roads in the Oregon Coast Range to examine the relationship between sediment production and road attributes such as distance between culverts, road slope, soil texture, and cutslope height. An additional comparison was made between road segments with cutslopes and ditches freshly cleared of vegetation and segments with established vegetation on cutslopes and in ditches. All road segments were 5 m wide and insloped with aggregate surfacing, light traffic, and no overhanging forest cover. Sediment production was correlated to the product of segment length times road slope squared. Sediment production from aggregate covered roads on a silty clay loam was about 9 times greater than that from roads constructed on a gravelly loam. Sediment production was not correlated to the cutslope height. Road segments where vegetation was cleared from the cutslope and ditch produced about 7 times as much sediment as road segments where vegetation was retained, showing the potential reduction in erosion by revegetation following construction and the potential impact of ditch cleaning during maintenance. Relationships and estimates from this study provide a basis for improved erosion estimates by commonly used empirical procedures.

460) Marcus, W.A., R.A. Marston, C.R. Colvard, Jr., and R.D. Gray. 2002. Mapping the spatial and temporal distributions of woody debris in streams of the Greater Yellowstone Ecosystem, USA. Geomorphology. 44: 323-335. (A, D)

Author abstract: The objectives of this study were: (1) to document spatial and temporal distributions of large woody debris (LWD) at watershed scales and investigate some of the controlling processes; and (2) to judge the potential for mapping LWD accumulations with airborne multispectral imagery. Field surveys were conducted on the Snake River, Soda Butte Creek, and Cache Creek in the Greater Yellowstone Ecosystem, USA. The amount of woody debris per kilometer is highest in 2nd order streams, widely variable in 3rd and 4th order streams, and relatively low in the 6th order system. Floods led to increases in woody debris in 2nd order streams. Floods redistributed the wood in 3rd and 4th order streams, removing it from the channel and stranding it on bars, but appeared to generate little change in the total amount of wood throughout the channel system. The movement of woody debris suggests a system that is the reverse of most sediment transport systems in mountains. In 1st and 2nd order tributaries, the wood is too large to be moved and the system is transport-limited, with floods introducing new material through undercutting, but not removing wood through downstream transport. In the intermediate 3rd and 4th order channels, the system displays characteristics of dynamic equilibrium, where the channel is able remove the debris at approximately the same rate that it is introduced. The spatial distribution and quantity of wood in 3rd and 4th order reaches varies widely, however, as wood is alternatively stranded on gravel bars or moved downstream during periods of bar mobilization. In the 6th order and larger channels, the system becomes supply-limited, where almost all material in the main stream can be transported out of the central channel by normal stream flows and deposition occurs primarily on banks or in eddy pool environments. Attempts to map woody debris with 1-m resolution digital four-band imagery were generally unsuccessful, primarily because the imagery could not distinguish the narrow

logs within a pixel from the surrounding sand and gravel background and due to problems in precisely coregistering imagery and field maps.

461) Martin, C.W., J.W. Hornbeck, G.E. Likens, and D.C. Buso. 2000. Impacts of intensive harvesting on hydrology and nutrient dynamics of northern hardwood forests. Canadian Journal of Fisheries and Aquatic Sciences. 57: 19-29. (G, I)

Author abstract: Whole-tree clear-cutting and progressive strip-cutting of northern hardwood forests at the Hubbard Brook Experimental Forest in central New Hampshire resulted in measurable changes in physical and chemical conditions of forest streams. As a result of reduced transpiration and interception, water yield for the first year after whole-tree harvesting increased by >150 mm, the majority of which occurred during the growing season. Peak flows increased only moderately. Water yield and peak flow increases disappeared within 4-6 years as a result of rapidly regrowing vegetation. Sediment yields increased during and after harvesting but can be maintained within normal ranges of reference streams by careful use of best management practices. Stream chemistry changes occurred immediately following harvesting, most notably in the form of increases in concentrations of Ca^{2+}, K^{+}, NO_3^{-}, and H^{+}. The concentrations return close to preharvest levels within 3-5 years. The above changes are discussed in terms of their causes and implications for aquatic habitat and fisheries.

462) May, C.L. 2002. Debris flows through different forest age classes in the central Oregon Coast Range. Journal of the American Water Resources Association. 38: 1097-1113. (D)

Author abstract: Debris flows in the Pacific Northwest can play a major role in routing sediment and wood stored on hillslopes and in firstthrough third-order channels and delivering it to higher-order channels. Field surveys following a large regional storm event investigated 53 debris flows in the central Oregon Coast Range to determine relationships among debris flow characteristics and the age class of the surrounding forest. The volume of sediment and wood delivered by debris flows was strongly correlated with runout length. Debris flows that initiated at roads were significantly longer than nonroad related failures, and road related landslides were an order of magnitude larger than nonroad related landslides. Clearcuts and roads tended to have more numerous contributing landslides relative to second growth and mature forests. No statistically significant difference in the average debris flow runout length was detected among the forest age classes, although debris flows initiating in clearcuts and mixed forest and at roads occasionally supported extremely long runout lengths that were outside the range of variability observed in completely forested basins. The size of wood in deposits was not correlated with the size of trees on the adjacent slopes, suggesting that the majority of wood in debris flow deposits was from remobilization of wood previously stored in low order channels.

463) May, C.L., and R.E. Gresswell. 2003. Large wood recruitment and redistribution in headwater streams in the southern Oregon Coast Range, U.S.A. Canadian Journal of Forest Research. 33: 1352-1362. (A, D)

Author abstract: Large wood recruitment and redistribution mechanisms were investigated in a 3.9 km^2 basin with an old-growth *Pseudotsuga menziesii* (Mirb.) Franco and *Tsuga heterophylla*

(Raf.) Sarg. forest, located in the southern Coast Range of Oregon. Stream size and topographic setting strongly influenced processes that delivered wood to the channel network. In small colluvial channels draining steep hillslopes, processes associated with slope instability dominated large wood recruitment. In the larger alluvial channel, windthrow was the dominant recruitment process from the local riparian area. Consequently, colluvial channels received wood from further upslope than the alluvial channel. Input and redistribution processes influenced piece location relative to the direction of flow and thus, affected the functional role of wood. Wood recruited directly from local hillslopes and riparian areas was typically positioned adjacent to the channel or spanned its full width, and trapped sediment and wood in transport. In contrast, wood that had been fluvially redistributed was commonly located in mid-channel positions and was associated with scouring of the streambed and banks. Debris flows were a unique mechanism for creating large accumulations of wood in small streams that lacked the capacity for abundant fluvial transport of wood, and for transporting wood that was longer than the bankfull width of the channel.

464) May, C.L., and R.E. Gresswell. 2003. Processes and rates of sediment and wood accumulation in headwater streams of the Oregon Coast Range, USA. Earth Surface Processes and Landforms. 28: 409-424. (A, D, I)

Author abstract: Channels that have been scoured to bedrock by debris flows provide unique opportunities to calculate the rate of sediment and wood accumulation in low-order streams, to understand the temporal succession of channel morphology following disturbance, and to make inferences about processes associated with input and transport of sediment. Dendrochronology was used to estimate the time since the previous debris flow and the time since the last stand-replacement fire in unlogged basins in the central Coast Range of Oregon. Debris flow activity increased 42 per cent above the background rate in the decades immediately following the last wildfire. Changes in wood and sediment storage were quantified for 13 streams that ranged from 4 to 144 years since the previous debris flow. The volume of wood and sediment in the channel, and the length of channel with exposed bedrock, were strongly correlated with the time since the previous debris flow. Wood increased the storage capacity of the channel and trapped the majority of the sediment in these steep headwater streams. In the absence of wood, channels that have been scoured to bedrock by a debris flow may lack the capacity to store sediment and could persist in a bedrock state for an extended period of time. With an adequate supply of wood, low-order channels have the potential of storing large volumes of sediment in the interval between debris flows and can function as one of the dominant storage reservoirs for sediment in mountainous terrain.

465) McCashion, J.D., and R.M. Rice. 1983. Erosion on logging roads in northwestern California: How much is avoidable? Journal of Forestry. 81(1): 23-26. (K)

Author abstract: A study was made on 344 miles of logging roads in northwestern California to assess sources of erosion and the extent to which road-related erosion is avoidable. At most, about 24 percent of the erosion measured on the logging roads could have been prevented by conventional engineering methods. The remaining 76 percent was caused by site conditions and choice of alignment. On 30,300 acres of commercial timberland, an estimated 40 percent of the

total erosion associated with management of the area was found to have been derived from the road system.

466) Meehan, W.R. 1996. Influence of riparian canopy on macroinvertebrate composition and food habits of juvenile salmonids in several Oregon streams. USDA Forest Service, Pacific Northwest Research Station, Research Paper PNW-RP-496. 14pp. (C)

Author abstract: The community composition of macroinvertebrates and the feeding habits of juvenile salmonids were studied in eight Oregon streams. Benthic, drift, sticky trap, and water trap samples were taken over a 3-year period, along with stomach samples of the fish. Samples were taken in stream reaches with and without riparian canopy.

Both main effects-fish diet versus macroinvertebrate composition in the environment, and canopied versus noncanopied stream condition-were highly significant, but probably not of practical importance in terms of the amount of preferred food available to the fish.

In all aquatic sample types, including fish stomachs, Diptera and Ephemeroptera were the predominant invertebrates collected. In sticky trap and water trap samples, Diptera and Collembola were the predominant orders, reflecting the input of terrestrial invertebrates.

467) Megahan, W.F., M. Wilson, and S.B. Monsen. 2000. Sediment production from granitic cutslopes on forest roads in Idaho, USA. Earth Surface Processes and Landforms. 26: 153-163. (K)

Author abstract: A series of 75 non-bordered plots was used to measure surface erosion on granitic road cuts on forest roads in the mountains of Idaho. Erosion data were collected for four years following road construction. Erosion rates for the first winter period after construction averaged about five times greater than the average of erosion rates for subsequent seasons. Both mass and surface erosion processes were observed on road cuts with mass erosion particularly important during the first season after construction. Regression analysis showed slope gradient, slope aspect, ground cover density and snow-free period rainfall erosivity had statistically significant effects on erosion. Slope gradient was by far the most influential site factor affecting erosion but slope length had no affect. Three erosion control treatments - dry seeding, hydroseeding plus mulch, and terracing with hydroseeding plus mulch - were evaluated. Two treatments - dry seeding and hydroseeding plus mulch -caused statistically significant reductions in erosion. Dry seeding was the most cost-effective treatment on sites with deep alluvial soil. Elsewhere, hydromulching was the most cost-effective treatment. Further testing is needed to evaluate the effectiveness of erosion control treatments during the first period after construction. We were unable to discriminate between erosion rates on the moderately to highly weathered granitic rock included in this study. A discussion of the application of the study results is presented.

468) Meleason, M.A., S.V. Gregory, and J.P. Bolte. 2002. Simulation of stream wood source distance for small streams in the western Cascades, Oregon. In: Proceedings of the Symposium on the Ecology and Management of Dead Wood in Western Forests, 2-4 November 1999, Reno, Nevada. W.F. Laudenslayer, Jr., P.J. Shea, B.E. Valentine, C.P. Weatherspoon, and T.E. Lisle, Technical Coordinators. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-181. Pages 457-466. (D)

Author abstract: The model, STREAMWOOD, is an individual-based stochastic model designed to simulate the dynamics of wood in small streams of the Pacific Northwest. We used STREAMWOOD to examine source distance as a function of tree fall regime and stand age. Our results suggest that source distance increased with stand age for the first 400 years of stand development and then declined. Simulated source distance for mature conifer forests (81 to 200 years old) were consistent with observed data, but simulated source distances for old-growth forests (201 to 1,000 years old) were below observed data. Further information on stand ages for the forests used in the observational study would refine the compassion with simulated data.

469) Meleason, M.A., S.V. Gregory, and J.P. Bolte. 2003. Implications of riparian management strategies on wood in streams of the Pacific Northwest. Ecological Applications. 13: 1212-1221. (D)

Author abstract: Riparian forest management plans for numerous regions throughout the world must consider long-term supply of wood to streams. The simulation model OSU STREAMWOOD was used to evaluate the potential effects of riparian management scenarios on the standing stock of wood in a hypothetical stream in the Pacific Northwest, USA. OSU STREAMWOOD simulates riparian forest growth, tree entry (includes breakage), and in-channel processes (log breakage, movement, and decomposition). Results of three simulation scenarios are reported. The first scenario assessed total wood volume in the channel from Douglas-fir plantations clearcut to the stream bank using three rotation periods (60, 90, and 120 yr). Without a forested riparian management zone, accumulation of wood in the channel was minimal and did not increase through time. In the second scenario, response of total wood volume to forested riparian management zones of widths between 6 m and 75 m was evaluated. Total wood volume associated with the 6 m wide nonharvested forest for forest ages $\geq$240 yr was 32% of the standing stock associated with a nonharvested forest buffer one potential tree height in width. Maximum standing stock associated with the channel for nonharvested riparian forests $\geq$30 m required 500-yr-old forests. In the third scenario, contribution of wood from forest plantations beyond nonharvested forests of various widths was explored. Forest plantations associated with nonharvested riparian buffers with widths >10 m contributed minimal amounts of wood volume to the stream. These results suggest that forest age and width of the nonharvested buffers are more important than the rotation age of plantation forests in providing long-term supplies of wood to streams.

470) Micheli, E.R., and J.W. Kirchner. 2002. Effects of wet meadow riparian vegetation on streambank erosion. 2. Measurements of vegetated bank strength and consequences for failure mechanics. Earth Surface Processes and Landforms. 27: 687-697. (F)

Author abstract: We measured the effect of wet meadow vegetation on the bank strength and failure mechanics of a meandering montane meadow stream, the South Fork of the Kern River at Monache Meadow, in California's Sierra Nevada. Streambanks colonized by 'wet' graminoid meadow vegetation were on average five times stronger than those colonized by 'dry' xeric meadow and scrub vegetation. Our measurements show that strength is correlated with vegetation density indicators, including stem counts, standing biomass per unit area, and the ratio of root mass to soil mass. Rushes appear better than sedges at stabilizing coarse bar surfaces, while sedges are far more effective at stabilizing actively eroding cut banks.

Wet meadow floodplain vegetation creates a composite cut bank configuration (a cohesive layer overlying cohesionless materials) that erodes via cantilever failure. Field measurements and a geotechnical model of cantilever stability show that by increasing bank strength, wet meadow vegetation increases the thickness, width, and cohesiveness of a bank cantilever, which, in turn, increases the amount of time required to undermine, detach, and remove bank failure blocks. At Monache Meadow, it takes approximately four years to produce and remove a 1 m wide wet meadow bank block. Wet meadow vegetation limits bank migration rates by increasing bank strength, altering bank failure modes, and reducing bank failure frequency.

471) Miller, A.J. 1990. Fluvial response to debris associated with mass wasting during extreme floods. Geology. 18: 599-602. (K)

Author abstract: Evolution of channels and bottomlands in mountain valleys of the central Appalachians is strongly influenced by debris supplied to stream channels from mass wasting during extreme storms. The type of change observed varies with basin scale and storm characteristics. Along channels receiving coarse sediment from debris avalanches or debris flows during Hurricane Camille in 1969, pure scour occurred in drainage areas less than 1 km^2 and gradients steeper than 0.1; in Hurricane Camille and in the June 1949 storm, mixed erosion and deposition with continuous reworking of the valley floor was observed along streams with drainage areas up to 65 km^2. In basins larger than 100 km^2, valley-floor reworking associated with influx of debris during both storms was localized and discontinuous.

In the South Branch Potomac River basin in West Virginia, intense precipitation within a small contributing area generated scores of debris slides and avalanches in June 1949; debris transported by tributaries to main valleys exceeded the competence of the larger channels and formed new bottomland. Long-duration moderate-intensity precipitation in November 1985 generated fewer debris avalanches. Flood peaks associated with a larger contributing area along the main valleys were 80% to 190% larger than in 1949 and caused extensive channel and flood-plain erosion, including truncation and removal of 1949 deposits. At some locations relict debris deposits may have influenced hydraulic conditions and affected patterns of erosion and deposition during the 1985 storm. Sequential occurrence of extreme storms with different hydrologic characteristics creates a bottomland mosaic of surfaces with varying elevations and textures.

472) Minakawa, N., and R.I. Gara. 2003. Effects of chum salmon redd excavation on benthic communities in a stream in the Pacific Northwest. Transactions of the American Fisheries Society. 132: 598-604. (C)

Author abstract: We studied effects of redd excavation by wild chum salmon *Oncorhynchus keta* on insect communities in a stream in the Pacific Northwest. During the salmon redd excavation, the total mean insect densities in the spawning reach decreased to 10.8–14.7% of their predisturbance values. Mean densities of the major taxa, mayflies *Baetis* spp. and *Cinygmula* spp., midges Orthocladiinae, stoneflies *Paraperla* spp., and black flies Simuliidae, in the spawning reach were 0.4–55.1% of the predisturbance values during redd excavation. Densities of these taxa in the spawning reach were 1.1–46.6% of densities in the nonspawning reach during salmon redd excavation. Twenty-nine days after redd excavation, the densities of *Baetis* spp., Orthocladiinae, and Simuliidae in the spawning reach exceeded the values of the same taxa in the nonspawning reach. Statistical analyses revealed that the presence or absence of spawning salmon was significantly associated with the distances (or dissimilarities) among stream insect communities (reach × sampling date combination) and the densities of insect taxa (except for Simuliidae); salmon redd excavation reduced insect densities and altered insect community structure.

473) Montgomery, D.R., T.M. Massong, and S.C.S. Hawley. 2003. Influence of debris flows and log jams on the locations of pools and alluvial channel reaches, Oregon Coast Range. Geological Society of America Bulletin. 115: 78-88. (A, D)

Author abstract: We investigated the influence of debris-flow deposits and log jams on the location of pools and alluvial channel reaches in three Oregon Coast Range watersheds. Our surveys reveal differences in the type and location of log jams and the associated influences on pool formation and the extent of alluvial channel beds between channels flowing through old-growth and industrial forests. In channels we surveyed, debris-flow deposits formed 3% of log jams in reaches flowing through old-growth forest and 12% and 25%, respectively, in the two industrial forest channels. Pools formed by the direct effects of debris flows accounted for 4%–7% of all pools in reaches surveyed in both old-growth and industrial forest channels. Logs and log jams accounted for about half of the pools formed in old-growth reaches, but just 12%–13% of pools in reaches flowing through industrial forest. The distribution of bedrock and alluvial reaches was influenced by drainage area, channel-reach slope, sediment trapping by log jams, and boulders deposited by debris flows. Although debris-flow deposits can locally create or influence aquatic habitat, our field observations suggest general contrasts between old-growth and industrial forest in both log jam locations and the relative importance of debris-flow processes in the formation of pools and alluvial reaches.

474) Montgomery, D.R., E.M. Beamer, G.R. Pess, and T.P. Quinn. 1999. Channel type and salmonid spawning distribution and abundance. Canadian Journal of Fisheries and Aquatic Sciences. 56: 377-387. (A, B)

Author abstract: Consideration of fundamental channel processes, together with map-based and field investigations, indicates that stream channel type influences salmonid spawning distributions across entire channel networks and salmonid abundance within channel reaches. Our analysis suggests that salmonid spawning patterns in mountain drainage basins of the Pacific Northwest are adapted to, among other things, the timing and depth of channel bed mobility. We hypothesize that because the bed of pool-riffle and plane-bed reaches scours to a variable fraction of the thickness of alluvium, survival to emergence is favored by either burying eggs

below the annual scour depth or avoiding egg burial during times of likely bed mobility. Conversely, annual mobility of all available spawning gravel in steeper step-pool and cascade channels favors either adaptations that avoid egg burial during times of likely bed mobility or selection of protected microhabitats. Consistent with these expectations, we find that salmonid spawning distributions track channel slope distributions in several west-slope Pacific Northwest watersheds, implying that spatial differences in channel processes influence community structure in these rainfall-dominated drainage basins. More detailed field surveys confirm that different channel types host differential use by spawning salmonids and reveal finer-scale influences of pool spacing on salmonid abundance.

475) Montgomery, D.R., K.M. Schmidt, H.M. Greenberg, and W.E. Dietrich. 2000. Forest clearing and regional landsliding. Geology. 28: 311-314. (K)

Author abstract: The influence of forest clearing on landsliding is central to longstanding concern over the effects of timber harvesting on slope stability. Here we document a strong topographic control on shallow landsliding by combining unique ground-based landslide surveys in an intensively monitored study area with digital terrain modeling using high-resolution laser altimetry and a coarser resolution regional study of 3224 landslides. As predicted by our digital terrain–based model, landslides occur disproportionately in steep, convergent topography. In terrain predicted to be at low risk of slope failure, a random model performs equally well to our mechanism-based model. Our monitoring shows that storms with 24 hr rainfall recurrence intervals of less than 4 yr triggered landslides in the decade after forest clearing and that conventional monitoring programs can substantially underestimate the effects of forest clearing. Our regional analysis further substantiates that forest clearing dramatically accelerates shallow landsliding in steep terrain typical of the Pacific Northwest.

476) Moody, J.A., and D.A. Martin. 2001. Initial hydrologic and geomorphic response following a wildfire in the Colorado Front Range. Earth Surface Processes and Landforms. 26: 1049-1070. (K)

Author abstract: A wildfire in May 1996 burned 4690 hectares in two watersheds forested by ponderosa pine and Douglas fir in a steep, mountainous landscape with a summer, convective thunderstorm precipitation regime. The wildfire lowered the erosion threshold in the watersheds, and consequently amplified the subsequent erosional response to shorter time interval episodic rainfall and created both erosional and depositional features in a complex pattern throughout the watersheds.

The initial response during the first four years was an increase in runoff and erosion rates followed by decreases toward pre-fire rates. The maximum unit-area peak discharge was 24 m^3 s^{-1} km^{-2} for a rainstorm in 1996 with a rain intensity of 90 mm h^{-1}. Recovery to pre-fire conditions seems to have occurred by 2000 because for a maximum 30-min rainfall intensity of 50 mm h^{-1}, the unit-area peak discharge in 1997 was 6.6 m^3 s^{-1} km^{-2}, while in 2000 a similar intensity produced only 0.11 m^3 s^{-1} km^{-2}. Rill erosion accounted for 6 per cent, interrill erosion for 14 per cent, and drainage erosion for 80 per cent of the initial erosion in 1996. This represents about a 200-fold increase in erosion rates on hillslopes which had a recovery or relaxation time of about three years. About 67 per cent of the initially eroded sediment is still stored in the watersheds after four years with an estimated residence time greater than 300 years. This

residence time is much greater than the fire recurrence interval so erosional and depositional features may become legacies from the wildfire and may affect landscape evolution by acting as a new set of initial conditions for subsequent wildfire and flood sequences.

477) Naiman, R.J., E.V. Balian, K.K. Bartz, R.E. Bilby, and J.J. Latterell. 2002. Dead wood dynamics in stream ecosystems. In: Proceedings of the Symposium on the Ecology and Management of Dead Wood in Western Forests, 2-4 November 1999, Reno, Nevada. W.F. Laudenslayer, Jr., P.J. Shea, B.E. Valentine, C.P. Weatherspoon, and T.E. Lisle, Technical Coordinators. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-181. Pages 23-48. (D)

Author abstract: Large woody debris (LWD: > 10 cm diameter and > 1 m in length) in stream channels of forested regions in North America is an essential ecosystem component. This article summarizes information from the literature on the spatial and temporal variability of LWD abundance, distribution and age; the processes of LWD delivery and elimination; and the influence of LWD on materials retention, habitat formation, and productivity of streams. Examples are drawn mostly from the Pacific Coastal Ecoregion, but the fundamental principles learned from this region have application over the broad, forested regions of the Temperate Zone. Key studies show that LWD is an integral component of stream and river corridors, positively affecting material retention, habitat formation, and productivity. It is abundant in streams of all sizes flowing through forested regions, although the density and form of accumulation changes with forest type, landscape topography, and flow regime. The management implications of maintaining natural stream LWD dynamics are significant. Overall, LWD is a fundamental component of streams in many western states. This suggests that measures assuring a continued supply of LWD of appropriate size, volume, and species composition are essential for maintaining the long-term integrity of streams and river corridors.

478) Neatrour, M.A., J.R. Webster, and E.F. Benfield. 2004. The role of floods in particulate organic matter dynamics of a southern Appalachian river-floodplain ecosystem. Journal of the North American Benthological Society. 23: 198-213. (C)

Author abstract: We investigated the effect of a flood on particulate organic matter (POM) dynamics in the floodplain and active channel of the Little Tennessee River in western North Carolina. We measured litterfall, leaf breakdown, and floodplain litter (before and after the flood) at 12 sites. Annual litterfall (256–562 g m^{-2} y^{-1}) was typical of a temperate deciduous forest but lower than lowland floodplain forests in the eastern US. Leaf breakdown rates of 4 tree species (*Acer rubrum*, *Carpinus caroliniana*, *Juglans nigra*, and *Platanus occidentalis*) ranged from 0.001 to 0.010/d. We separated the 12 sites into 2 groups (inundated and non-inundated) based on the degree of flooding after a flood on 8 January 1998 and determined POM exchange between the active channel and floodplain. Significant transport of leaves from the floodplain to the river occurred at inundated sites, but transport of herbaceous or woody material did not occur. The flood increased leaf breakdown rates of all 4 tree species. Our measurements of litterfall, leaf breakdown, and floodplain litter standing crop suggest that leaves entrained from the floodplain of Little Tennessee River during floods are a source of POM to the active channel. However, flood input of leaves to the river were a small source of POM compared to direct leaf fall.

479) Newbrey, M.G. 2002. Morphologic and meristic characteristics of lacustrine coarse woody structure as fish habitat. M.S. Thesis, University of Wisconsin, Stevens Point. 176pp. (D)

Author abstract: Riparian areas are inextricably linked to aquatic systems. In light of widespread riparian and littoral zone tree removal caused by logging, cottage development, and road development, more research needs to be done to asses the importance of woody structures as fish habitat. The objectives of this study are to: 1) quantify the morphology (e.g, branching complexity, length, etc) of trees in lakes as it relates to physical habitat for fish, and 2) identify relations between species richness, diversity, abundance, and total length of individual fish species and the physical characteristics of submerged trees. Trees in Katherine Lake, Wisconsin were selected using random and random-stratified sampling. Tree morphology (e.g, branching complexity, bole diameter, wet length, freeboard, clearance, minimum depth of tree, total water depth at tree, and bridging distance), general site habitat characteristics (e.g., distance to other coarse woody structure, site slope, mean depth, and dominant and subdominant particle sizes), and fish metrics (e.g., taxa richness, diversity, adult abundance, and adult total length) were quantified at each site. Conifers were found to more abundant than deciduous tree in Katherine Lake and physically complex trees of either type were rare. Branching complexity in coniferous trees was highly correlated with bole diameter, wet length, and clearance, whereas, branching complexity in deciduous trees was highly correlated with wet length. A total of 16 species of fish utilized submerged wood as habitat. There were significantly more smallmouth bass (*Micropterus dolomieu*) and bluegill (*Lepomis macrochirus*) on sites with submerged wood compared to sites without submerged wood in Katherine Lake. Conifer trees had significantly higher numbers of schooling cyprinids (Cyprinidae), bluegill, and walleye (*Stizostedian vitreum*) when compared to deciduous trees. Fish taxa richness, diversity, and abundance increased in coniferous and deciduous trees that were morphologically more complex with greater amounts of fine branching. Complex trees were dominated by schooling cyprinids, rock bass (*Ambloplites rypestris*), smallmouth bass, bluegill, and yellow perch (*Perca flavescens*). Walleyes were common in complex conifers but not deciduous trees. Less complex trees appeared to attract great numbers of young-of-the-year (YOY) smallmouth bass, and YOY rock bass as opposed to adults of the same species. Adult black crappie and rock bass showed seasonal tendencies in moving off of CWS sites in late August. This study demonstrated that wood is important in lakes as fish habitat and continuous recruitment of new, more-complex trees from riparian areas is important to sustain the long-term ecological processes inherent to the riparian area-littoral zone ecotone. Ultimately, better policies need to be established in order to protect riparian vegetation, shoreline wood, and wood recruitment into lakes.

480) Nislow, K.H., and W.H. Lowe. 2003. Influences of logging history and stream pH on brook trout abundance in first-order streams in New Hampshire. Transactions of the American Fisheries Society. 132: 166-171. (I)

Author abstract: In New England streams, both logging and acidification may influence native populations of brook trout *Salvelinus fontinalis*. We assessed the relationship between these factors and brook trout abundance in 16 first-order streams that had been logged 6 to more than 30 years prior; we quantitatively sampled fishes and collected habitat and water chemistry data

from these streams. Logging history (years since harvest) was negatively correlated with substrate embeddedness, suggesting that this aspect of physical habitat quality improves with forest recovery. Brook trout density and biomass, however, were negatively correlated to years since logging. In contrast, stream pH (ranged from <6 to >7 during low-flow conditions in August) was positively correlated with trout density and biomass. These results suggest that forest recovery alone may not result in across-the-board increases in brook trout abundance and that among-site variation in stream chemistry needs to be accounted for when assessing the effects of land-use on trout populations in the New England region.

481) Nolan, K.M., T.E. Lisle, and H.M. Kelsey.1987. Bankfull discharge and sediment transport in northwestern California. In: Erosion and Sedimentation in the Pacific Rim. Proceedings of the Corvallis Symposium, August 1987. R. Beschta, T. Blinn, G.E. Grant, F.J. Swanson, and G.G. Ice, Editors. International Association of Hydrological Sciences Publication Number 165. Pages 439-449. (G, I)

Author abstract: High-magnitude, low-frequency discharges are more responsible for transporting suspended sediment and forming channels in northwestern California than in previously studied areas. Bankfull discharge and the magnitude and frequency of suspended sediment discharge were determined at five gaging stations in northwestern California. Although discharges below which 50 percent of the suspended sediment was transported and discharges which transport the greatest suspended sediment (effective discharge) occurred relatively frequently, recurrence intervals for these discharges were relatively high when compared to data from other areas. Likewise, discharges below which 90 percent of the suspended sediment was transported were also relatively infrequent. In most cases, the recurrence interval of bankfull discharge was several times greater than that of the effective discharge. This is because floodplain formation appears to be due more to overbank deposition during large sediment-laden discharges than to lateral channel migration and point bar formation.

482) North Coast Regional Water Quality Control Board (In cooperation with the California Department of Forestry). 1993. Testing indices of cold water fish habitat. Final Report for Development of Techniques for Measuring Beneficial Use Protection and Inclusion into the North Coast Region's Basin Plan by Amendment of the "Guidelines for Implementing and Enforcement of Discharge Prohibitions Relating to Logging, Construction and Associated Activities" September 18, 1990. 56pp. (B, I)

Author abstract (Author Executive Summary): Water quality regulations normally are promulgated to provide quality water for domestic consumption or for the protection of other dependent resources (fish and wildlife for example). Regulations for domestic quality such as turbidity, alkalinity or hardness, are easily measured and conclusions regarding the suitability of water for drinking are unambiguous. However, regulations established to protect fish have been problematic because:

1) The most common problems affecting fish in forested watersheds are changes in habitat, not changes in the chemical constituents or physical attributes of the water. Therefore, most of our current regulations which are based on water quality variables, are ineffective in protecting fish.

2) Very little information exists that can be directly applied to the establishment of new regulations based on habitat variables. Changes in habitat (usually additional sand in the channel or removal of instream logs) affect fish habitat by reducing areas where fish can hide from predators and adverse environmental conditions, and by reducing the quality of gravels the fish need to spawn in. While much is known about habitat and fisheries relationships, little is known regarding which habitat elements can be reliably measured and what those measurements mean in the context of natural habitat conditions.

The objective of this study was to determine which components of cold water fish habitat could serve as future regulatory tools and provide a means to achieve effective fisheries protection. Specifically, this project sought to determine: 1) Which physical elements of instream habitat are affected by human activity in the upslope watershed? 2) What is the current range of values for those elements? 3) What is the range of values that represents undisturbed habitat conditions and, 4) How the results from this study might be used in a regulatory framework?

This study measured a range of habitat variables in 60 streams within the North Coast Planning Basin of California. Sampling was limited to the Franciscan geologic formation. The variables used in this study were selected following consultation with over 30 scientists throughout the Western United States. Sample locations and measurement methods were designed to provide a statistically reliable assessment. Sampling sites were divided into three descriptive categories of increasing upslope erosion potential to assess whether the variables selected for this study were affected by that activity. Sample locations for the Index group included all available streams (18), while reaches in the other two categories were selected randomly from a pool of over 120 watersheds (21 streams in each category). Sampling occurred without regard to ownership boundaries (Temperature is a notable exception. However, temperature was not a variable measured in this study). The results from this study indicate that “V*", the amount of fine sediment collected in the bottom of stream pools, "RASI" or Riffle Armour Stability Index, a measure of the composition of riffle gravels and “D50”, the median particle size of the riffle gravels all showed significant differences between reaches with different levels of upslope disturbance. An important finding of this study is that these three variables can be used to identify habitat condition in similar streams. Options are presented for using this study’s results in a regulatory framework. This study did not evaluate how the observed differences in habitat affect fish populations.

The importance of this study is:1) It identifies variables and sampling methods which can be expanded into other geologic formations which will improve our ability to regulate upslope activities and protect fisheries resources. 2) It provides baseline data for habitat variables that makes meaningful rankings of instream habitat condition possible. This may influence instream restoration priorities and upslope management techniques. 3) The indices (variables) verified in this study provide a way to assess the cumulative effects of all upslope activities and to concurrently monitor the aggregate effectiveness of upslope protection measures. 4) It provides new data suggesting that the consequences of historical forest management are still adversely affecting instream habitat. This new information may have far reaching effects on how restoration priorities are established.

483) O’Connor, J.E., M.A. Jones, and T.L. Haluska. 2003. Flood plain and channel dynamics of the Quinault and Queets Rivers, Washington, USA. Geomorphology. 51: 31-59. (A, D, F, I)

Author abstract: Comparison of historic channel migration rates, modern planform conditions, and overall sediment, wood, and flow conditions and interactions for the Quinault River and Queets River in the western Olympic Peninsula, Washington, reveals decadal- to century-scale interactions between gravel-bed channels and forested flood plains in temperate maritime environments. The downstream alluvial portions of these two rivers can be divided into three reaches of different slope, flow, sediment, and wood regimes: (i) the upper Quinault River is aggrading behind Lake Quinault, a natural lake that traps most sediment and wood transported from the Olympic Mountain headwaters. (ii) The lower Quinault River, downstream of Lake Quinault, transports only sediment and wood derived from reworking of flood-plain deposits and contributed from valley margins. (iii) The Queets River has unimpeded movement of sediment and water from the mountainous headwaters to the Pacific Ocean. Measurements of channel planform characteristics and historic migration rates and patterns show that these three reaches have correspondingly distinct channel and flood-plain morphologies and dynamics. The aggrading and sediment-rich upper Quinault River has the widest flood plain, widest active channel, greatest number of low-flow channels and flanking gravel bars, and an average channel migration rate of 12.7±3.3 m/year between 1900 and 1994. The comparatively sediment-poor lower Quinault River has the narrowest flood plain, narrowest active channel, and lowest channel migration rate (4.0±1.2 m/year); and most flow is through a single channel with few adjacent gravel bars. The Queets River has attributes intermediate between the lower and upper Quinault Rivers, including an average channel migration rate of 7.5±2.9 m/year. Flood-plain turnover rates are similar for all three reaches, with channels eroding the flood plain at the rate of about 0.2% of the flood-plain area per year, and with corresponding flood-plain half-lives of 300 to 500 years.

Observations from this study and previous studies on the Queets River show that channel and flood-plain dynamics and morphology are affected by interactions between flow, sediment, and standing and entrained wood, some of which likely involve time frames similar to 200–500-year flood-plain half-lives. On the upper Quinault River and Queets River, log jams promote bar growth and consequent channel shifting, short-distance avulsions, and meander cutoffs, resulting in mobile and wide active channels. On the lower Quinault River, large portions of the channel are stable and flow within vegetated flood plains. However, locally, channel-spanning log jams have caused channel avulsions within reaches that have been subsequently mobile for several decades. In all three reaches, log jams appear to be areas of conifer germination and growth that may later further influence channel and flood-plain conditions on long time scales by forming flood-plain areas resistant to channel migration and by providing key members of future log jams. Appreciation of these processes and dynamics and associated temporal and spatial scales is necessary to formulate effective long-term approaches to managing fluvial ecosystems in forested environments.

484) O'Connor, M.D., and R.R. Ziemer. 1989. Coarse woody debris in a second-growth *Sequoia sempervirens* forest stream. In: Proceedings of the California Riparian System Conference: Protection, Management, and Restoration for the 1990s, 22-24 September 1988, Davis, California. D.L. Abell, Technical Coordinator. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-110. Pages 165-171. (A, D, F)

Author abstract: Coarse woody debris (CWD) contributes to high quality habitat for anadromous fish. CWD volume, species, and input mechanisms was inventoried in North Fork Caspar Creek to assess rates of accumulation and dominant sources of CWD in a 100-year-old second-growth red wood (*Sequoia sempervirens*) forest. CWD accumulation in the active stream channel and in pools was studied to identify linkages between the forest and fish habitat. CWD accumulates more slowly in the active stream channel than on the surrounding forest floor. Of CWD in the active channel, 59 percent is associated with pools and 26 percent is in debris jams. CWD associated with pools had greater mean length, diameter, and volume, than CWD not associated with pools. The majority of the CWD is Douglas-fir (Pseudotsuga menziesii) and grand fire (Abies grandis). CWD entered the stream primarily through bank erosion and windthrow. The estimated rate of accumulation of CWD in and near the stream was 5.3 m^3. Selective additions of CWD to stream channels to compensate for reduced inputs following timber harvest could maintain or enhance fish habitat.

485) Paul, M.J., and R.O. Hall, Jr. 2002. Particle transport and transient storage along a stream-size gradient in the Hubbard Brook Experimental Forest. Journal of the North American Benthological Society. 21: 195-205. (C, G, I)

Author abstract: The transport and deposition of fine particulate organic matter (FPOM) is an important flux linking upstream and downstream reaches of stream ecosystems. However, few studies have attempted to identify physical controls on particle transport. One reason has been the lack of relatively simple, inexpensive methods. We describe a new technique for measuring fine particle transport in streams using fluorescently labeled yeast as FPOM analogs. We used steady state injections of yeast and a conservative tracer (Cl) in 6 reaches along a stream continuum at the Hubbard Brook Experimental Forest to explore the relationship between hydrologic properties of stream reaches and particle transport. The yeast technique is relatively easy and inexpensive, and measures of fine particle transport derived from this approach were comparable to those obtained for natural seston and other seston analogs in similarly sized streams. The transport distance of yeast particles (S_p) increased along the stream continuum. S_p was negatively correlated with relative transient storage (k_1/k_2) and positively correlated with hydrologic exchange rates of the main channel (k_1) and transient storage (k_2). The depositional velocity of yeast (v_{dep}), which normalizes average transport distances for stream velocity and depth, showed no trend along the continuum and was not related to k_1, k_2, or k_1/k_2. Together, these results suggest that velocity and depth were the most important factors in determining differences in determining differences in particle transport along the continuum.

486) Pepin, D.M., and F.R. Hauer. 2002. Benthic responses to groundwater-surface water exchange in 2 alluvial rivers in northwestern Montana. Journal of the North American Benthological Society. 21: 370-383. (C, G)

Author abstract: We tested the hypotheses that groundwater–surface water exchange regimes affect spatial distribution of algal biomass and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa in main-channel riffle habitats of 2 northwestern Montana rivers flowing through alluvial flood plains. We used a stratified random design to sample riffles with contrasting groundwater–surface water exchange regimes, but with similar bedform, current velocity, and substrata grain size. We examined general patterns of exchange between river channel and

hyporheic zone waters by measuring vertical hydraulic gradients (VHG) and hydraulic conductivities using mini-piezometers. Riffles near the upstream limit of each flood plain were characterized by strong, hyporheic recharge (–VHG, downwelling), whereas riffles throughout the lower half of each flood plain were characterized by weak, dispersed hyporheic discharge (+VHG, upwelling). There were no differences in mean seston concentrations between riffles on either flood plain within any season. Although mean algal biomass was not significantly different across seasons, maximum biomass was generally higher in upwelling zone riffles (+VHG) than in downwelling zone riffles (–VHG). Variation in algal standing crop in upwelling riffles was ~30% greater than in downwelling riffles. There was no difference in mean EPT density between upwelling and downwelling sites. However, there were species-specific responses to differential hyporheic exchange, which were correlated with differences in algal biomass and VHG. The results of our study suggest that hyporheic exchange patterns influence physical habitat structure of main-channel riffles, and affect the distribution and abundance of algae and EPT macroinvertebrates in these habitats.

487) Pess, G.R., D.R. Montgomery, E.A. Steel, R.E. Bilby, B.E. Feist, and H.M. Greenberg. 2002. Landscape characteristics, land use, and coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Wash., U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 59: 613-623. (K)

Author abstract: We used temporally consistent patterns in the spatial distribution of returning adult coho salmon (*Oncorhynchus kisutch*) to explore relationships between salmon abundance, landscape characteristics, and land use patterns in the Snohomish River watershed, Wash. The proportion of total adult coho salmon abundance supported by a specific stream reach was consistent among years, even though interannual adult coho salmon abundance varied substantially. Wetland occurrence, local geology, stream gradient, and land use were significantly correlated with adult coho salmon abundance. Median adult coho salmon densities in forest-dominated areas were 1.5–3.5 times the densities in rural, urban, and agricultural areas. Relationships between these habitat characteristics and adult coho salmon abundance were consistent over time. Spatially explicit statistical models that included these habitat variables explained almost half of the variation in the annual distribution of adult coho salmon. Our analysis indicates that such models can be used to identify and prioritize freshwater areas for protection and restoration.

488) Quinn, T.P., and N.P. Peterson. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (*Oncorhynchus kisutch*) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences. 53: 1555-1564. (D)

Author abstract: Wild juvenile coho salmon (*Oncorhynchus kisutch*) were individually marked in October 1990 and 1991 to evaluate the effects of habitat complexity and fish size on over-winter survival in Big Beef Creek, Washington. Habitat complexity was quantified for the habitat unit where the fish were collected and, in 1991, also for the 500-m reach downstream from the collection site. Survival, estimated from recovery of marked smolts at the stream's mouth, differed between years (25.4 and 46.2%) and also varied among habitat units and reaches within years. Survival was at most weakly correlated with complexity of the habitat units but was

strongly correlated with the quantity of woody debris and density of habitat units in the 500-m reach, and distance from the estuary. Because distance covaried with habitat complexity, we could not ascertain which factor had the primary influence on survival. In addition, larger fish generally survived at a higher rate than smaller individuals. However, fish tagged above William Symington Lake were smaller in the fall but larger as smolts and had higher survival rates than those tagged below the lake. Taken together, these results reveal complex relationships between size, habitat, and growth that may affect over-winter survival and subsequent life-history events.

489) Reeves, G.H., K.M. Burnett, and E.V. McGarry. 2003. Sources of large wood in the main stem of a fourth-order watershed in coastal Oregon. Canadian Journal of Forest Research. 33: 1363-1370. (D)

Author abstract: We compared the contribution of large wood from different sources and wood distributions among channel zones of influence in a relatively pristine fourth-order watershed in the central Coast Range of Oregon. Wood in the main stem of Cummins Creek was identified as coming from either (*i*) streamside sources immediately adjacent to the channel or (*ii*) upslope sources delivered by landslides or debris flows more than 90 m from the channel. About 65% of the number of pieces and 46% of the estimated volume of wood were from upslope sources. Streamside sources contributed about 35% of the number of pieces and 54% of the estimated volume of wood. The estimated mean volume of upslope-derived pieces was about one-third that of streamside-derived pieces. Upslope-derived pieces were located primarily in the middle stream reaches and in the zones of influence that had the most contact with the low-flow channel. Streamside-derived pieces were more evenly distributed among the examined reaches and were predominately in the influence zones that had the least contact with the low-flow channel. Our findings suggest that previous studies that examined only streamside sources of wood have limited applications when designing and evaluating riparian management approaches in landslide-prone areas. The failure to recognize the potential sources of wood from upslope areas is a possible reason for the decline of large wood in streams in the Pacific Northwest.

490) Reid, L.M., and S. Hilton. 1998. Buffering the buffer. In: Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story, 6 May 1998, Ukiah California. R. R. Zeimer, Technical Coordinator. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-168. Pages 71-80. (D)

Author abstract: Riparian buffer strips are a widely accepted tool for helping to sustain aquatic ecosystems and to protect downstream resources and value in forested areas, but controversy persists over how wide a buffer strip is necessary. The physical integrity of stream channels is expected to be sustained if the characteristics and rates of tree fall along buffered reaches are similar to those in undisturbed forests. Although most tree-fall-related sediment and woody debris input to Caspar Creek are generated by trees falling from within a tree's height of the channel, about 30 percent of those tree falls are triggered by trees falling from upslope of the contributing tree, suggestions that the core zone over which natural rates of tree fall would need to be sustained is wider than one-tree-height's width previously assumed. Furthermore, an additional width of "fringe" buffer is necessary to sustain appropriate tree-fall rates within the core buffer. Analysis of the distribution of tree falls in buffer strips and un-reentered streamside

forest along the North Fork of Caspar Creek suggest that rates of tree fall are abnormally high for a distance of at least 200 m from a clearcut edge, a distance equivalent to nearly four times the current canopy height. The appropriate width of fringe buffer needed to protect the core zone will need to be determined using an analysis of the long-term effects and significance of accelerated tree-fall rates after logging.

491) Rice, R.M., and D.J. Furbish. 1984. Erosion and soil displacement related to timber harvesting in northwestern California, U.S.A. In: Contributions to Research on Torrent Erosion and Avalanches. Prevention and Control of Torrent Erosion, Floods and Mud Flows, Snow Damage and Avalanches. IUFRO Subject Group S1.04-00. Pages 99-109. (K)

Author abstract (Author Summary): The relationship between measures of site disturbance and erosion resulting from timber harvest was studied by regression analyses. None of the 12 regression models developed and tested yielded a coefficient of determination (R^2) greater than 0.60. The results indicated that the poor fits to the data were due, in part, to unexplained qualitative differences in disturbance associated with cable and tractor yarded harvests. Improved prediction might be achieved by weighting each elementary area of disturbance by the sine of its slope for estimates of surface erosion and by both the sine of its slope and its cut bank height for estimates of mass erosion.

492) Rice, R.M., and J.D. McCashion. 1985. Site conditions related to erosion on logging roads. In: Proceedings of the International Symposium on Erosion, Debris Flow and Disaster Prevention, 3-5 September 1985, Tsukuba, Japan. Erosion Control Engineering Society. Pages 69-74. (K)

Author abstract (Author Synopsis): Data collected from 299 road segments in northwestern California were used to develop and test a procedure for estimating and managing road-related erosion. Site conditions and the design of each segment were described by 30 variables. Equations developed using 149 of the road segments were tested on the other 150. The best multiple regression equation explained only 37% of the variance in the logarithm of road-related erosion. A discriminant analysis correctly classified 74% of the test data set. Road segments it predicted to be hazardous produced 82% of the measured erosion in the test data set. Analysis of the variables in the discriminant function indicates that the effect of terrain slope nearly overwhelms the effects of all other variables in determining the posterior probability of instability. Discriminate analysis also provides a means by which a forest manager can explore the expected effect that different strategies will have on erosion and on the resources spent on mitigation measures.

493) Rice, R.M., and J. Lewis. 1986. Identifying unstable sites on logging roads. Proceedings Division 1. 18th IUFRO World Congress. vol. 1. International Union of Forestry Research Organizations, Vienna, Austria. Pages 239-249. (K)

Author abstract (Author Summary): This paper is the third in a series concerning erosion from logging roads in northwestern California. It contrasts sites of large erosional features with randomly selected sites from 481 km of roads. The data were first divided so that relationships

developed with one half could be tested on the second half. Linear discriminant functions were used to analyze the data. An analysis of both road and site variables found the best contrast to be based on cut height and geologic parent material. A prediction equation based only on site variables (slope and geology) had a 76% classification accuracy with both the developmental and test data sets. Major erosional features occupied only 0.6% of the length of roads studied. Therefore, if our function is to be useful, the threshold of concern will have to be quite low. In practice, high risk sites should be identified by their posterior probabilities and then be evaluated by technical specialists to determine if the risk should be revised up or down because of the presence of risk factors not included in our equation.

494) Rice, R.M., and J. Lewis. 1991. Estimating erosion risks associated with logging and forest roads in northwestern California. Water Resources Bulletin. 27: 809-818. (K)

Author abstract: Erosion resulting from logging and road building has long been a concern to forest managers and the general public. An objective methodology was developed to estimate erosion risk on forest roads and in harvest areas on private land in northwestern California. It was based on 260 plots sampled from the area harvested under 415 Timber Harvest Plans completed between November 1978 and October 1979. Results confirmed previous findings that most erosion related to forest management occurs on a small fraction of the managed area. Erosion features larger than the minimum size inventories in this study (> 13 yd^3) occupied only 0.2 percent of the area investigated. Linear discriminant analysis was used to develop two equations for identifying critical sites (sites with erosion >100 yd^3ac^{-1}). The equations were based on slope, horizontal curvature (an expression of local topography), and soil color (on road sites) or the strength of the underlying rocks (on harvest sites). The equations can be used in planning to estimate the erosion risk of proposed activities. They can also be used to estimate acceptable risk thresholds based on the value of competing resources.

495) Rice, R.M., and N.H. Pillsbury. 1982. Predicting landslides in clearcut patches. In: Recent Developments in the Explanation and Prediction of Erosion and Sediment Yield. Proceedings of the Exeter Symposium, July 1982. International Association of Hydrological Sciences Publication Number 137. Pages 303-311. (K)

Author abstract: Accelerated erosion in the form of landslides can be an undesirable consequence of clearcut logging on steep slopes. Forest managers need a method of predicting the risk of such erosion. Data collected after logging in a granitic area of northwestern California were used to develop a predictive equation. A linear discriminant function was developed that correctly classified almost 90% of the data. The equation was based on measurements of slope, crown cover, tributary drainage area, and distance from a stream. A procedure was then developed by which the discriminant function can be used to determine the optimum strategy for managing landslide-susceptible terrain.

496) Rice, R.M., and P.A. Datzman. 1981. Erosion associated with cable and tractor logging in northwestern California. In: Erosion and Sediment Transport in Pacific Rim Steeplands. Proceedings of the Christchurch Symposium, 25-31 January 1981, Christchurch, New Zealand. T.R.H. Davies and A.J. Pearce, Editors. International Association of Hydrological Sciences Publication Number 132. Pages 362-374. (K)

Author abstract: Erosion and site conditions were measured at 102 logged plots in northwestern California. Erosion averaged 26.8 m^3/ha. A log-normal distribution was a better fit to the data. The antilog of the mean of the logarithms of erosion was 3.2 m^3/ha. The Coast District Erosion Hazard Rating was a poor predictor of erosion related to logging. In a new equation that "explained" about 40 percent of the variability in erosion, yarding method was associated with a 3.7-fold difference in erosion, aspect with a 4.3-fold difference, geologic type with a 13.5-fold difference, and slope with a 16-fold difference. The analysis suggests that an additional source of variation was operative that may be related to how the logging was done. Future investigations, therefore, should focus more on the conduct of logging operations than descriptions of the site logged.

497) Rice, R.M., and P.D. Gradek. 1984. Limits on the usefulness of erosion-hazard ratings: Experiences in northwestern California. Canadian Journal of Forest Research. 14: 559-564. (K)

Author abstract: Although erosion-hazard ratings are often used to guide forest practices, those used in California from 1974 to 1982 have been inadequate for estimating erosion potential. To improve the erosion-hazard rating procedure, separate estimating equations were used for different situations. The ratings were partitioned according to yarding method, erosional process, and both yarding method and erosional process. Partitioning by yarding method resulted in a slight improvement in the precision of erosion estimates. The other two methods resulted in fourfold increases in prediction errors. Results indicate that a single unified erosion-hazard rating procedure is the most practical way of predicting logging-related erosion in northwestern California.

498) Rice, R.M., and S.A. Sherbin. 1977. Estimating sedimentation from an erosion-hazard rating. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Research Note PSW-323. 4pp. (K)

Author abstract: Data from two watersheds in northern California were used to develop an interpretation of the erosion-hazard rating (EHR) of the Coast Forest District as amount of sedimentation. For the Caspar Creek Experimental Watershed (North Fork and South Fork), each EHR unit was estimated as equivalent to 0.0543 cubic yards per acre per year, on undisturbed forest. Experience within the District provided estimates of average excess sediment produced by logging: 17.5 cu. yd/acre for tractor yarding, and 6.3 cu. yd/acre for cable yarding. These estimates based on limited data should be supplemented by additional research to cover wide variations in conditions.

499) Rice, R. M., R.R. Ziemer, and J. Lewis. 2001. Forest management effects on erosion, sediment, and runoff: Lessons from Caspar Creek and northwestern California. In: Proceedings of the Society of American Foresters 2000 National Convention, 16-20 November, 2000, Washington, D.C: Society of American Foresters. Pages 69-75. (G, I)

Author abstract: The effects of multiple logging disturbances on peak flows and suspended sediment loads from second-growth redwood watersheds were approximately additive. Downstream increases were no greater than would be expected from the proportion of the area disturbed. Annual sediment load increases of from 123 to 269% were measured in tributary watersheds but were not detected at the main channel gages, implying that sediment was being temporarily stored in the intervening channels. The failure of previous studies to detect increases in large peak flows following timber harvests may be due to variability in measurements rather than absence of an effect. A few sites are responsible for a large proportion of the erosion resulting from management-related disturbances.

500) Robison, E.G., and R.L, Beschta. 1990. Identifying trees in riparian areas that can provide coarse woody debris to streams. Forest Science. 36: 790-801. (D)

Author abstract: The natural fall of trees into mountain streams provides coarse woody debris that can improve fish habitat and influence stream morphology. Geometric and empirical equations, based on tree size and distance from the stream, were used to determine the conditional probability of a tree's adding coarse woody debris to a stream. Additional equations were developed to relate this probability to basal area factor. For conditions in the Pacific Northwest, Douglas-fir (*Pseudotsuga menziesii* [Mirb] Franco) was selected to illustrate how the equations can be used for varying tree sizes and probabilities. After selecting a probability and determining basal area factor by these equations, resource managers can use prisms or wedge devices before timber harvesting in riparian areas to identify specific trees that can potentially add woody debris to the stream.

501) Rot, B.W., R.J. Naiman, and R.E. Bilby. 2000. Stream channel configuration, landform, and riparian forest structure in the Cascade Mountains, Washington. Canadian Journal of Fisheries and Aquatic Sciences. 57: 699-707. (A, D)

Author abstract: The hierarchical relationship of five key elements, valley constraint, riparian landform, riparian plant community, channel type, and channel configuration, are described for 21 sites in mature to old-growth riparian forests of the western Cascades Mountains, Washington, U.S.A. Channel type (bedrock, plane-bed, and forced pool-riffle) was closely related to channel configuration (especially large woody debris (LWD) volume, density, and LWD-formed pools) at the smallest spatial scale and valley constraint at the largest. Valley constraint significantly influenced off-channel habitat (r^2=0.71) and LWD volume within forced pool-riffle channels (r^2 =0.58). Riparian plant community composition was differentiated by four landform classes: three alluvial landforms based on height above the channel and one based on hillslope. Just above the active channel, floodplain landforms contained more deciduous stems than conifer and greater conifer basal area than deciduous. Conifers dominated other landforms. The diameter of in-channel LWD increased with the age of the riparian forest (r^2=0.34). In old-

growth forests, LWD diameter was equivalent to or greater than the average riparian tree diameter for all sites. In younger forests, the mixed relationship between LWD and riparian tree diameter may reflect a combination of LWD input from the previous old-growth stand and LWD input from the existing stand.

502) Rothacher, J. 1971. Regimes of streamflow and their modification by logging. In: Forest Land Uses and Stream Environment. Proceedings of a symposium, 19-21 October 1970, Oregon State University, Corvallis. J. Morris, Editor. Pages 40-54. (G)

Author abstract: Streamflow in the Pacific Northwest is most strongly influenced by the precipitation pattern, somewhat less by evapotranspiration losses. Evaporation and transpiration are strongly influenced by logging. Logging and burning old-growth Douglas-fir forests on an experimental watershed increased annual yields of streamwater by 18 inches or more. Most of the increase occurred in fall and winter months. We can't positively attribute any great increase in major "wet mantle" flood flows to logging in west slope forests. Logging which removes transpiring vegetation increases lowest summer streamflow. Such increases may be short lived as vegetation rapidly invades the cutover areas.

503) Sedell, J.R., and F.J. Swanson. 1984. Ecological characteristics of streams in old-growth forests of the Pacific Northwest. In: Fish and Wildlife Relationships in Old-Growth Forests. Proceedings of a symposium, 12-15 April 1982, Juneau, Alaska. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley, Editors. Pages 9-16. (D, E, I)

Author abstract: Forest vegetation strongly affects aquatic habitat in streams and rivers of all sizes. Streams associated with old-growth forests are dominated by large tree-sized woody debris. Large woody debris traps sediment and creates a great diversity of habitat for both fish and aquatic invertebrates. Woody debris slows the routing of finer organic matter, and allows organisms time to more fully process these materials before they are moved downstream. The structural influences of woody debris differ little between streams flowing through old-growth and through natural, young, post-wildfire stands. Large logs may reside in a channel for a century, or more, and provide a variety of benefits to the aquatic ecosystem until the post-wildfire stand matures to the point of contributing large debris to the channel. The United States has few remaining examples of the full, natural interaction of rivers with adjacent forests except in Alaska and national parks. Undisturbed streams in old-growth forests are restricted to small, high-gradient examples in relatively inaccessible and mountainous areas. A rich archival record documents man-imposed changes in forest influences on rivers in a variety of regions and geological and topographic settings. These old records—from fur trappers, the U. S. Army Corps of Engineers, and others—describe natural river systems greatly influenced by numerous downed trees, and large jams of floated debris.

504) Sedell, J.R., J.E. Yuska, and R.W. Speaker. 1984. Habitats and salmonid distribution in pristine, sediment-rich river valley systems: S. Fork Hoh and Queets River, Olympic National Park. In: Fish and Wildlife Relationships in Old-Growth Forests. Proceedings of a symposium, 12-15 April 1982, Juneau, Alaska. W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley, Editors. Pages 33-46. (A, D)

Author abstract: Four distinct running-water habitats are defined and examined on the South Fork Hoh River and Upper Queets River—main river channel, river off-channel areas, terrace tributaries, and valley-wall tributaries. Species compositions, densities, and total fish biomasses are distinctly different for each habitat examined. Habitat formed by the main river channel and its tributaries is controlled by the valley terrace structures and the modifying effects of large woody debris. Large woody debris is important to all habitats regardless of size of stream. Without large wood, spawning and rearing-habitat quality would be poorer, even in the large, sediment-rich main channel. Large wood-capped side channels had eight times the coho salmon (*Oncorhynchus kisutch*) densities as side channels without debris. During late summer, the majority of juvenile salmonid rearing occurs in river side-channel areas and tributaries.

505) Simon, A., and A.J.C. Collison. 2001. Pore-water pressure effects on the detachment of cohesive streambeds: Seepage forces and matric suction. Earth Surface Processes and Landforms. 26: 1421-1442. (F)

Author abstract: Erosion of cohesive channel materials is not fully understood, but is assumed to occur largely as a result of hydraulic shear stress. However, field and laboratory observations of pore-water pressures in cohesive streambed materials reveal the presence of positive and negative pore-water pressure effects that may significantly affect the erosion process, as contributing and resisting forces respectively.

Measurements of pore-water pressures below cohesive streambeds in the loess area of the midwestern USA were conducted *in situ* and in undisturbed cores with a digital, miniature tensiometer. Results disclosed matric suction values in the range of 15-50 kPa in eastern Nebraska and northern Mississippi. Repetitive tests in soft materials verified a change from positive pore-water pressures in the upper 10-15 cm, to negative pore-water pressures to depths of at least 50 cm. In firm materials, the entire sampled profile was unsaturated.

Laboratory experiments were carried out in which synthetic hydrographs were imposed on undisturbed streambed cores from the same sites. Miniature tensiometers in the cores monitored the resulting pattern of pore-water pressures, and revealed upward directed seepage forces on the recessional limb of the hydrograph. Maximum calculated values of the force ranged from 10 to 275 kN for the materials and heads tested. The maximum value obtained after application and release of a 2·5 m head was 119 kN, with 275 kN after a 5·0 m head. These results were supported independently by subsequent simulations using a finite-element hydrology model coupled with a stress-deformation model.

A numerical scheme was developed to calculate the forces acting on cohesive aggregates in an idealized streambed, and to evaluate the potential for their detachment. The scheme added upward-directed seepage as an additional driving force, and matric suction as an additional resisting force, to the commonly applied factors of particle weight, fluid drag and lift force. Results demonstrate that upward-directed seepage forces of the magnitude measured in the laboratory with 5.0 m stages have the potential to detach particles larger than 10 cm in diameter

without requiring fluid drag and lift forces. When added to these hydraulic forces, erosion thresholds are lowered, enabling erosion at lower hydraulic stresses.

A hypothesis for detachment of chips or blocks of cohesive bed material is proposed: (1) large (>5 m) rises in stage increase pore-water pressures or decrease matric suction dramatically in the region just below the bed surface; (2) a relatively rapid decrease in stage causing a loss of water pressure above the bed, combined with low-rates of excess pore-water pressure dissipation just below the bed surface result in steepened hydraulic gradients; and (3) a resulting net upward seepage force is great enough to contribute to detachment of cohesive bed material, or rupture the bed by exceeding the available strength and confining stress.

506) Smith, D.G., and C.M. Pearce. 2002. Ice jam-caused fluvial gullies and scour holes on northern river flood plains. Geomorphology. 42: 85-95. (A)

Author abstract: Two anomalous fluvial landforms, gullies and scour holes, eroded into flood plains bordering meandering and braiding river channels have not been previously reported. We observed these features along the Milk River in southern Alberta, Canada, and northern Montana, USA, which has a history of frequent (50% probability of recurrence) and high-magnitude (12% probability of recurrence greater than bankfull) ice jam floods. Gullies have palmate and narrow linear shapes with open-ends downvalley and measure up to 208 m long×139 m wide×3.5 m deep (below bankfull). Channel ice jams reroute river water across meander lobes and cause headward gully erosion where flow returns to the main channel. Erosion of the most recent gully was observed during the record 1996 ice breakup flood and ice jams. Scour holes (bowl-shaped, closed depressions), eroded by water vortices beneath and between grounded ice jam blocks, measure up to 91 m long×22 m wide×4.5 m deep. Ice jam-caused gullies may be precursors to the formation of U-shaped oxbow lakes and multiple channels, common in many northern rivers.

507) Sponseller, R.A., and E.F. Benfield. 2001. Influence of land use on leaf breakdown in southern Appalachian headwater streams: A multiple-scale analysis. Journal of the North American Benthological Society. 20: 44-59. (C, E)

Author abstract: Stream ecosystems can be strongly influenced by land use within watersheds. The extent of this influence may depend on the spatial distribution of developed land and the scale at which it is evaluated. Effects of land-cover patterns on leaf breakdown were studied in 8 southern Appalachian headwater streams. Using a GIS, land cover was evaluated at several spatial scales, including the watershed, riparian corridor, and subcorridors that extended upstream in 200-m increments for 2 km. Breakdown rate for American sycamore (*Plantanus occidentalis*) leaf packs varied significantly among sites (k = 0.0051–0.0180/d), but fell within the range reported in the literature for sycamore. Leaf breakdown rate increased at sites with high shredder density and biomass. Further, breakdown rate and shredder density and biomass were positively related to mean substrate particle size. Several instream variables were related to watershed-scale features, but leaf breakdown rate was not related to land cover at the watershed scale. Leaf breakdown rate was inversely related to % nonforested land within riparian subcorridors of ~1 km. Results suggest that the distribution of shredders is critical to leaf processing in these streams. In some streams, increased sediment inputs resulting from agricultural activity or residential development in riparian corridors may limit the distribution of

shredders and thus influence leaf breakdown rates. Alternatively, near-stream development may alter the quality of allochthonous inputs to streams, and thus indirectly influence the distribution of shredders and instream processing.

508) Sridhar, V., A.L. Sansone, J. LaMarche, T. Dubin, and D.P. Lettenmaier. 2004. Prediction of stream temperature in forested watersheds. Journal of the American Water Resources Association. 40: 197-213. (G, H, J)

Author abstract: Removal of streamside vegetation changes the energy balance of a stream, and hence its temperature. A common approach to mitigating the effects of logging on stream temperature is to require establishment of buffer zones along stream corridors. A simple energy balance model is described for prediction of stream temperature in forested headwater watersheds that allows evaluation of the performance of such measures. The model is designed for application to "worst case" or maximum annual solar radiation and arid temperature. Low flows are estimated via a regional regression equation with independent variables readily accessible from GIS databases. Testing of the energy balance model was performed using field data for mostly forested basins on both the west and east slopes of the Cascade Mountains, and was then evaluated using the regional equation for low flow and observed maximum reach temperatures in three different east slope Cascades catchments. A series of sensitivity analyses showed that increasing the buffer width beyond 30 meters did not significantly decrease stream temperatures, and that other vegetation parameters such as leaf area index, average three height, and to a lesser extent streamside vegetation buffer width, more strongly affected maximum stream temperatures.

509) Stauffer, J.C., R.M. Goldstein, and R.M. Newman. 2000. Relationship of wooded riparian zones and runoff potential to fish community composition in agricultural streams. Canadian Journal of Fisheries and Aquatic Sciences. 57: 307-316. (K)

Author abstract: The relationship of fish community composition to riparian cover and runoff potential was investigated in 20 streams in the agricultural Minnesota River Basin during the summer of 1997. Analysis of variance indicated significant differences in fish community composition due to both riparian cover (wooded versus open) and runoff potential (high or low). Streams with wooded riparian zones had higher index of biological integrity (IBI) scores, species richness, diversity, and percentages of benthic insectivores and herbivores than streams with open riparian zones. Streams with low runoff potential had higher IBI scores and species richness than streams with high runoff potential. The riparian cover and runoff potential interaction was marginally significant with respect to IBI scores and species richness, suggesting a weak interaction between the two factors. Although both factors were important, riparian cover influenced fish community composition more than runoff potential in these streams, indicating that local factors (close to the stream) dominated landscape- or basin-level factors.

510) Steinblums, I. 1977. Streamside buffer strips: Survival, effectiveness, and design. M.S. Thesis, Oregon State University, Corvallis. (H)

Author abstract: Streamside buffers are an important tool for protecting the stream environment. This research documents the losses from 40 stream buffer strips, in the Western

Cascades of Oregon, established 1 to 15 years before the study. Predictive equations are developed which identify the major reasons for buffer strip losses. Losses from wind, sunscald, logging damage, and other factors were estimated. The effectiveness of buffer strips for stream shading was quantified.

Wind is the major cause of stream buffer strip mortality. Damage from wind is often sudden, and catastrophic, while damage due to logging or disease and insects occurs at a slower rate. The average percent of standing timber remaining in the stream buffer strips sampled was 84 percent, ranging from 22 to 100 percent. Additional losses occurred over the winter of 1975-1976, amounting to 5 percent of an initial sample of 34 buffer strips. A second set of 6 buffer strips suffered a 52 percent loss. The combined array of buffer strips lost 13 percent additional volume in this relatively mild winter.

Topography and uncut timber stand protection are the most important factors modifying the amount of windthrow in a buffer strip. The distance to the cutting line in the direction of damaging winds was the most important single variable influencing buffer strip survival, with increasing distances leading to significantly poorer survival. Two other significant protection factors were the distance and change in elevation from the buffer strip to the nearest major ridge in the direction of damaging winds. Nearby ridges and steeper slopes give better protection.

Timber factors also influence stream buffer strip survival. Increasing values for the following timber factors are associated with significantly poorer survival: average stand height, average height of trees taller than 100 feet, number of trees per acre taller than 160 feet, original timber volume per acre, original basal area per acre, and average volume per tree. Western red cedar (*Thuja plicata*), was the most windfirm tree species, followed by western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziessi*), and true fir (*Abies spp.*), in decreasing order of windfirmness. Species tolerance to wet sites, plus the timber factors described above, may help explain the windfirmness ranking.

Wet sites increase a tree's susceptibility to windthrow. Water table measurements in two buffer strips with windthrow indicated that the water table rose high enough to reach a tree's rooting zone, while the water table in a buffer strip without windthrow did not enter the root zone. Water tables within a tree's rooting zone may result in poorer rooting and tree anchorage.

The above factors, combined in multiple regression equations developed in this study, account for approximately 68 to 95 percent of the variation in predicting buffer strip survival.

Measured buffer strip shading shows that a buffer strip 85 feet wide shades a stream as well as an average undisturbed canopy, while 75 percent of the undisturbed canopy shading can be achieved with a buffer strip 52 feet wide. Width alone is not adequate for buffer strip design as topographic, timber stand, and understory factors greatly influence stream shading.

Windthrow in stream buffer strips poses a difficult salvage problem, and may also damage the stream environment. Therefore, on sites very susceptible to windthrow, the best stream protection alternative may be to carefully remove streamside trees with directional falling methods.

511) Steinblums, I.J., H.A. Froehlich, and J.K Lyons. 1984. Designing stable buffer strips for stream protection. Journal of Forestry. 82(1):49-52. (H)

Author abstract: On 40 streamside buffer strips in the Cascade Mountains of western Oregon, stability was a function of one vegetation and six topographic variables, and shading was related to three characteristics of buffer strips and one of adjacent clearcuts. Prediction equations were

developed from these relationships to aid assessment of stream protection in proposed harvest designs and to aid rapid evaluation of design modification. Options can be quantified so that the most suitable design may be chosen.

512) Sullivan, K., D.J. Martin, R.D. Cardwell, J.E. Toll, and S. Duke. 2000. An analysis of the effects of temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria. Sustainable Ecosystems Institute, Portland Oregon. 192pp. (J)

Author abstract: To administer the Clean Water Act, the U.S. Environmental Protection Agency and state water quality agencies throughout the nation have adopted numeric and qualitative criteria that establish environmental conditions known to protect aquatic life from adverse effects. Pacific Northwest states have adopted temperature criteria designed specifically to protect fish with emphasis on salmonid species because water temperature plays a role in virtually every aspect of salmon life. Adverse levels of temperature can affect growth, behavior, disease resistance, and mortality. In recent years, the EPA and National Academies of Science and Engineering have promoted risk assessment techniques to develop water quality criteria, including formal protocols that have been peer reviewed nationally. Risk assessment is designed to combine the information from biological studies with an analysis of each population's exposure to quantified effects. Risk occurs when the stress' magnitude, frequency and duration exceed the species' ability to deal with that stress. A risk-based approach seems ideally suited to developing criteria for and assessing temperature risk to fish because exposure has been well documented through temperature monitoring and extensive research on the lethal and sublethal effects on salmon physiology has been conducted over the past 40 years. Nevertheless, risk-based approaches have not yet been used to establish temperature criteria in recent state agency reviews of water quality standards.

In this paper we develop a risk-based approach to analyze summertime temperature effects on juvenile salmon species. We use available research findings to quantitatively evaluate the biological effects of temperature in combination with measured stream temperature ranging from very cold to very warm. Many currently exceed Washington's temperature standard. Acute risk to high temperatures was assessed using laboratory-derived values of mortality in relation to duration of exposure. Despite warm temperatures, the risk analysis found that direct mortality from temperature is unlikely in the range of temperature in study streams because temperatures high enough to cause mortality are either never observed, or occur over too short of periods of time to cause death. The analysis suggested that there is little or no risk of mortality if annual maximum temperature is less than 26^{o}C, although site-specific analyses are suggested when annual maximum temperature exceeds 24^{o}C to affirm this result in local river conditions. Short-term occurrence of temperatures sufficient in duration and magnitude to cause mortality is feasible, within parts of the Pacific Northwest region, and therefore streams in other geographic areas or streams with known temperature extremes should be individually evaluated with the method. Chronic exposure to temperature was based on the growth potential of fish as assessed using a simplified bioenergetics approach developed in the report. This analysis found that growth predicted from ambient temperatures is somewhat less than the maximum potential growth in all streams regardless of temperature regime, because no stream experienced temperatures that fully optimized growth all of the time during the summer rearing period. Generally the effect of temperature regime on growth was small in the range of streams studied,

but growth effects were evident at higher temperatures. The results suggest that quantitative analysis of growth effects can be determined with reasonably simple methods that can be applied at specific sites or at a region scale to identify appropriate temperature thresholds. Assuming a 10% growth loss represents an appropriate risk level, an upper threshold for the 7-day maximum temperature of 16.5°C is appropriate for coho and 20.5°C is appropriate for steelhead. Criteria derived in this manner are somewhat lower than those developed in a U.S.E.P.A. paper in 1977 and close to, but not identical, to those currently specified in Washington and Oregon criteria.

513) Surfleet, C.G., and R.R. Ziemer. 1996. Effects of forest harvesting on large organic debris in coastal streams. In: Conference on Coast Redwood Forest Ecology and Management, 18-20 June 1996, Humboldt State University, Arcata, California. J. LeBlanc, Editor. Pages 134-136. (D)

Author abstract: Large organic debris (LOD) was inventoried in two coastal streams to assess the impacts of forest harvesting on LOD recruitment in 90-year-old, second-growth redwood and fir stands on the Jackson Demonstration State Forest in northern California. One stream, North Fork of Caspar Creek, drained a 508-ha watershed that had been 60% clear-cut, with riparian buffer strips left, four years earlier. The second stream, South Fork of Caspar Creek, drains a 424-ha catchment that 60% of the timber volume had been selectively harvested and the stream cleared of LOD twenty-five years earlier. Results from these two study reaches were compared to a LOD study in the North Fork prior to logging. LOD levels increased following harvest because residual trees were left adjacent to the stream or in streamside buffer strips. Windthrow of fir provided the largest input of LOD in these second-growth redwood and fir stands due to the stand age and structure of the residual trees adjacent to the stream. Residual old-growth LOD pieces still play a major role in streams running through a mixed-second redwood and fir stand, this important element of stream LOD will continue to decline and must be compensated for in the future. Stream clearing can significantly reduce LOD levels for more than twenty-five years.

514) Suttle, K.B., M.E. Power, J.M. Levine, and C. McNeely. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecological Applications. 14: 969-974. (C, I)

Author abstract: Although excessive loading of fine sediments into rivers is well known to degrade salmonid spawning habitat, its effects on rearing juveniles have been unclear. We experimentally manipulated fine bed sediment in a northern California river and examined responses of juvenile salmonids and the food webs supporting them. Increasing concentrations of deposited fine sediment decreased growth and survival of juvenile steelhead trout. These declines were associated with a shift in invertebrates toward burrowing taxa unavailable as prey and with increased steelhead activity and injury at higher levels of fine sediment. The linear relationship between deposited fine sediment and juvenile steelhead growth suggests that there is no threshold below which exacerbation of fine-sediment delivery and storage in gravel bedded rivers will be harmless, but also that any reduction could produce immediate benefits for salmonid restoration.

515) Swanson, F.J., and G.W. Lienkaemper. 1978. Physical consequences of large organic debris in Pacific Northwest streams. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-69. 12pp. (A, D, F)

Author abstract: Large organic debris in streams controls the distribution of aquatic habitats, the routing of sediment through stream systems, and the stability of streambed and banks. Management activities directly alter decries loading by addition or removal of material and indirectly by increasing the probability of debris torrents and removing standing streamside trees. We propose that by this combination of factors the character of small and intermediate-sized streams in steep forested terrain of the Pacific Northwest is being substantially altered by forest practices.

516) Swanson, F.J., L.E. Benda, S.H. Duncan, G.E. Grant, W.F. Megahan, L.M. Reid, and R.R. Ziemer. 1987. Mass failures and other processes of sediment production in Pacific Northwest forest landscapes. In: Streamside Management: Forestry and Fishery Interactions. E.O. Salo and T.W. Cundy, Editors. College of Forest Resources, and Institute of Forest Resources, University of Washington, Seattle, Contribution No. 57. Pages 9-38. (K)

Author abstract: Accelerated sediment production by mass failures and other erosion processes is an important link between management of forest resources and fish resources. Dominant processes and the rates of sediment production vary greatly throughout the Pacific Northwest in response to geologic and climatic factors. The complex sediment routing systems characteristic of the area involve numerous processes that move soil down hillslopes and sediment through channels. Sediment routing models and sediment budgets offer conceptual and quantitative descriptions of movement and storage of soil and sediment in drainage basins. Temporal and spatial patterns of sediment production and routing through basins have many direct and indirect effects on fish. In addition to their role as dominant mechanisms of sediment production in many parts of the region, mass failures also affect the geometry and disturbance regimes of channels and streamside areas. Earth flows locally control the vegetation structure and composition of riparian zones through influences on valley floor width, gradient of side slopes and channels, and frequency of streamside debris slides. Debris flows can have long-term effects on channels and streamside landforms and vegetation. It is important to consider sediment production and the effects of mass failures on channels and riparian zones in the context of an entire drainage basin, because effects vary with location in a basin. Forestry practices can increase production of sediment. Results of experimental manipulations of vegetation on small drainage basins and studies of individual erosion processes indicate that debris slides and road surfaces are commonly dominant sources of accelerated sediment production. Some techniques are available for locating sites susceptible to accelerated erosion, for predicting change in sediment production, for evaluating the biological consequences of accelerated erosion, and for designing mitigation measures, but clearly more work is needed in each of these areas.

517) Swanston, D.N. 1974. Slope stability problems associated with timber harvesting in mountainous regions of the western United States. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-21. 14pp. (K)

Author abstract: Natural soil-mass-movements on forested slopes in the Western United States can be divided into two major groups of closely related landslide types. These include, in order of decreasing importance and regional frequency of occurrence: (1) debris slides, debris avalanches, debris flows, and debris torrents; and (2) creep, slumps, and earth flows. Each type requires the presence of steep slopes, frequently in excess of the angle of slope stability. All characteristically occur under high soil moisture conditions and usually develop or are accelerated during periods of abnormally high rainfall. Further, all are encouraged or accelerated by destruction of the natural mechanical support on the slopes.

As forest operations shift to steeper slopes, they play an increasing role in initiation and acceleration of soil mass movements. The logging operation itself is a major contributor through (1) destruction of roots, the natural mechanical support of slope soils, (2) disruption of surface vegetation cover which alters soil water distribution, and (3) obstruction of main drainage channels by logging debris. Road building stands out at the present time as the most damaging operation with soil failures resulting largely from slope loading (from road fill and sidecasting), oversteepened bank cuts, and inadequate provision for slope and road drainage.

At the present time attempts at prevention and control are limited to identification and avoidance of highly unstable areas and development and implementation of timber harvesting techniques least damaging to natural slope stability.

518) Sweeney, B.W., T.L. Bott, J.K. Jackson, L.A. Kaplan, J.D. Newbold, L.J. Standley, W.C. Hession, and R.J. Horwitz. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. Proceedings of the National Academy of Sciences. 101: 14132-14137. (A, C, E, F, I)

Author abstract: A study of 16 streams in eastern North America shows that riparian deforestation causes channel narrowing, which reduces the total amount of stream habitat and ecosystem per unit channel length and compromises in-stream processing of pollutants. Wide forest reaches had more macroinvertebrates, total ecosystem processing of organic matter, and nitrogen uptake per unit channel length than contiguous narrow deforested reaches. Stream narrowing nullified any potential advantages of deforestation regarding abundance of fish, quality of dissolved organic matter, and pesticide degradation. These finding show that forested stream channels have wider and more natural configuration, which significantly affects the total in-stream amount and activity of the ecosystem, including processing pollutants. The results reinforce both current policy of the United States that endorses riparian forest buffers as best management practice and federal and state programs that subsidize riparian reforestation for stream restoration and water quality. Not only do forest buffers prevent nonpoint source pollutants from entering small streams, they also enhance the in-stream processing of both nonpoint and point source pollutants, thereby reducing their impact on downstream rivers and estuaries.

519) Sweka, J.A., and K.J. Hartman. 2001. Influence of turbidity on brook trout reactive distance and foraging success. Transactions of the American Fisheries Society. 130: 138-146. (C, I)

Author abstract: Past research has focused on the effects of sediment action on stream morphology and the habitat of brook trout *Salvelinus fontinalis.* Throughout the Appalachian Mountains, the watersheds in which brook trout reside are being influenced by timber harvesting and related road construction. Although these streams may have gradients steep enough to prevent deleterious sediment deposition, elevated stream turbidity is nevertheless common. An understanding of the sublethal effects of increased sedimentation and turbidity is essential to further our knowledge of the effects of increased sediment loading on stream fish production and how these effects differ among species living in sympatry. The specific objectives of this study were to determine (1) the effects of turbidity on the reactive distance of brook trout, (2) how turbidity affects encounter rates between brook trout and their prey, and (3) how turbidity affects brook trout's foraging success. We used videographic techniques to study brook trout foraging behavior in an artificial stream. Three brook trout were tested during each sampling period, creating a competitive situation under which a more accurate measure of reactive distance could be made. Treatment turbidity levels ranged from 0 to 43 nephelometric turbidity units. The reactive distance of brook trout decreased curvilinearly with increasing turbidity. The probability of a brook trout's reacting to a given prey item was correlated with reactive distance and also decreased with turbidity. However, turbidity had no influence on the probability of attack given a reaction, the probability of capture given an attack, or the probability of ingestion given capture. In natural streams, invertebrate drift densities typically increase with turbidity as flows increase, but this increase may not be enough to compensate for the decreased ability of brook trout to detect drifting prey.

520) Swift, L.W., Jr., and R.G. Burns. 1999. The three Rs of roads: Redesign, reconstruction, and restoration. Journal of Forestry. 97(8): 40-44. (K)

Author abstract: All too often, unpaved forest access roads in the southern Appalachian Mountains were located near streams and rivers, thereby contributing storm flow and sediment to the aquatic ecosystem. Landowners and managers may not have the resources to reconstruct and relocate all these roads to protect water quality. However, simple techniques for redesign of storm water drainage structures can provide low-cost alternatives where the forest floor can absorb and filter runoff from roads. These practices could apply not just in the Appalachians but wherever storms and roads are placing sediment in the stream. Land managers and consultants who assist nonindustrial forestland owners can use the principles for maintenance, reconstruction, or restoration of problem roads.

521) Switalski, T.A., J.A. Bissonette, T.H. DeLuca, C.H. Luce, and M.A. Madej. 2003. Wildland road removal: Research needs. Proceedings of the International Conference on Ecology and Transportation, August 2003, Lake Placid, New York. Pages 642-646. (K)

Author abstract: Wildland road removal is a common practice across the U.S. and in some parts of Canada. The main types of road removal include ripping, stream crossing restoration,

and full recontour. Road removal creates a short-term disturbance that may temporarily increase sediment loss. However, research and long-term monitoring have shown that road removal both reduces erosion rates and the risk of road-induced landslides. Research is needed to determine whether road removal is effective at restoring ecosystem processes and wildlife habitat. We propose several research questions and the types of studies needed to further road removal efforts. With greater understanding of the impacts of road removal, land managers can more effectively prioritize which roads to leave open and which roads to consider for future road removal projects.

522) Tague, C., and L. Band. 2000. Simulating the impact of road construction and forest harvesting on hydrologic response. Earth Surface Processes and Landforms. 26: 135-151. (K)

Author abstract: This paper incorporates a conceptual model of the effect of roads and forest harvesting on hillslope soil moisture and runoff production into a hydroecological modelling system and discusses model results for a range of scenarios for a small catchment in the Western Oregon Cascades, USA. The model is used to explore the implications of road cut depth and road drainage patterns on seasonal hydrologic responses including runoff production, soil moisture and ecological processes such as evapotranspiration. By examining hydrologic response within a seasonal and hillslope context, we illustrate the complex role played by roads in terms of both the spatial and temporal persistence of the effects of an increase in local drainage efficiency associated with particular road segments. Model results are compared with observed outflow responses for a paired catchment study using the test case watershed. (catchment area in UK terminology). Results show the potential for an ecologically significant change in soil moisture in the area downslope from the road. These changes are mediated by the drainage patterns associated with roads, specifically whether road culverts serve to concentrate or to diffuse flow. Field verification of these findings presents an avenue for further research. The modelled effects on seasonal outflow response are less significant but do show clear temporal patterns associated with climate pattern, hillslope drainage organization and road construction. Comparison between modelled and observed outflow response suggests that the model does not yet capture all of the processes involved in assessing the effects of forest road construction.

523) Tang, S.M., and D.R. Montgomery. 1995. Riparian buffers and potentially unstable ground. Environmental Management. 19: 741-749. (K)

Author abstract: The spatial coincidence between riparian buffers of various widths and extents and potentially unstable ground was quantified using a physically based model for shallow landslide initiation and GIS for two watersheds on the Olympic Peninsula, Washington, USA. The proportion of unstable ground in each watershed within riparian buffers is a function of both buffer width and the extent of the stream channel network being buffered. While current buffers required by Washington State cover less than 5% of the potentially unstable ground, buffering all stream channels in these watersheds with 100-m buffers covered 75%-90% of the potentially unstable areas. Our analyses further show that: (1) riparian buffers are not efficient mechanisms for protecting potentially unstable ground, and (2) identifying potentially unstable ground using a physically based model should prove more effective for designing methods to reduce shallow landsliding hazards than relying on extensive buffer zones along stream channels.

524) Wagner, R.G., and J.M. Hagan (Editors). 2000. Forestry and the riparian zone. Conference proceedings, 26 October 2000, Wells Conference Center, University of Maine, Orono. Hosted by the Cooperative Forestry Research Unit, University of Maine and Manomet Center for Conservation Sciences, Manomet, Massachusetts. 88pp. (C, E, I, J)

Compiler abstract: This document includes papers from invited speakers and poster abstracts from a symposium focused on the theme of forestry practices and the riparian zone as it relates to forests in Maine. Topics from invited speakers and posters included:

- forestry effects on water quality;
- effects of timber harvest on insect communities of small headwater streams;
- cumulative watershed effects of forestry;
- a method to determine effective riparian buffers for Atlantic salmon habitat conservation;
- water temperature characteristics of 1st through 4th order streams in western Maine;
- rate of stream water warming in buffered-clearcut and intact-forest streams in western Maine;
- usage and effectiveness of forestry best management practices in Maine; and
- testing the effectiveness of different buffer widths for protecting stream physical, chemical, and biotic integrity in managed forests.

525) Wallerstein, N.P., and C.R. Thorne. 2004. Influence of large woody debris on morphological evolution of incised, sand-bed channels. Geomorphology. 57: 53-73. (A, D)

Author abstract: This paper documents the influence of Large Woody Debris (LWD) on the morphological evolution of unstable, degrading, sand-bed rivers in the Yazoo Basin, North Mississippi, USA. The study was performed as part of the Demonstration Erosion Control (DEC) project. Twenty-three river reaches were studied, with the aim of determining whether the presence of LWD was beneficial or detrimental to the recovery of stability in degrading, sand-bed river systems and to provide the geomorphic understanding necessary to underpin enhanced LWD management strategies. The results demonstrate that locations of LWD inputs, volumes of LWD stored in different reaches and number of jams per unit channel length are causally related to the morphological processes occurring during different stages of adjustment in these unstable, incised fluvial systems and may be explained using a Channel Evolution Model (CEM). The net impact of LWD jams on reach-scale sediment budgets was found, in general, to be positive: that is, jams trap more sediment than they mobilise. This suggests that LWD probably accelerates rather than retards recovery of a stable longitudinal profile and channel configuration following incision. Field typing of LWD jams, based on their impacts on the flow pattern, reveals that jam type is a function of the size of large, key elements in the jam in relation to the channel width. A Debris Jam Classification Scheme is proposed on this basis, with the spatial relationship between jam type and drainage basin area expressed using a dimensionless function of the ratio between channel width and average riparian tree height. The scheme features four jam types, Underflow, Dam, Deflector and Flow Parallel/Bar Head, each of which has a different morphological impact on local channel geometry. These jam types may be used to classify LWD jams as an aid in

determining appropriate management strategies, according to their location within the drainage basin.

526) Wallerstein, N.P, C.V. Alonso, S.J. Bennett, and C.R. Thorne. 2001. Distorted Froude-scaled flume analysis of large woody debris. Earth Surface Processes and Landforms. 26: 1265-1283. (A, D)

Author abstract: This paper presents the results of a movable-boundary, distorted, Froude-scaled hydraulic model based on Abiaca Creek, a sand-bedded channel in northern Mississippi. The model was used to examine the geomorphic and hydraulic impact of simplified large woody debris (LWD) elements. The theory of physical scale models is discussed and the method used to construct the LWD test channel is developed. The channel model had bed and banks moulded from 0·8 mm sand, and flow conditions were just below the threshold of motion so that any sediment transport and channel adjustment were the result of the debris element. Dimensions and positions of LWD elements were determined using a debris jam classification model. Elements were attached to a dynamometer to measure element drag forces, and channel adjustment was determined through detailed topographic surveys.

The fluid drag force on the elements decreased asymptotically over time as the channel boundary eroded around the elements due to locally increased boundary shear stress. Total time for geomorphic adjustment computed for the prototype channel at the Q_2 discharge (discharge occurring once every two years on average) was as short as 45 hours. The size, depth and position of scour holes, bank erosion and bars created by flow acceleration past the elements were found to be related to element length and position within the channel cross-section. Morphologies created by each debris element in the model channel were comparable with similar jams observed in the prototype channel.

527) Warren, D.R., and C.E. Kraft. 2003. Brook trout (*Salvelinus fontinalis*) response to wood removal from high-gradient streams of the Adirondack Mountains (N.Y., U.S.A.). Canadian Journal of Fisheries and Aquatic Sciences. 60: 379-389. (A, D)

Author abstract: A before–after, control–impact study was conducted to evaluate brook trout (*Salvelinus fontinalis*) response to the removal of debris dams and woody debris from an ice-storm-impacted stream system in the eastern Adirondack Mountains in New York State. A total of 10 reach pairs were established on two first-order streams, two second-order streams, and one third-order stream, all within the same watershed. Analyses, conducted separately for each stream order, used linear contrasts to compare differences in trout abundance between reference (upstream) and removal (downstream) reaches 1 month and 1 year after the manipulation. We expected trout abundance to decrease in removal reaches relative to reference reaches; however, responses varied temporally and with respect to stream order. Trout abundance had not changed significantly 1 month after removal. One year after removal, relative trout abundance had increased in the third-order stream, decreased in the second-order streams, and exhibited no significant change in the first-order streams. In areas with abundant boulders and preexisting habitat complexity, accumulated woody debris may have limited influence on trout abundance.

528) Welsh, H.H., Jr., G.R. Hodgson, and B.C. Harvey. 2001. Distribution of juvenile coho salmon in relation to water temperatures in tributaries of the Mattole River, California. North American Journal of Fisheries Management. 21: 464-470. (J)

Author abstract: In an attempt to define the upper thermal tolerance of coho salmon *Oncorhynchus kisutch*, we examined the relationship between the presence of this species and the summer temperature regime in 21 tributaries of the Mattole River of northwestern California. We characterized the temperature regime of each tributary by determining the highest average of maximum daily temperatures over any 7-d period (maximum weekly maximum temperature, MWMT) and the highest average of mean daily temperatures over any 7-d period (maximum weekly average temperature MWAT), by the use of hourly measurements throughout the summer. Coho salmon presence was determined by divers in late summer. Both variables that were used to describe the temperature regime provided good-fitting models of the presence or absence of coho salmon in separate logistic regressions, and both correctly determined the presence or absence in 18 of 21 streams, given the previous probability of a 50% likelihood of coho salmon presence. Temperature regimes in the warmest tributaries containing juvenile coho salmon had MWMT of 18.0°C or less or MWAT of 16.7°C or less; conversely, all of the streams where MWMT was less than 16.3°C or MWAT was less than 14.5°C contained juvenile coho salmon. These results, combined with historical and current watershed conditions that affect stream temperatures, suggest that management strategies to restore and conserve coho salmon in the Mattole River drainage should focus on the water temperature regime. Such a focus is also likely to benefit other declining species requiring cold water, including the tailed frog *Ascaphus truei* and southern torrent salamander *Rhyacotriton variegatus*.

529) Wemple, B.C., F.J. Swanson, and J.A. Jones. 2001. Forest roads and geomorphic process interactions, Cascade Range, Oregon. Earth Surface Processes and Landforms. 26: 191-204. (K)

Author abstract: A major flood in February 1996 triggered more than 100 geomorphic features affecting forest roads in a 181 km^2 study area in the western Cascade Range, Oregon. Eight types of features, including mass movements and fluvial features, were mapped, measured and analysed using geographic information systems and sediment budgets for the road network. Although roads functioned as both production and depositional sites for mass movements and fluvial processes, the net effect of roads was an increase in basin-wide sediment production. Debris slides from mobilized road fills were the dominant process of sediment production from roads. Road-related sedimentation features were concentrated in a portion of the study area that experienced a rain-on-snow event during the storm and was characterized by the oldest roads and steep slopes underlain by unstable, highly weathered bedrock. The downslope increase in frequency of features and volumes of sediment produced, combined with the downslope increase in relative frequency of fluvial over mass-wasting processes, suggests that during an extreme storm event, a road network may have major impacts on stream channels far removed from initiation sites. Overall this study indicated that the nature of geomorphic processes influenced by roads is strongly conditioned by road location and construction practices, basin geology and storm characteristics.

530) Wing, M.G., and A. Skaugset. 2002. Relationships of channel characteristics, land ownership, and land use patterns to large woody debris in western Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences. 59: 796-807. (A, D)

Author abstract: Regression tree analysis was used to test the relationship of channel and aquatic habitat characteristics from 3793 stream reaches in western Oregon State to the abundance of large woody debris (LWD). Stream reaches were drawn from diverse ownerships and land uses – land cover types over a broad geographic extent. When all land uses – land covers were considered, ownership and land use patterns were related to LWD abundance. When nonforested land uses were excluded, however, these factors became less important. In forested streams, LWD abundance was predicted primarily by stream gradient and bankfull channel width, with the volume, frequency, and size of LWD pieces decreasing as channel size increased. Within forested lands, stand age and forest distribution were related to LWD size but had small correlations with LWD volume and abundance. The strong relationship of stream gradient and bankfull channel width with LWD suggests that in forested areas, the most significant factor related to LWD counts is the geomorphology of stream reaches and their surrounding areas. Land managers in western Oregon who want to improve aquatic habitat quality may want to direct their efforts to increasing LWD in larger streams, which typically include smaller quantities of LWD.

531) Wohl, E., J.N. Kuzma, and N.E. Brown. 2004. Reach-scale channel geometry of a mountain river. Earth Surface Processes and Landforms. 29: 969-981. (A, D, G)

Author abstract: Mountain rivers can be subject to strong constraints imposed by changes in gradient and grain size supplied by processes such as glaciation and rockfall. Nonetheless, adjustments in the channel geometry and hydraulics of mountain rivers at the reach scale can produce discernible patterns analogous to those in fully alluvial rivers. Mountain rivers can differ in that imposed reach-scale gradient is an especially important control on reach-scale channel characteristics, as indicated by examination of North St Vrain Creek in Colorado.

North St Vrain Creek drains 250 km^2 of the Rocky Mountains. We used 25 study reaches within the basin to examine controls on reach-scale channel geometry. Variables measured included channel geometry, large woody debris, grain size, and mean velocity. Drainage area at the study reaches ranged from 2.2 to 245 km^2, and gradient from 0.013 to 0.147 m m^{-1}.

We examined correlations among (1) potential reach-scale response variables describing channel bankfull dimension and shape, hydraulics, bedform wavelength and amplitude, grain size, flow resistance, standard deviation of hydraulic radius, and volume of large woody debris, and (2) potential control variables that change progressively downstream (drainage area, discharge) or that are likely to reflect a reach-specific control (bed gradient). We tested the hypothesis that response variables correlate most strongly with local bed gradient because of the segmented nature of mountain channels.

Results from simple linear regression analyses indicate that most response variables correlate best with gradient, although channel width and width/depth ratio correlate best with discharge. Multiple regression analyses using Mallow's C_p selection criterion and log-transformation of all variables produced similar results in that most response variables correlate strongly with gradient. These results suggest that the hypothesis is partially supported: channel bed gradient is

likely to be a good predictor for many reach-scale response variables along mountain rivers, but discharge is also an important predictor for some response variables.

532) Wolman, M.G. 1959. Factors influencing erosion of a cohesive river bank. American Journal of Science. 257: 204-216. (F)

Author abstract: The sinuous channel of Watts Branch in Montgomery County, Maryland, traverses a grassy meadow nearly devoid of trees. The creek has a drainage area of four square miles and the river bank is composed primarily of cohesive silt. Resurveys of cross sections during the five years 1953-1957 have revealed as much as seven feet of lateral erosion. Over the past two years, additional measurements of the amount of erosion around rows of steel pins driven horizontally into the bank have been made at frequent intervals. These observations indicate several combinations of factors primarily responsible for the progressive recession.

Approximately 85 percent of the observed erosion occurred during the winter months of December, January, February, and March. A thickness of as much as 0.4 feet of sediment was eroded from the bank at specific points in a period of several hours during which a bankfull flow attacked banks which had previously been thoroughly wetted. Erosion was most severe at the water surface. Little or no erosion was observed during the summer despite the occurrence of the highest flood on record in July, 1956.

Second in erosion effectiveness were cold periods during which wet banks, frost action, and low rises in stage combined to produce 0.6 foot of erosion in six weeks during the winter of 1955-56. Significant erosion also resulted from the combination of moist banks and low rises in stage. Lastly, crystallization of ice and subsequent thawing, without benefit of changes in stage, also produced some erosion as did flashy summer floods even on hard, dry banks. In as much as such summer floods constitute the rare and "catastrophic" events on a small drainage basins in this region, present observation suggest that the cumulative effect of more moderate climatic conditions on this process of erosion exceeds the effect of rarer events of much greater magnitude.

This preliminary analysis of several factors responsible for erosion of the cohesive river bank indicates that there is perhaps a crude correlation between precipitation and erosion during selected intervals of time. Precipitation exerts and affect both through increasing discharge in the channel and by increasing the moisture in the bank. Frost action acts similarly both to hold moisture in the soil and to communicate surface material, thus preparing it for erosion.

533) Wooster, J., and S. Hilton. 2004. Large woody debris volumes and accumulation rates in cleaned streams in redwood forest in southern Humboldt County, California. USDA Forest Service, Pacific Southwest Research Station, Research Note PSW-RN-426. 14pp. (A, D)

Author abstract Large woody debris (LWD) was inventoried in 1999 in five streams where LWD was removed in the early 1980s, and no LWD has been artificially introduced since. All study sites are second order channels near the confluence of the South Fork and main-stem Eel River, California. Watershed contributing areas range from 4.7 to 17.4 km^2, and mean active channel widths within study reaches range from 5.6 to 8.4 m. Vegetation is dominated by redwood (*Sequoia sempervirens* (D. Don) Endl.); three streams have old- and second-growth study reaches and two streams are entirely second growth. LWD volumes in old-growth reaches

averaged 589 m^3/ha compared to 251 m^3/ha for second-growth reaches. The mean volumes in cleaned old-growth streams were significantly less (90 percent confidence level) than in undisturbed old-growth redwood streams in Prairie Creek, California (Keller and others 1985), with our reaches averaging less than a third of the mean volume in undisturbed reaches. LWD accumulation rates since cleaning were estimated using field evidence to exclude any pieces left during cleaning. Input rates averaged 13.7 m^3/ha/yr for old growth and 4.2 m^3/ha/yr for second growth. The discrepancy between old- and second-growth accumulation rates is primarily in the rate of input from the hillslope to the potential zone (defined as >0.5 m above the water surface and extending 1m laterally from the active channel). Of new LWD in the active channel, 41 percent (by volume) was associated with pools and 65 percent (by volume) was trapped in debris jams.

534) Wright, K.A. 1985. Changes in storm hydrographs after roadbuilding and selective logging on a coastal watershed in northern California. M.S. Thesis, Humboldt State University, Arcata, California. 55pp. (G)

Author abstract: The effects of road building and selective tractor harvesting on storm peak flows and storm volumes were assessed for a small (424 hectare) coastal watershed in Northern California. Two watersheds, the North and South Fork of Caspar Creek were calibrated from 1962 to 1967 while no treatments took place. Roads were then built on the South Fork, and the two watersheds were monitored until 1971. Between 1971 and 1973 the South Fork was selectively tractor logged, removing 60 percent of the timber volume. The storm flows were monitored until 1976.

Only the very small (566 l/s or less) storm peaks or volumes (121 kiloliters or less) were increased after roadbuilding and logging. Roadbuilding alone significantly ($p < 0.10$) increased the small storm peaks approximately 20 percent, but did not affect the storm volumes. Logging increased both the peaks and volumes of the small storms by about 80 percent and 40 percent respectively. The large storm peaks and volumes were not significantly increased by either roads or logging, even though over 15 percent of the watershed was compacted in roads, skidtrails and landings. The increase in small storm peaks and volumes are not considered significant to the stream's stability or sediment regime.

535) Wright, K.K., and J.L. Li. 2002. From continua to patches: Examining stream community structure over large environmental gradients. Canadian Journal of Fisheries and Aquatic Sciences. 59: 1404-1417. (K)

Author abstract: We present an approach that integrates a conceptual framework with multivariate ordination techniques and traditional parametric analyses to examine biotic and abiotic gradients in stream ecosystems. Ordinations were used to examine multivariate patterns along an environmental gradient, with individual variables used to interpret those patterns across spatial scales. The conceptual framework provides a consistent context to compare community distributions and consequently allows for hypothesis testing using ordinations. To illustrate the approach, we examined the physical template, fish and benthic macroinvertebrate communities, and algal biomass and production along a 1st- through 5th-order stream gradient in eastern Oregon. We hypothesized that longitudinal distributions of physical habitat characteristics, fishes, macroinvertebrates, and periphyton would reflect highly variable, discontinuous

gradients. Multivariate patterns were determined by rotating nonparametric ordinations to a common set of variables and comparing them to conceptual models of (*i*) an ideal continuum, (*ii*) a random distribution, and (*iii*) discrete patches. Physical habitat and fishes reflected strong longitudinal gradients, macroinvertebrates were the most patchy, and algal biomass and production were highly variable. Distributions of individual variables from site and stream-order perspectives revealed how different factors, potentially influencing stream communities, may be continuous or patchy depending on spatial scale.

536) Zelt, R.B., and E.E. Wohl. 2004 .Channel and woody debris characteristics in adjacent burned and unburned watersheds a decade after wildfire, Park County, Wyoming. Geomorphology. 57: 217-233. (D, F)

Author abstract: Large variability in responses of stream sediment and large woody debris (LWD) to severe fire has limited the accurate prediction of the magnitude and duration of fire effects on streams. Conditions in one Absaroka Range stream that was severely burned in 1988 were compared to those in an adjacent, undisturbed stream to improve understanding of fire effects on channel and LWD characteristics beyond the first few years. Ten reaches of each stream were sampled during summer 1999.Average bankfull channel width was greater in burned Jones Creek than in unburned Crow Creek. LWD frequency and overall frequency of LWD accumulations were greater in Crow Creek than Jones Creek. Debris-jam frequency was greater in Jones Creek after accounting for differences in the frequency of pieces with length greater than channel width. Larger piece size and better anchoring contributed to more frequent, small accumulations of LWD in Crow Creek. Differences between streams in LWD frequency are consistent with greater mobility of debris in burned Jones Creek. LWD-associated fine-sediment deposits were thicker but less frequent along Jones Creek than Crow Creek.

537) Ziemer, R.R. 1984. Response of progressive hillslope deformation to precipitation. In: Symposium on the Effects of Forest Land Use on Erosion and Slope Stability. Proceedings of a symposium, 7-11 May, 1984, Honolulu, Hawaii. C.L. O'Loughlin and A.J. Pearce, Editors. Pages 91-98. (K)

Author abstract: To document a relationship between progressive hillslope deformation and precipitation, boreholes on the Redwood Creek basin in northern California were surveyed semiannually from 1974 to 1982. Regressions were calculated between borehole displacement and an antecedent precipitation index (API) variable. Values for the API variable were obtained by summing daily API values over the time between borehole surveys, if the daily API value exceeded some threshold, The coefficient of determination, r^2 8 was maximized by calculating a series of regressions with various API recession factors and thresholds. The "best" regressions had a recession factor of 0.99 and a zero threshold. Results suggest that creep and earthflow rates increase in response to precipitation and that graywacke and schist terrain respond to similar mechanisms of movement.

538) Ziemer, R.R. 1992. Effect of logging on subsurface pipeflow and erosion: Coastal northern California. In: Erosion, Debris Flows and Environment in Mountain Regions. Proceedings of the Chengdu Symposium, July 1992. International Association of Hydrological Sciences Publication No. 209. Pages 87-197. (K)

Author abstract: Three zero-order swales, each with a contributing drainage area of about 1 ha, were instrumented to measure pipeflows within the Caspar Creek Experimental Watershed in northwestern California, USA. After two winters of data collection, the second-growth forest on two of the swales was clearcut logged. The third swale remained as an uncut control. After logging, peak pipeflow was about 3.7 times greater than before logging. Before logging, little sediment was transported through the pipes. Suspended sediment concentrations before logging were less than 20 mg l-1 and coarse-grained sediment was rare. After logging, there was great spatial and temporal variability in sediment transport. Sediment loads increased dramatically from some pipes during some storms, but from other pipes, sediment discharge remained unchanged after logging.

539) Ziemer, R.R., and R.L. Hubbard. 1991. Chapter seven. Forestry and anadromous fish. In: California's Salmon and Steelhead: The Struggle to Restore an Imperiled Resource. A. Lufkin, Editor. University of California Press, Berkeley. Pages 88-95. (K)

Compiler abstract: The authors address the issue of timber harvest and its effects on fish resources, specifically in California. They trace the history and evolution of events in California that led to some of the forest practices regulations from the 1940s to the 1990s. Discussions on specific legislation, research projects, and directions for future research are included.

540) Ziemer, R.R., and T.E. Lisle. 1998. Hydrology. In: River Ecology and Management: Lessons From the Pacific Coastal Ecoregion. R.J. Naiman and R.E. Bilby, Editors. Springer-Verlag, New York. Pages 43-68. (G)

Author abstract (Author Overview): Streamflow is highly variable in mountainous areas of the Pacific coastal ecoregion. The timing and variability of streamflow is strongly influenced by form of precipitation (e.g., rainfall, snowmelt, or rain on snow).

High variability in runoff processes limits the ability to detect and predict human-caused changes in streamflow. Changes in flow are usually associated with changes in other watershed processes that may be of equal concern. Studies of how land use affects watershed responses are thus likely to be most useful if they focus on how runoff processes are affected at the site of disturbance and how these effects, hydrologic or otherwise, are propagated downstream.

Land use and other site factors affecting flows have less effect on major floods and in large basins than on smaller peak flows and in small basins. Land use is more likely to affect streamflow during rain on snow events, which usually produce larger floods in much of the Pacific coastal ecoregion than purely rainfall events.

Long-term watershed experiments indicate that clear-cutting and road building influence rates and modes of runoff, but these influences are stronger for some areas, events, and seasons than or others. Logging and road building can increase areas that generate overland. Row and convert subsurface flow to overland flow, thereby increasing rates and volumes of stormflow. Logging and road building can also increase runoff rates and volumes from transient snow packs during rain on snow events.

Removal of trees, which consume water, tends to increase soil moisture and base streamflow in summer when rates of evapotranspiration are high. These summertime effects tend to

disappear within several years. Effects of tree removal on soil moisture in winter are minimal because of high seasonal rainfall and reduced rates of evapotranspiration.

The rate of recovery from land use depends on the type of land use and on the hydrologic processes that are affected.

541) Ziemer, R.R., J. Lewis, R.M. Rice, and T.E. Lisle. 1991. Modeling the cumulative watershed effects of forest management strategies. Journal of Environmental Quality. 20: 36-42. (K)

Author abstract: There is increasing concern over the possibility of adverse cumulative watershed effects from intensive forest management. It is impractical to address many aspects of the problem experimentally because to do so would require studying large watersheds for 100 yr or more. One such aspect is the long-term effect of forest management strategies on erosion and sedimentation and the resultant damage to fish habitat. Is dispersing activities in time and space an effective way to minimize cumulative sedimentation effects? To address this problem, Monte Carlo simulations were conducted on four hypothetical 10 000-ha fifth-order forested watersheds: one watershed was left undisturbed, one was completely clearcut and roaded in 10 yr, with cutting starting at the head of the watershed and progressing toward the mouth, another was cut at the rate of 1% each year beginning at the watershed's mouth and progressing upstream, and another was cut at a rate of 1% each year, with individual cut areas being widely dispersed throughout the watershed. These cutting patterns were repeated in succeeding centuries, rebuilding one-third of the road network every 100 yr. The parameters governing the simulations were based on recent data from coastal Oregon and northwestern California, Mass wasting, the most important source of sediment in that environment, was the only hillslope process modeled. The simulation results suggest that (i) the greatest differences between management strategies appeared in the first 100 yr and were related primarily to the rate of treatment. By the second 100 yr, when all watersheds had been treated, the principal difference between logging strategies was the timing of impacts. (ii) Dispersing harvest units did not significantly reduce cumulative effects. (iii) The frequency of bed elevation changes between 1 and 4 cm is dramatically increased by logging.

542) Zwieniecki, M.A., and M. Newton. 1999. Influence of streamside cover and stream features on temperature trends in forested streams of western Oregon. Western Journal of Applied Forestry. 14: 106-113. (J)

Author abstract: Clearcut harvesting along low-elevation western Oregon streams with forest buffers (8.6 to 30.5 m wide) was followed by little direct local effect on water temperature. A study of 14 streams demonstrated that all have a tendency to warm with downstream direction even under full forest cover. After the natural warming trend of the stream water was accounted for, water at slightly higher temperatures within the buffered clearcut zones cooled to the trend line of temperature by 150 m downstream. Because of the natural warming trends in streams, estimating the net temperature effect associated with management practices requires use of a warming trend line as the norm for fully covered forests for each general level of discharge.