Relevant Literature For an Evaluation of The Effectiveness of The Alaska Forest Resources And Practices Act: An Annotated Bibliography

Compiled by:

Robert A. Ott, Ph.D.
Alaska Department of Natural Resources, Division of Forestry, and
the Tanana Chiefs Conference Forestry Program
Fairbanks, Alaska

Angie K. Ambourn, M.S.
USDA Forest Service, Alaska Region, State and Private Forestry
Forest Health Protection
Fairbanks, Alaska

Fabian Keirn
Tanana Chiefs Conference Forestry Program
Fairbanks, Alaska

Alison E. Arians, Ph.D.
Alaska Department of Natural Resources, Division of Forestry
Anchorage, Alaska

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ALASKA COASTAL MANAGEMENT PROGRAM

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INTRODUCTION

The intent of this annotated bibliography was to identify projects throughout Alaska that address the effectiveness of the current Alaska Forest Resources and Practices Act (FRPA) in protecting fish habitat and water quality. The Act requires protection of ten components:

A.) channel morphology,
B.) clean spawning gravels,
C.) food sources,
D.) large woody debris,
E.) nutrient cycling,
F.) stream bank stability,
G.) stream flow,
H.) sunlight,
I.) water quality,
J.) water temperature.

Very little research has been conducted specifically to evaluate the effectiveness of FRPA. Therefore, this review takes a broader approach and identifies projects that contribute to knowledge of the ten fish habitat and water quality components and the impact of forest management practices on these components. We expanded the literature search beyond Alaskan projects to provide additional information contributing to a general understanding of aquatic ecosystems and the impacts of forest management upon them.

The literature search focused on recent (i.e. the last ~10-15 years) publications, although older documents are included. We used several sources to identify pertinent literature, including:

- direct contact with individuals conducting relevant research in Alaska and individuals with personal libraries on these topics;
- an internet search using the Google® search engine;
- an on-line search of the table of contents and abstracts of peer-reviewed journals that regularly publish articles related to the fish habitat and water quality variables identified in FRPA (e.g. Canadian Journal of Forest Research, Earth Surface Processes and Landforms, Journal of the North American Benthological Society, Transactions of the American Fisheries Society);
- an electronic key word search (see the next paragraph) of Goldmine, the electronic library catalog of the University of Alaska Fairbanks, to identify relevant gray literature (e.g. agency reports, University of Alaska dissertations and theses) of projects conducted in Alaska;
- an electronic key word search of the following article databases available through Rasmuson library at the University of Alaska Fairbanks to identify additional Alaska-related peer-reviewed and gray literature: Academic Search Premier, Alaska/Polar Periodical Index, Aquatic Sciences and Fisheries abstracts, Arctic & Antarctic Regions, Cambridge Scientific abstracts, Fish and Fisheries Worldwide abstracts, and Water Resources.

We used the following key words, singly or in various combinations, when conducting key word searches of electronic databases and the internet: Alaska, Alaska Forest Resources and Practices Act, anadromous, bank stability, benthic, benthos, boreal, buffer strip, channel migration, channel morphology, clear cut, clearcut, CWD, erosion, fish, fish habitat, fish passage, forest management, forestry, FRPA, invertebrate drift, large woody debris, logging, logging roads, LWD, macroinvertebrate, nutrient cycling, redd(s), riparian, riparian buffer, roads, salmon, sedimentation, spawning gravels, stream flow, sunlight, timber harvest, water quality, and water temperature.

This annotated bibliography has two main sections, which are further divided into several subsections. The first main section contains citations and abstracts of work conducted in Alaska, and is divided into four subsections (Figure 1):

- FRPA Region I—Coastal Sitka Spruce/Hemlock Forest;
- FRPA Region II—Interior Spruce/Hardwood Forest, South of the Alaska Range;
- FRPA Region III—Interior Spruce Hardwood Forest, North and West of the Alaska Range;
- Alaska General—State-wide references and references in which the location of the study area was not identified.

The second main section contains citations and abstracts of work that was conducted outside Alaska, or which is general in nature (e.g. topical literature reviews), or lacks the identification of a study area in the abstract. This second section is divided into four subsections:

- Canada,
- Lower 48 States,
- International—Other Than Canada,
- Miscellaneous.

Each abstract is identified as being an author abstract, an electronic abstract, or a compiler abstract. Author abstracts were copied verbatim from journal articles and reports that were available to us, or from electronic abstracts that were posted on websites of individual peer-reviewed journals. In a few instances, a report did not contain an abstract, but a summary, introduction, or conclusions section contained information that was adequate for summarizing the described project. In these cases, the appropriate sections were copied verbatim and labeled as an author abstract as well. Electronic abstracts are those which were obtained from the electronic key word search of the article databases identified above. From experience, we knew that many of these abstracts were not complete author abstracts, so we did not want to identify them as such. Compiler abstracts are those that were written by the compilers of this bibliography for those reports that did not contain an abstract or a suitable introduction, summary, or conclusions section.

At the end of each citation, the letter designations of the FRPA fish habitat and water quality component(s) (A-J) that are discussed in the article or report are identified in parentheses. In addition, we added a variable (K) to identify articles relevant to the discussion of forest management impacts on fish habitat and water quality that do not specifically identify one of the ten FRPA components. For example, articles discussing forest harvest-related landslides or sediment production from forest roads are important in a discussion of forestry impacts on water quality, but the abstracted articles may not specifically address landslides or forest road erosion in the context of water quality. The variable K was used only if an article or report did not specifically address any of the 10 fish habitat and water quality variables identified in FRPA. Refer to the first paragraph for the letter designations of the FRPA variables.

Appendix A is intended to assist readers of this bibliography with locating specific references. The Appendix lists all of the references contained in this bibliography in alphabetical order, identifies in which bibliography section the reference is located, and identifies which FRPA variables are discussed in each reference.

This review is intended to complement the bibliographies compiled during the reviews of the FRPA riparian standards for FRPA regions II and III. This review references those bibliographies, although some of the individual references included in them also appear in this bibliography.

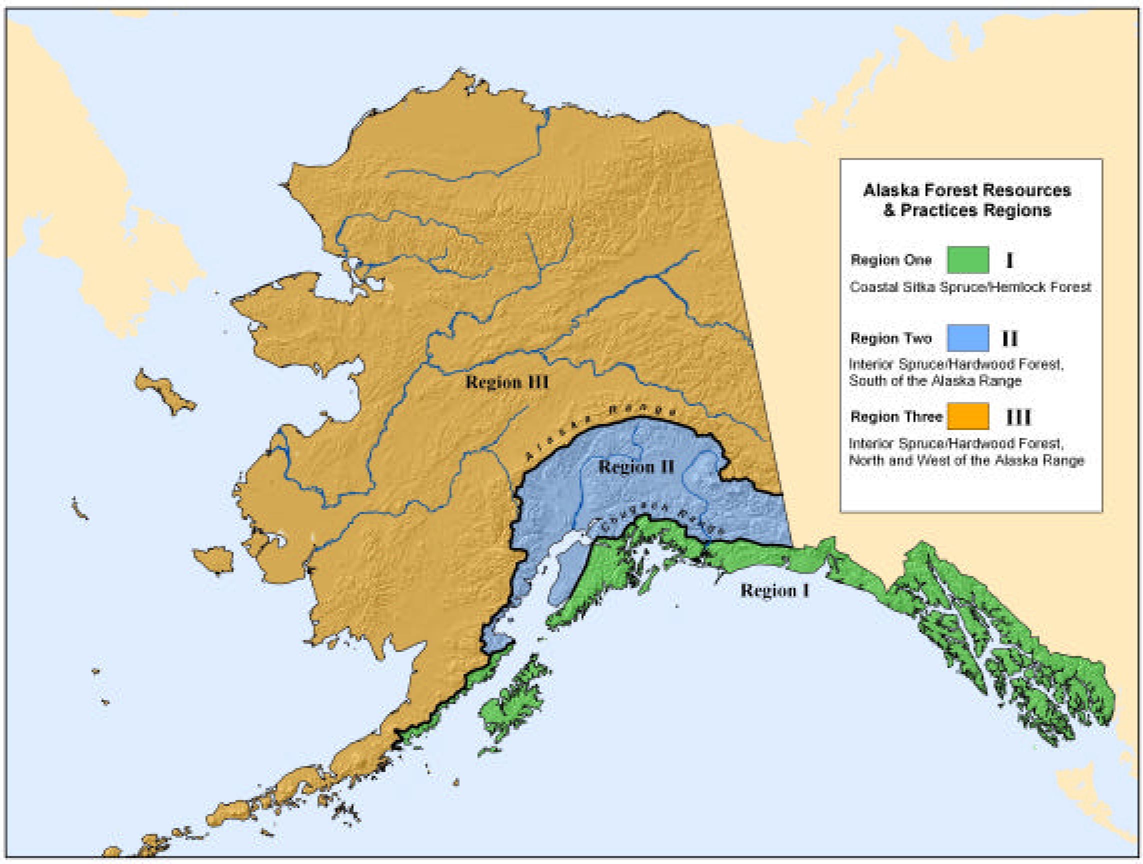

Figure 1. Alaska Forest Resources and Practices Act management regions.

ALASKA REFERENCES

Alaska—FRPA Region I
(Coastal Sitka Spruce/Hemlock Forest)

1) Allan, J.D., M.S. Wipfli, J.P. Caouette, A. Prussian, and J. Rodgers. 2003. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. Canadian Journal of Fisheries and Aquatic Sciences. 60: 309-320. (C)

Author abstract: Salmonid food webs receive important energy subsidies via terrestrial in-fall, downstream transport, and spawning migrations. We examined the contribution of terrestrially derived invertebrates (TI) to juvenile coho (*Oncorhynchus kisutch*) in streams of southeastern Alaska by diet analysis and sampling of TI inputs in 12 streams of contrasting riparian vegetation. Juvenile coho ingested 12.1 $mg \cdot fish^{-1}$ of invertebrate mass averaged across all sites; no significant differences associated with location (plant or forest type) were detected, possibly because prey are well mixed by wind and water dispersal. Terrestrial and aquatic prey composed approximately equal fractions of prey ingested. Surface inputs were estimated at ~80 $mg \cdot m^{-2} \cdot day^{-1}$, primarily TI. Direct sampling of invertebrates from the stems of six plant species demonstrated differences in invertebrate taxa occupying different plant species and much lower TI biomass per stem for conifers compared with overstory and understory deciduous plants. Traps placed under red alder (*Alnus rubra*) and conifer (mix of western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*)) canopies consistently captured higher biomass of TI under the former. Management of riparian vegetation is likely to influence the food supply of juvenile coho and the productivity of stream food webs.

2) Bartos, L. 1989. A new look at low flows after logging. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Pages 95-98. (G)

Author abstract: On the west side of Prince of Wales Island, a 51.6 square mile drainage basin was used to systematically evaluate low flow trends, before and after timber harvest. Both yearly flow duration curves and the 2 and 20 year recurrence low flow derived by Log Pearson Type III analysis, showed significantly greater low flows after timber harvesting 35 percent of the drainage area.

3) Bartos, L.R. 1993. Stream discharge related to basin geometry and geology, before and after logging. In: Proceedings of Watershed '91: A Conference on the Stewardship of Soil, Air, and Water Resources, 16-17 April 1991, Juneau, Alaska. T. Brock, Editor. USDA Forest Service, Alaska Region, R10-MB-217. Pages 29-32. (G)

Author abstract: Utilizing available U.S.G.S. hydrologic data on five watersheds in SE Alaska with different intensities of logging and two watersheds for a no harvest control; a composite analysis was done to determine the degree of hydrologic change caused by harvesting. The possible controlling basin parameters effecting a streams regimen, i.e., water yield, peak flood flows and mean seven day low flows other than drainage area and amount of timber harvest are geologic makeup, mean basin side slope gradient and basin shape. When considering these basin parameters (excepting basin shape) on floods before and after timber harvest, it was found that in all cases they were significant in S.E. Alaska.

4) Bjornn, T.C., S.C. Kirking, and W.R. Meehan. 1991. Relation of cover alterations to the summer standing crop of young salmonids in small southeast Alaska streams. Transactions of the American Fisheries Society. 20: 562-570. (K)

Electronic abstract: Summer abundance of young coho salmon *Oncorhynchus kisutch*, steelhead *O. mykiss* , and Dolly Varden *Salvelinus malma* was assessed in small streams on Prince of Wales Island, Alaska, in an attempt to measure the response of these fish to various types of cover alterations. The standing crop of subyearlings decreased during summer, but none of the decrease could be attributed to the changes in cover we made. Subyearling coho salmon (about 75% of the fish present) did not respond either to the removal of natural riparian vegetation or to the addition of simulated riparian canopy, large boulders, woody debris, or simulated undercut banks. Localized movements within the streams were sufficient to provide relatively rapid recolonization of the experimental habitat units. The forms of cover we evaluated were relatively unimportant in regulating abundance of young coho salmon in small streams.

5) Brabets, T.P. 1995. Application of surface geophysical techniques in a study of the geomorphology of the Lower Copper River, Alaska. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Resources Investigations Report 94-4165. 47pp. (A, G, I)

Electronic abstract: The Copper River, located in southcentral Alaska, drains an area of more than 24,000 square miles. About 30 miles above its mouth, this large river enters Miles Lake, a proglacial lake formed by the retreat of Miles Glacier. Downstream from the outlet of Miles Lake, the Copper River flows past the face of Childs Glacier before it enters a large, broad, alluvial flood plain. The Copper River Highway traverses this flood plain and in 1996, 11 bridges were located along this section of the highway. These bridges cross parts or all of the Copper River and in recent years, some of these bridges have sustained serious damage due to the changing course of the Copper River. Although the annual mean discharge of the lower Copper River is 57,400 cubic feet per second, most of the flow occurs during the summer months from snowmelt, rainfall, and glacial melt. Approximately every six years, an outburst flood from Van Cleve Lake, a glacier-dammed lake formed by Miles Glacier, releases approximately 1 million acre-feet of water into the Copper River. At the peak outflow rate from Van Cleve Lake, the flow of the Copper River will increase an additional 140,000 and 190,000 cubic feet per second. Bedload sampling and continuous seismic reflection were used to show that Miles Lake traps virtually all the bedload being transported by the Copper River as it enters the lake from the north. The reservoir-like effect of Miles Lake results in the armoring of the channel of the Copper River downstream from Miles Lakes, past Childs Glacier, until it reaches the alluvial flood plain. At this point, bedload transport begins again. The lower Copper River transports 69 million tons per year of suspended sediment, approximately the same quantity as the Yukon River, which drains an area of more than 300,000 square miles. By correlating concurrent flows from a long-term streamflow-gaging station on the Copper River with a short-term streamflow-

gaging station at the outlet of Miles Lake, long-term flow characteristics of the lower Copper River were synthesized. Historical discharge and cross-section data indicate that as late as 1970, most of the flow of the lower Copper River was through the first three bridges of the Copper River Highway as it begins to traverse the alluvial flood plain. In the mid 1980's, a percentage of the flow had shifted away from these three bridges and in 1995, only 51 percent of the flow of the Copper River passed through them. Eight different years of aerial photography of the lower Copper River were analyzed using Geographical Information System techniques. This analysis indicated that no major channel changes were caused by the 1964 earthquake. A flood in 1981 that had a recurrence interval of more than 100 years caused significant channel changes in the lower Copper River. A probability analysis of the lower Copper River indicated stable areas and the long-term locations of channels. By knowing the number of times a particular area has been occupied by water and the last year an area was occupied by water, areas of instability can be located. A Markov analysis of the lower Copper River indicated that the tendency of the flood plain is to remain in its current state. Large floods of the magnitude of the 1981 event are believed to be the cause of major changes in the lower Copper River.

6) Brownlee, K. 1991. Prey consumption by juvenile salmonids on the Taku River, southeast Alaska. M.S. Thesis, University of Alaska, Fairbanks. 166pp. (C)

Author abstract: Stomach contents were collected from juvenile salmonids (genus *Oncorhynchus* and *Salvelinus*) from habitats on the Taku River in 1987. Differences were defined between groups on fry. A linear discriminant function (LDF) analysis was applied to prey frequencies grouped by species, habitat, and period. The analysis discriminated between: fish in beaver ponds; sockeye in side-slough sites and fish from other mainstem sites; and beaver ponds and mainstem sites. An exclusion experiment was established in a beaver pond. The diet of sockeye (*O. nerka*) and coho (*O. kisutch*) fry was sampled from allopatric and sympatric treatment enclosures. LDF analysis applied to prey categories assigned group membership between species, treatment, and period factors. A log-linear analysis yielded significant interaction effects between the treatment, habitat, and period explanatory variables and the response, prey, confirming the influence of the presence of cogenerics on prey consumed.

7) Bryant, M.D. 1980. Evolution of large, organic debris after timber harvest: Maybeso Creek, 1949 to 1978. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-101. 30pp. (A, D)

Author abstract: The Maybeso Creek valley was logged from 1953 to 1960. Stream maps showing large accumulations of debris and stream channel features were made in 1949 and updated to 1960. The objectives of this paper are to document the effects of natural and logging debris on channel morphometry and to examine the fate of logging debris during and after logging. Map sections from 1949 through 1963 are examined and compared with a ground survey in 1978 of debris accumulations.

Natural conditions before logging revealed sparse accumulations of large debris scattered throughout the stream; these accumulations increased in number and density during logging. Natural material appeared to be well controlled and stable; whereas, logging debris was floatable. Year-to-year changes in accumulations were noted throughout the period of logging from 1953 to 1969. Fewer accumulations were observed in 1978 than in 1949, before the start of logging. Further studies are needed to quantify physical changes and to relate these changes to salmon habitat.

8) Bryant, M.D. 1981. Evaluation of a small diameter baffled culvert for passing juvenile salmonids. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Forest Service Research Note PNW-384. 8 pp. (K)

Electronic abstract: Poorly constructed road crossings of small streams can block upstream movement of juvenile salmonids. Where gradients are more than 1%, baffled culverts may facilitate fish passage to nursery areas above road crossings. The baffles create a series of short high velocity runs between the baffles and a series of low velocity backwater areas behind the baffles. These areas allow the fish to swim in short bursts and then rest. A 90-cm diameter culvert with off-set baffles was set at a 10% gradient in an artificial stream channel on Admiralty Island, Alaska. Juvenile coho salmon, Dolly Varden, and cutthroat trout used in the study were taken from two nearby streams. All fish, with the exception of a few larger (110 to 120 mm) Dolly Varden, were less than 100 mm fork length. All three species were able to negotiate the culvert, but more Dolly Varden than Coho salmon or Cutthroat trout were successful. Within the range of discharges commonly examined between 10 1/S and 16 1/S, discharge did not appear to affect fish movement up the culvert. Two potential problems with baffled culverts may occur at the outlet: outlet velocity; and scour of the stream bottom. Both can be avoided by proper design.

9) Bryant, M.D. 1984. Distribution of salmonids in the Trap Bay Basin, Tenakee Inlet. 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 17-31. (K)

Author abstract: Because land management may affect a stream system at various points along its progression to the sea, it is important to identify zones used in the watershed by juvenile salmonids. This 2-year study examined the distribution of juvenile salmonids in an undisturbed, old-growth forest drainage. The purpose of the study was to determine the distribution of juvenile salmonids in a small stream basin from the main stream through the upper tributaries. Differences in density, species ratios, and size among juvenile salmonids in main-stream zones, lower tributary zones, and upper tributary zones were observed. Upper reaches of tributaries were used by age-0 coho, cutthroat trout, and Dolly Varden. Lower reaches of tributaries were extensively used by juvenile coho of all age-classes and Dolly Varden up to about 120 mm in length. Main-stream zones were sparsely populated by all species, but where off-channel rearing areas were available, coho were more abundant. Differences in density occurred from early summer to early fall.

10) Bryant, M.D. 1985. Changes 30 years after logging in large woody debris, and its use by salmonids. In: Riparian ecosystems and their management: Reconciling conflicting uses. R.R. Johnson, C.D. Ziebell, D.R. Paton, P.F. Ffolliot, and R.H. Hamre, Coordinators. Rocky Mountain Forest and Range Experiment Station, General Technical Report GTR RM-120. Pages 329-334. (D)

Electronic abstract: Changes in large woody debris in fourth and fifth-order salmon streams with logged, unlogged, and partially logged riparian zones are documented from maps--for 1949 to 1960--and from field surveys done in 1983 and 1984. Over the 30-year period, most changes in the amount of large woody debris occurred in the logged systems. During and immediately after logging large increases were noted, but in 1984 the amount of large woody debris in the logged systems was less than that observed before logging in most categories. Amounts of large woody debris in the other streams remained relatively stable. Thirty years after logging, habitat formed as a result of large debris provides important rearing areas for juvenile salmonids.

11) **Bryant, M.D., and F.H. Everest. 1998. Management and condition of watersheds in southeast Alaska: The persistence of anadromous salmon. Northwest Science. 72: 249-267. (K)**

Electronic abstract: In contrast to most of North America and Europe, numerous intact or lightly disturbed watersheds are present throughout southeast Alaska. These watersheds support abundant and diverse populations of anadromous salmonids. While the watersheds throughout the northern hemisphere have been exposed to human disturbance from millennia to centuries, significant human disturbance to the watersheds of southeast Alaska did not begin until the 1950's with the start of industrial logging. Although management of watersheds has evolved to reduce risks to aquatic habitat, the most intensive logging occurred during the first 20 years of timber harvest when few restraints were placed on timber harvest in watersheds. As a result, a legacy of streams with deteriorating habitat remains. While few salmon stocks in southeast Alaska appear to be in decline, escapement records on specific watersheds, particularly those most severely affected by management are non-existent or qualitative. The present status of salmon stocks may be attributed to abundant intact watersheds, high marine survival, and escapement levels that fully seed most watersheds. The numerous intact watersheds throughout southeast Alaska are a critical factor in maintaining sustainable salmon stocks in southeast Alaska.

12) **Bryant, M.D., B.E. Wright, and B.J. Davies. 1992. Application of a hierarchical habitat unit classification system: Stream habitat and salmonid distribution in Ward Creek, southeast Alaska. USDA Forest Service, Pacific Northwest Research Station, Research Note PNW-RN-508. (A)**

Electronic abstract: A hierarchical classification system separating stream habitat into habitat units defined by stream morphology and hydrology was used in a pre-enhancement stream survey. The system separates habitat units into macrounits, mesounits, and microunits and includes a separate evaluation of instream cover that also uses the hierarchical scheme. The paper presents an application of the system to a pre-enhancement survey of habitat and salmonid populations. Application of the method accompanied by snorkel counts of fish allowed us to determine habitat area, salmonid densities within habitat units, and an estimate of the total salmonid population by species. The method is useful to rapidly describe and stratify stream habitat to determine salmonid distribution and abundance during stream surveys.

13) Bryant, M.D., J.P. Caouette, and B.E. Wright. Evaluating stream habitat survey data and statistical power using an example from southeast Alaska. Draft manuscript. First author address: USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, Juneau, Alaska. (A)

Author abstract: Stream habitat surveys and watershed assessments have been developed and used as monitoring tools for decades. Most rely on type I error as the primary criterion with minor consideration of statistical power and effect size. We test for statistical differences in fish habitat condition between harvested and non-harvested watersheds from habitat survey data collected in Southeast Alaska. We apply statistical power analysis to judge whether non-significant results could be interpreted with confidence. None of the fish habitat variables we examined were significant at $P = 0.05$; however, several p-values were less than 0.10 and consistent differences between harvested and unharvested reaches were observed among channel types. Statistical power is low and the probability of not detecting differences is high when the effect size, scaled to the standard deviation of the measurement, is small to medium. For large effect sizes the ability to detect differences increased but did not exceed 85% for any measurement. Statistical power, effect size and biological significance of the outcome are important considerations when the results are interpreted and can lend additional information to managers making decision with less than perfect data.

14) Bryant, M.D., N.D. Zymonas, and B.E. Wright. 2004. Salmonids on the fringe: Abundance, species composition, and habitat use of salmonids in high gradient headwater streams, southeast Alaska. Transactions of the American Fisheries Society. 133: 1529-1538. (A)

Author abstract: We evaluated the species distribution, abundance, and habitat relationships of salmonids in small, 1st to 2nd order headwater streams in Southeast Alaska. Streams were separated into three zones based on gradient and sampled during the spring, summer, and fall. Dolly Varden (*Salvelinus malma*) were found in all streams where fish were present. They were the dominant species in moderate (mean gradient 5.5 %) and high gradient (mean gradient 12.9 %) zones. Coho salmon (*Oncorhynchus kisutch*) fry and parr were dominant species in the low gradient zone (mean gradient 3.1 %), but were present in higher gradient zones. Small numbers of steelhead parr (*O. mykiss*) were present in all three zones in the spring and fall. Few were captured during the summer. Coastal cutthroat trout (*O. clarki*) were found primarily in one stream and in all three zones. Density of all species decreased as gradient increased. Anadromous Dolly Varden in spawning condition were observed in the fall up to the highest accessible locations in four streams. Salmonids use high gradient reaches when pools are present and accessible. Headwater tributaries comprise a large proportion of most Southeast Alaska watersheds and the combined contribution from all of these tributaries to the fish community may be large. Results from this study underscore the importance of maintaining access for fish throughout watersheds and into small high gradient streams.

15) Bryant, M.D., D.N. Swanston, R.C. Wissmar, and B.E. Wright. 1998. Coho salmon populations in the karst landscape of North Prince of Wales Island, southeast Alaska. Transactions of the American Fisheries Society. 127: 425-433. (E, I)

Electronic abstract: Karst topography is a unique and distinct landscape and its geology may have important implications for salmon productivity in streams. The relationship between salmonid communities and water chemistry and the influence of habitat was examined in a set of streams on north Prince of Wales Island, southeast Alaska. Streams in karst landscapes showed higher alkalinities (1,500-2,300 mu eq/L) than streams not influenced by karst landscapes (750-770 mu eq/L). A significant, positive relationship was observed between alkalinity and density of coho salmon parr *Oncorhynchus kisutch*. Backwater pools supported higher densities of coho salmon than did other habitat units. Both coho salmon fry and parr tended to be larger in most karst-influenced streams than in nonkarst streams. Although past timber harvest practices in the riparian areas of several of the streams appeared to influence stream habitat and water temperature, streams flowing through karst landscapes had distinct water chemistry. Furthermore, these streams appeared to support more fish than nonkarst streams.

16) **Buffington, J.M., and D.R. Montgomery. 1999. Effects of hydraulic roughness on surface textures of gravel-bed rivers. Water Resources Research. 35: 3507-3521. (A, B, D, G)**

Electronic abstract: Field studies of forest gravel-bed rivers in northwestern Washington and southeastern Alaska demonstrate that bed-surface grain size is responsive to hydraulic roughness caused by bank irregularities, bars, and wood debris. We evaluate textural response by comparing reach-average median grain size (D_{50}) to that predicted from the total bank-full boundary shear stress ($t_{0_{bf}}$), representing a hypothetical reference condition of low hydraulic roughness. For a given $t_{0_{bf}}$, channels with progressively greater hydraulic roughness have systematically finer bed surfaces, presumably due to reduced bed shear stress, resulting in lower channel competence and diminished bed load transport capacity, both of which promote textural fining. In channels with significant hydraulic roughness, observed values of D_{50} can be up to 90% smaller than those predicted from $t_{0_{bf}}$. We find that wood debris plays an important role at our study sites, not only providing hydraulic roughness but also influencing pool spacing, frequency of textural patches, and the amplitude and wavelength of bank and bar topography and their consequent roughness. Our observations also have biological implications. We find that textural fining due to hydraulic roughness can create usable salmonid spawning gravels in channels that otherwise would be too coarse.

17) **Buffington, J.M., T.E. Lisle, R.D. Woodsmith, and S. Hilton. 2002. Controls on the size and occurrence of pools in coarse-grained forest rivers. River Research and Applications. 18: 507-531. (A, D)**

Electronic abstract: Controls on pool formation are examined in gravel- and cobble-bed rivers in forest mountain drainage basins of northern California, southern Oregon, and southeastern Alaska. We demonstrate that the majority of pools at our study sites are formed by flow obstructions and that pool geometry and frequency largely depend on obstruction characteristics (size, type, and frequency). However, the effectiveness of obstructions to induce scour also depends on channel characteristics, such as channel gradient, width:depth ratio, relative submergence (ratio of flow depth to grain size), and the calibre and rate of bed material supply. Moreover, different reach-scale channel types impose different characteristic physical processes and boundary conditions that further control the occurrence of pools within a catchment. Our findings indicate that effective management of pools and associated aquatic habitat requires consideration of a variety of factors, each of which may be more or less important depending on channel type and location within a catchment. Consequently, strategies for managing pools that are based solely on single-factor, regional target values (e.g. a certain number of wood pieces or pools per stream length) are likely to be ineffective because they do not account for the variety of local and catchment controls on pool scour and, therefore, may be of limited value for proactive management of complex ecosystems.

18) Campbell, A.J., and R.C. Sidle. 1985. Bedload transport in a pool-riffle sequence of a coastal Alaska stream. Water Resources Bulletin. 21: 579-590. (I)

Electronic abstract: A Helley-Smith pressure differential bedload sampler was used to measure bedload transport at consecutive riffle sections of a riffle-pool-riffle sequence on Bambi Creek, a small (154 ha), second-order stream on Chichagof Island, Alaska, during four storms over a 2-year period. Maximum bedload transport rate measured was 4920 kg/h at a streamflow of 2.35 m^3/s corresponding to a storm having a 5-year return interval. Transport of larger sediment (> 8 mm) varied systematically with streamflow at the two sampling locations. At flows up to approximately bankfull, transport of large sediment was greatest at the upstream site; at flows above bankfull, transport of large sediment was greatest at the downstream site.

19) Chaloner, D.T., and M.S. Wipfli. 2002. Influence of decomposing Pacific salmon carcasses on macroinvertebrate growth and standing stock in southeastern Alaska streams. Journal of the North American Benthological Society. 21: 430-442. (C, E)

Author abstract: We compared macroinvertebrate growth rates and standing stock in the absence and presence of meat from Pacific salmon (*Oncorhynchus* spp.) carcasses in microcosm and natural stream rearing experiments in southeastern Alaska. In microcosm experiments, the presence of salmon meat increased growth rates and standing stock for the shredder *Zapada cinctipes* and the collector *Psychoglypha subborealis*, but not the predator *Rhyacophila* sp., or the scraper *Cinygmula* sp. In natural stream experiments, the presence of salmon meat increased the growth rate and standing stock of *P. subborealis*, but increased only the growth rate of *Z. cinctipes*. Macroinvertebrate responses to inputs of salmon-derived organic material can vary by species, which may reflect their feeding ecology. Macroinvertebrate taxa belonging to the collector functional-feeding group are likely to be important in transferring the effects of spawning salmon to the rest of the food web in southeastern Alaska streams.

20) Chaloner, D.T., M.S. Wipfli, and J.P. Caouette. 2002. Mass loss and macroinvertebrate colonisation of Pacific salmon carcasses in south-eastern Alaskan streams. Freshwater Biology. 47: 263-273. (C, E)

Author abstract: 1. We examined the spatial and temporal dynamics of pink salmon (*Oncorhynchus gorbuscha*) carcass decomposition (mass loss and macroinvertebrate colonisation) in south-eastern Alaskan streams. Dry mass and macroinvertebrate fauna of carcasses placed in streams were measured every two weeks over two months in six artificial streams and once after six weeks in four natural streams. We also surveyed the macroinvertebrate fauna and wet mass of naturally occurring salmon carcasses.

2. Carcass mass loss in artificial streams was initially rapid and then declined over time (k =-0.033 day^{-1}), and no significant differences were found among natural streams.
3. Several macroinvertebrate taxa colonized carcasses, but chironomid midge (Diptera: Chironomidae) and *Zapada* (Pleceoptera: Nemouridae) larvae were found consistently and were the most abundant (on average 95 and 2%, respectively, of the invertebrates found). Chironomid abundance and biomass increased over time, whereas *Zapada* abundance and biomass did not. Significant differences in abundance were found among natural streams for *Baetis* (Ephemeroptera: Baetidae) and *Sweltsa* (Plecoptera: Chloroperlidae) larvae, while no significant differences were found for chironomid and *Zapada* abundance or biomass.
4. Our results suggest that salmon carcasses initially undergo a high rate of mass loss that tapers off with time. Chironomid and *Zapada* larvae are likely to be important in mediating nutrient and energy transfer between salmon carcasses and other components of the freshwater-riparian food web in south-eastern Alaskan streams.

21) Chaloner, D.T., K.M. Martin, M.S. Wipfli, P.H. Ostrom, and G.A. Lamberti. 2002. Marine carbon and nitrogen in southeastern Alaska stream food webs: Evidence from artificial and natural streams. Canadian Journal of Fisheries and Aquatic Sciences. 59: 1257-1265. (C, E)

Author abstract: Incorporation of marine-derived nutrients (MDN) into freshwater food webs of southeastern Alaska was studied by measuring the natural abundance of nitrogen and carbon stable isotopes in biota from artificial and natural streams. Biofilm, aquatic macroinvertebrates (detritivores, shredders, and predators), and fish (coho salmon, *Oncorhynchus kisutch*, and cutthroat trout, *Oncorhynchus clarki*) were sampled from streams in which Pacific salmon (*Oncorhynchus* spp.) carcasses had been artificially placed or were present naturally. In the presence of carcasses, all trophic levels incorporated marine-derived nitrogen (range, 22–73% of total N) and carbon (range, 7–52% of total C). In general, chironomid midges assimilated more marine-derived nitrogen and carbon than did other consumers. The assimilation of MDN by aquatic organisms and subsequent isotopic enrichment (5–6‰ for ^{15}N, 3–4‰ for ^{13}C) were similar in experimentally and naturally carcass-enriched streams. For specific taxa, however, percent assimilation for marine nitrogen and carbon were often dissimilar, possibly because of fractionation or transfer inefficiencies. These results suggest that pathways of MDN incorporation into stream food webs include both consumption of salmon material by macroinvertebrates and fish and uptake of mineralized MDN by biofilm. Incorporation of MDN into multiple trophic levels demonstrates the ecological significance of annual returns of anadromous fishes for sustaining the productivity of freshwater food webs.

22) Chaloner, D.T., G.A. Lamberti, R.W. Merritt, N.L. Mitchell, P.H. Ostrom, and M.S. Wipfli. 2004. Variation in response to spawning Pacific salmon among three south-eastern Alaska streams. Freshwater Biology. 49: 587-599. (C, E)

Author abstract: 1. Pacific salmon are thought to stimulate the productivity of the fresh waters in which they spawn by fertilizing them with marine-derived nutrients (MDN). We compared the influence of salmon spawners on surface streamwater chemistry and benthic biota among three southeastern Alaska streams. Within each stream, reaches up- and downstream of barriers to salmon migration were sampled during or soon after spawners entered the streams. 2. Within streams, concentrations of dissolved ammonium and soluble reactive phosphorus (SRP), abundance of epilithon (chlorophyll *a* and ash-free dry mass) and biomass of chironomids were significantly higher in reaches with salmon spawners. In contrast, biomass of the mayflies Epeorus spp. and Rhithrogena spp. was significantly higher in reaches lacking spawners. 3. Among streams, significant differences were found in concentrations of dissolved ammonium, dissolved organic carbon, nitrate and SRP, abundance of epilithon, and the biomass of chironomids and Rhithrogena. These differences did not appear to reflect differences among streams in spawner density, nor the changes in water chemistry resulting from salmon spawners. 4. Our results suggest that the 'enrichment' effect of salmon spawners (e.g. increased streamwater nutrient concentrations) was balanced by other concurrent effects of spawners on streams (e.g. sediment disturbance). Furthermore, the collective effect of spawners on lotic ecosystems is likely to be constrained by conditions unique to individual streams, such as temperature, background water chemistry and light attenuation.

23) Deal, R.L. 1997. Understory plant diversity in riparian alder-conifer stands after logging in southeast Alaska. USDA Forest Service, Pacific Northwest Research Station, Research Note PNW-RN-523. 8pp. (D)

Author abstract: Stand structure, tree height growth, and understory plant diversity were assessed in five mixed alder-conifer stands after logging in southeast Alaska. Tree species composition ranged from 7- to 91-percent alder, and basal area ranged from 30 to 55 m^2/ha. The alder exhibited rapid early growth, but recent growth has slowed considerably. Some conifers have been suppressed, but some spruce are now nearly as tall as the overstory alders. The four stands with the most alder had high species richness of shrubs, herbs, ferns, and mosses, but the predominantly spruce stand had slightly fewer species of shrubs and ferns, and considerably fewer herbs. Mixed alder-conifer stands have maintained species-rich understories for 45 years after logging, and stands with conifers and alders of relatively equal stocking contained the largest diameter conifers. Riparian alder-conifer stands maintain plant diversity and also will provide some large-diameter conifers for large woody debris for streams.

24) Deal, R., M. Wipfli, A. Johnson, T. De Santo, P. Hennon, and T. Hanley. 2002. Does red alder enhance wildlife, aquatic, and fisheries resources in young-growth western hemlock-Sitka spruce forests of southeast Alaska? In: Beyond 2001: A Silvicultural Odyssey to Sustaining Terrestrial and Aquatic Ecosystems. Proceedings of the 2001 National Silviculture Workshop, 6-10 May, Hood River, Oregon. S. Parker and S.S. Hummel, Compilers. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-546. Pages 93-102 (C, D, F)

Author abstract: Red alder (*Alnus rubra* Bong.) appears to influence the productivity and community composition of young growth conifer forests and affect the major resources (timber, wildlife, and fishes) of forested ecosystems in southeast Alaska. We propose that landscapes may be managed to concurrently enhance these resources. Historically, red alder has often been regarded as an undesirable species by forest managers and has been thinned from riparian and upland forests. We present an integrated approach to study the function of young-growth forest ecosystems and to understand how alder influences selected trophic linkages and processes in managed landscapes. We will assess the physical disturbances that are associated with alder establishment. We will also investigate mixed red alder-conifer forests and determine if these forests provide a greater biomass of understory vegetation and forage for herbivores (e.g., deer) and invertebrates than young-growth conifer forests. We will determine the effect of mixed red alder-conifer forests on the abundance of aquatic, riparian, and terrestrial invertebrates that provide food for fish, bats, and birds. We will also determine if most red alder trees die standing (as opposed to uprooting or bole snapping), and assess woody debris and sediment input in streams. We will investigate whether red alder in mixed stands may enhance conifer growth and total wood production. The inclusion of red alder in young-growth stands may allow clearcutting in areas where purely even-aged conifer forests would compromise wildlife, fish, and aquatic resources.

25) Dolloff, C.A. 1983. The relationships of wood debris to juvenile salmonid production and microhabitat in small southeast Alaska streams. Ph.D. Thesis, Montana State University, Bozeman. 109pp. (D)

Author abstract: Many small streams in Southeast Alaska contain both wood debris deposited by natural causes and/or logging and populations of juvenile salmonids. Resource managers have assumed that large amounts of wood debris were detrimental to fish populations and have recommended debris removal. This study was initiated to describe the effects of wood debris and debris removal on populations of juvenile coho salmon and Dolly Varden in four tributary streams of Staney Creek, Prince of Wales Island, Alaska during the summers of 1979-1981. Three streams were located in clearcuts and had debris removed from selected subsections by manual labor. A fourth stream was located in an uncut forest stand and provided information on fish populations under natural conditions. Population densities and production of both species were typically higher in subsections having debris accumulations intact. Production during the June-September period for age 0+ and age 1+ coho combined ranged from 0.464-2.496 g/square meter. Dolly Varden production ranged from 0.106-0.879 g/square meter. For coho, debris provided visual isolation, permitting larger numbers of fish to live together without excessive territorial interactions. Greater Dolly Varden numbers were related to increased cover provided by debris. There was little apparent competition between the species. An examination of microhabitat preferences showed that each of two coho and three Dolly Varden age classes was found in distinct areas. Coho occupied midwater positions that they defended from other fish. Dolly Varden were found on the stream bottom in dense cover. Analysis of stomach contents showed that coho selected most dietary items from the drift whereas Dolly Varden primarily exploited benthic prey. Discriminant analysis showed that depth of focal point, depth of water, distance to nearest fish and distance to nearest cover were the most important variables accounting for separation of the five species-age class groups. Discriminant analysis using species as groups and incorporating the proportion of diet from terrestrial sources as an independent variable revealed that dietary differences also contributed to group separation. Stream cleaning in streams similar to those studied will likely be detrimental to anadromous juvenile fish populations.

26) Dolloff, C.A. 1986. Effects of stream cleaning on juvenile Coho salmon and Dolly Varden in southeast Alaska. Transactions of the American Fisheries Society. 115: 743-755. (D)

Author abstract: The effects are described of selective removal of woody debris on populations of juvenile Coho salmon *Oncorhynchus kisutch* and Dolly Varden *Salvelinus malma* in two small streams on Prince of Wales Island, Alaska, during the summers of 1979-1981. These streams contained debris left when surrounding forests were clear-cut in the late 1960s. Debris smaller than 60 mm in diameter and larger debris not embedded in the stream channel were manually removed from half of the study reach on each stream in 1979 by state-of-the-art techniques. Immigration and emigration of fish from the study sections and intrastream movements were very limited after an initial period of population adjustment in the spring regardless of treatment. Population densities and production of both species were typically higher in sections where debris accumulations had not been removed. Production of age-0+ and age-1+ Coho salmon and age-1+ and age-2+ Dolly Varden during the June-September period ranged from 0.70 to 2.22 g/sq m in the cleaned sections and from 0.84 to 2.10 g/sq m in the uncleaned sections. Carrying capacities for both species were lower in cleaned sections despite the use of selective techniques for removing woody debris.

27) Duncan, W.F.A., and M.A. Brusven. 1985. Energy dynamics of three low-order southeast Alaskan streams: Autochthonous production. Journal of Freshwater Ecology. 3: 155-166. (K)

Electronic abstract: Physical and biotic processes of three low-order southeast Alaska streams located on Prince of Wales Island were studied. These streams drained an undisturbed watershed representing a coniferous climax forest, a recently logged watershed with little riparian regeneration, and a logged watershed with heavy riparian growth. Community respiration and production were measured in closed, recirculating 12-L Plexiglas metabolism chambers using the dissolved oxygen method. Gross production among the streams varied from 0.1-2.7 g $O_2/m^2/d$; respiration varied from 0.1-1.0 g $O_2/m^2/d$. Highest rates of production and respiration occurred in the recently logged stream; lowest rates were measured in the mature, climax forest stream. Seasonal differences in production and respiration were apparently influenced by logging.

28) Duncan, W.F.A., and M.A. Brusven. 1986. Benthic macroinvertebrates in logged and unlogged low-order southeast Alaskan streams. Freshwater Invertebrate Biology. 4: 125-132. (C)

Electronic abstract: The benthic macroinvertebrate communities of three low-order streams in southeast Alaska exhibiting pre- and post logging conditions were examined. The logged watersheds had the highest densities and biomass of benthic macroinvertebrates, while an unlogged coniferous climax forest watershed had the lowest. Benthic macroinvertebrate community composition was similar for key species among the three streams. Collector-gatherers were generally the most abundant functional group comprising up to 80% of the insect community; predator-engulfers were the second most abundant functional group. Salmonid fishes greatly altered the macroinvertebrate community composition during spawning because of mass disturbance of the streambed. Gravels disturbed during spawning were most rapidly recolonized by mayflies and stoneflies, especially *Alloperla* spp.

29) Duncan, W.F.A., M.A. Brusven, and T.C. Bjornn. 1989. Energy-flow response models for evaluation of altered riparian vegetation in three southeast Alaskan streams. Water Research. 23: 965-974. (C)

Electronic abstract: First approximation production-response models to riparian vegetation alteration for low-order southeast Alaskan streams are presented. The models reflect negative and positive production responses with respect to estimated maximum production values (kcal). Using the models we predict the response of autochthonous of allochthonous production, benthic and terrestrial macroinvertebrate production, and potential salmonid tissue elaboration to variation in riparian cover, riparian composition and stream nutrients. Higher amounts of net usable allochthonous input are predicted with increasing riparian cover and percentage deciduous composition. Autochthonous production and net usable allochthonous production form the primary energy base of the stream ecosystem and are linked via energy transfer coefficients to higher trophic levels, e.g., benthic macroinvertebrate (BMI) production. Like the energy transfer coefficients derived for autochthonous and allochthonous production, the terrestrial invertebrate and salmonid production estimates are first approximations and require validation. These models provide resource managers with criteria to assess probable consequences of different riparian management strategies on fisheries resources in S.E. Alaska.

30) Edgington, J. 1976. Study of land use - salmon problems and planning in southeastern Alaska. Alaska Department of Fish Game, Compliance Report No. 5-31-R. (B)

Electronic abstract: During the period 1973-1976 detailed stream inventories have been completed for Southeastern Alaska salmon Districts 2 and 4 and published in Technical Report No 23. A total of 438 streams have been surveyed and accounts for a total of 3,119,433 m^2 of available spawning gravel. The effects of logging study of Kadashan Creek has established the pre-logging data base describing the average pink salmon escapements as {approx} 53,300 for the even-yr cycle and {approx} 44,200 for the odd-yr cycle. Chum salmon have averaged 16,700 escapements. Fry production and survival have been greatest in the intertidal sample area although other sample areas had high values also. Gravel particles < 0.833 mm diam have fluctuated at approx the 8% level of a mix of other gravel sizes. All sample areas show normal levels of intra-gravel dissolved oxygen. The project awaits the logging phase for continued sampling

31) Edgington, J.R. 1984. Some observations of fine sediment in gravels of five undisturbed watersheds in southeast Alaska. 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 109-114. (B, I)

Author abstract: Analysis of gravel samples is reported for five streams in southeast Alaska. A 10-cm diameter cylinder sampler was used, with sieve analysis presented as percent fines, by weight. No consistency was apparent in the levels of fines, which was less than 0.833 mm, from stream to stream. The monitoring standard of percent of fines less than 0.833 mm detected wide variations in fines, and demonstrated long-term trends in the Kadashan River. The highest percentage of fines was approximately 13 percent for three streams.

Increased escapement goals are advocated for streams suspected of having increased amounts of fines.

32) Elliot, S.T. 1986. Reduction of a Dolly Varden population and macrobenthos after removal of logging debris. Transactions of the American Fisheries Society. 115: 392-400. (C, D)

Electronic abstract: Logging debris resident for five or more years in small streams of southeastern Alaska is frequently removed to improve salmonid habitat. This practice was evaluated for its effects on juvenile anadromous Dolly Varden *Salvelinus malma* and macrobenthos populations in a small spring-fed stream during 1973-1981. Debris, consisting of limbs, needles, and fragmented logs, was removed by hand from the entire stream in July 1976. The surface area, number, and size of pools were reduced thereafter, and the water velocity increased. Macrobenthos density and invertebrate drift decreased 60-90% immediately after debris removal but returned to pretreatment levels in 1977. The Dolly Varden population decreased from 900 to less than 100 fish by 1978 and then fluctuated sharply between late 1978 and 1981. Removal of old logging debris does not improve habitat and can result in smaller rearing populations. Old debris should not be removed unless a block to migrating adult spawners or impairment of water quality can be demonstrated.

33) Estep, M.A., and R.L. Beschta. 1985. Transport of bedload sediment and channel morphology of a southeast Alaska stream. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-430. 15pp. (A, D, G, I)

Author abstract: During 1980-81, transport of bedload sediment and channel morphology were determined at Trap Bay Creek, a third-order stream that drains a 13.5-square kilometer watershed on Chichagof Island in southeast Alaska. Bedload sediment was sampled for 10 storms: peak flows ranged from 0.6 to 19.0 cubic meters per second, and transport rated ranged from 4 to 4400 kilograms per hour. Peak transport rates typically occurred during peak streamflow. Transport of bedload sediment at a riffle over 1600 meters upstream from the mouth of the watershed was greater for most storm events than that measured at another riffle 22 meters downstream. Transport was greatest at the downstream riffle, however, during the most severe storm of the season and during another storm 1 week later. Both magnitude of storm and availability of sediment appeared to determine the transport of bedload sediment in Trap Bay Creek. Regression relationships were developed between streamflow (independent variable), several transport variables, and particle sizes in two diameter classes (D_{50} and D_{90}). Analysis revealed that total bedload discharge was positively correlated with streamflow; transport of either diameter class, however, had no consistent relationship with streamflow from one storm to the next. Relationships between particulate organic matter and streamflow were also highly variable from storm to storm. Observations indicated that large organic debris, especially fallen trees, played a major role in determining channel morphology; tidal action was an important factor affecting channel characteristics in the lower 1300 meters of the channel.

34) Fish Habitat Analysis Team. 1994. Appendix C: An evaluation of the effectiveness of current procedures for protecting anadromous fish habitat on the Tongass National Forest. In: Report to Congress: Anadromous Fish Habitat Assessment (January 1995). USDA Forest Service, Pacific Northwest Research Station, Alaska Region, R10-MB-279. 63pp. plus Appendices (A, B, D, F, I, J)

Compiler abstract: The Fish Habitat Analysis Team (FHAT) used three interrelated investigations to respond to a Congressional request to study the effectiveness of current procedures in protecting fish habitat on the Tongass National Forest:

1. Assessment of existing literature and data (published and unpublished) related to forest management effects on fish in southeast Alaska;
2. Convening of a group of experts in watershed science and fish habitat that examined a group of managed watersheds and determined the effectiveness of current management practices on protecting fish habitat; and
3. Analyses of a pilot project of three watersheds representing a range of management conditions on the Tongass.

The literature review resulted in 1,542 citations related to land management effects on anadromous fish habitats. No studies directly evaluated BMPs as practiced on the Tongass National Forest. Studies in landscapes similar to southeast Alaska, however, demonstrated that salmonid habitat declined when >25% of a watershed was harvested.

The watershed and fish habitat experts determined that under current management practices, two watersheds were at a low risk of experiencing adverse changes to fish habitat and water quality, five watersheds were at moderately low risk, and one watershed was at moderate risk. Future fish habitat risk was rated moderate or moderately high because of an expectation of continued timber harvest and road building. The experts expressed concerns regarding some buffers that were too narrow, streams without buffers, timber harvest on unstable slopes, and road-related problems.

The analyses of the pilot watershed project resulted in the determination that existing fish habitat is in relatively good condition in the two watersheds with the least amount of timber harvest activity (5-6%). The third watershed with 15% timber harvest may be an exception to this conclusion.

The overall conclusion of the FHAT was that current BMPs, although an improvement from previous procedures, are not entirely effective at protecting fish habitat over the long term.

35) Flory, E.A., and A.M. Milner. 1999. Influence of riparian vegetation on invertebrate assemblages in a recently formed stream in Glacier Bay National Park, Alaska. Journal of the North American Benthological Society. 18: 261-273. (C)

Electronic abstract: Influence of the development of riparian vegetation on benthic invertebrate assemblages was analyzed in a recently formed stream in southeast Alaska. Several features of riparian interaction were documented: 1) invertebrate use of willow catkins entering streams in summer, 2) invertebrate use of submerged alder roots as a substrate for attachment and as a source of building material for caddisfly cases, and 3) retention of leaf litter by salmon carcasses. The development of riparian vegetation markedly influenced colonization of the stream by certain invertebrate taxa and thereby played an important role in the successional sequence of macroinvertebrates and overall assemblage development in this new stream.

36) Flory, E.A., and A.M. Milner. 2000. Macroinvertebrate community sucession in Wolf Point Creek, Glacier Bay National Park, Alaska. Freshwater Biology. 44: 465-480. (C)

Author abstract: Macroinvertebrate community development in Wolf Point Creek in Glacier Bay National Park, Alaska formed by ice recession was investigated from 1991 to 1994 as part of a long-term study of colonization now exceeding 20 years. Chironomidae, the first taxon to colonize the stream, still dominated the community comprising 75–95% by number, but species succession was apparent. 2. Species richness in August increased from five species in 1978 to 11 in 1991 and 16 in 1994. 3. *Diamesa* species, abundant in 1978 at densities exceeding 2 750 m^{-2}, were not collected in 1994, while *Pagastia partica* dominated the community with densities exceeding 10 000 m^{-2}. 4. Sixteen taxa, never previously collected, colonized the stream between 1991 and 1994 including representatives of Coleoptera, Muscidae, Trichoptera, and the first noninsect taxon, Oligochaeta. Colonization by new taxa was associated with an increase in summer water temperature and the development of riparian vegetation. 5. Inter-specific competition is suggested as a possible factor in species succession and is incorporated into a taxa richness model of community development in postglacial streams incorporating stable and unstable channels.

37) Gende, S.M., T.P. Quinn, M.F. Willson, R. Heintz, and T.M. Scott. 2004. Magnitude and fate of salmon-derived nutrients and energy in a coastal stream ecosystem. Journal of Freshwater Ecology. 19: 149-160. (C, E)

Electronic abstract: We quantified the energy and mineral (nitrogen, phosphorous) composition of live pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*), their eggs, and carcasses, and tracked the fate of chum salmon spawning in a small Alaskan coastal stream. On average, salmon entered streams with 5.3 $kJ \cdot g^{-1}$, 3.3% N, 0.48% P. Much of the energy in female salmon was stored in the gametes because the gonads were both large (20% of their wet body mass) and high in energy density (11 kJ/g). Carcasses following senescent death had lower mass-specific energy and N (but not P) compared to fish at stream entrance. Bears removed nearly 50% of the salmon-derived nutrients and energy from the stream by capturing salmon and dragging the carcasses from the stream. Much of the salmon biomass was made available to riparian scavengers because bears partially consumed the fish. Nutrients bound in salmon tissue at senescent death were quickly exported to the estuary after only a few days because of periodic high flows and low rates of scavenging by bears.

38) Gillilan, S.E. 1989. Storage dynamics of fine woody debris for two low-order coastal streams in southeast Alaska. M.S. Thesis, Oregon State University, Corvallis. (C, D)

Author abstract: The characteristics and associated storage dynamics of approximately 2000 pieces of fine woody debris (FWD; 2.5 cm < diameter < 10 cm and 0.3 m < length < 10 m) was evaluated over a three-year period in two undisturbed salmonid nursery streams in southeast Alaska. To index a given reach propensity to capture and store FWD over time, 100 survey stakes (diameter = 2.9 cm, length = 44 cm) were introduced at one-year intervals to the head of four reaches with distinct coarse woody debris (CWD; diameter > 10 cm, length > 1 m) loadings, and their downstream dispersal monitored.

Between 1987 and 1989, storage of FWD was temporally and spatially variable and not suggestive of steady-state conditions. In the 1987-1988 stormflow period, the total resident FWD volume (cm^3 per meter of reach) declined 43%. This was followed by a resident volume increase of 9% in the 1988-1989 period. These changes in FWD storage occurred despite maximum peak flows which differed between periods by only 10%. These annual changes in FWD storage indicate that factors and processes in addition to magnitude of peak flow were important in FWD storage dynamics. Factors important in describing the observed storage fluctuations might include the effects of an unusually low peak flow regime (20% of nine-year average) in the year prior to the study's commencement, as well as variable rates of FWD recruitment from the riparian environment.

The majority of FWD was shorter (66-102 cm) than bankfull width (3.8-5.6 m), approximately 4.7 cm in diameter, geometrically simple in form, and in moderate to advanced states of decay. Shorter pieces were generally entrained more frequently than longer pieces, resulting in selective retention of longer pieces through time. The data strongly suggest FWD loadings are positively correlated with the amount of CWD in the reach.

Retention of stakes was generally highest in a reach with high CWD loading (0.47 m^3/m), intermediate in two reaches with moderate CWD loading (0.13 m^3/m and 0.11 m^3/m), and lowest in a reach with low CWD loading (0.0082 m^3/m). Distinct spatial and temporal stake dispersal patterns were noted between reaches. The retention of stakes declined most dramatically during the first stormflow (1.31 m^3/m) following their introduction, while succeeding storms of equal or greater magnitude had less of an effect.

39) Glass, R.L., and T.P. Brabets. 1988. Summary of water resources data for the Girdwood-Alyeska area, Alaska. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Open-File Report 87-678. 24pp. (G, I)

Electronic abstract: Surface water, groundwater and water quality data for the Girdwood-Alyeska area are presented in graphs, tables, and maps. Surface water data include streamflow measurements and water quality analyses from three streams. Groundwater data include descriptions of 106 wells, with lithologic and water quality data from selected wells. The report also contains a map depicting the geology of the area.

40) Gomi, T., R.C. Sidle, and D.N. Swanston. 2004. Hydrogeomorphic linkages of sediment transport in headwater streams, Maybeso Experimental Forest, southeast Alaska. Hydrological Processes. 18: 667-683. (B, D, F, I)

Author abstract: Hydrogeomorphic linkages related to sediment transport in headwater streams following basin wide clear-cut logging on Prince of Wales Island, southeast Alaska, were investigated. Landslides and debris flows transported sediment and woody debris in headwater tributaries in 1961, 1979, and 1993. Widespread landsliding in 1961 and 1993 was triggered by rainstorms with recurrence intervals (24 h precipitation) of 7.0 years and 4.2 years respectively. Occurrence, distribution, and downstream effects of these mass movements were controlled by landform characteristics such as channel gradient and valley configuration. Landslides and channelized debris flows created exposed bedrock reaches, log jams, fans, and abandoned channels. The terminus of the deposits did not enter main channels because debris flows spread and thinned on the unconfined bottom of the U-shaped glaciated valley. Chronic sediment input to channels included surface erosion of exposed till (rain splash, sheet erosion, and freeze-thaw action) and bank failures. Bedload sediment transport in a channel impacted by 1993 landslides and debris flows was two to ten times greater and relatively finer compared with bedload transport in a young alder riparian channel that had last experienced a landslide and debris flow in 1961. Sediment transport and storage were influenced by regeneration of riparian vegetation, storage behind recruited woody debris, development of a streambed armour layer, and the decoupling of hillslopes and channels. Both spatial and temporal variations of sediment movement and riparian condition are important factors in understanding material transport within headwaters and through channel networks.

41) Gomi, T., R.C. Sidle, M.D. Bryant, and R.D. Woodsmith. 2001. The characteristics of woody debris and sediment distribution in headwater streams, southeastern Alaska. Canadian Journal of Forest Research. 31: 1386-1399. (B, C, D)

Author abstract: Large woody debris (LWD), fine woody debris (FWD), fine organic debris (FOD), and sediment deposition were measured in 15 steep headwater streams with five management and disturbance regimes. Clear-cut channels logged in 1995 contained large accumulations of logging residue that initially provided sites for sediment storage. Half of the LWD in clear-cut channels was recruited during and immediately after logging. Woody debris from logging activities remains in young growth conifer channels 37 years after logging. Numbers of LWD in clear-cut and young conifer channels were significantly higher than in old-growth channels, although numbers of FWD pieces were not significantly different because of higher recruitment from old-growth stands. Channels that experienced recent (1979 and (or) 1993) and earlier (1961 and (or) 1979) scour and runout of landslides and debris flows contained less LWD and FWD, although large volumes of LWD and FWD were found in deposition zones. The volumes of sediment stored in young alder and recent landslide channels were higher than in the other channels. Because of the recruitment of LWD and FWD from young alder stands, the ratio of sediment stored behind woody debris to total sediment volume was higher in young alder channels compared with recent landslide channels. Numbers of LWD and FWD pieces in all streams were significantly correlated with the volumes of sediment stored behind woody debris. Timber harvesting and soil mass movement influence the recruitment, distribution, and accumulation of woody debris in headwater streams; this modifies sediment storage and transport in headwater channels.

42) Gomi, T., R.C. Sidle, R.D. Woodsmith, and M.D. Bryant. 2003. Characteristics of channel steps and reach morphology in headwater streams, southeast Alaska. Geomorphology. 51: 225-242. (A, D)

Author abstract: The effect of timber harvesting and mass movement on channel steps and reach morphology was examined in 16 headwater streams of SE Alaska. Channel steps formed by woody debris and boulders are significant channel units in headwater streams. Numbers, intervals, and heights of steps did not differ among management and disturbance regimes. A negative exponential relationship between channel gradient and mean length of step intervals was observed in the fluvial reaches (<0.25 unit gradient) of recent landslide and old-growth channels. No such relationship was found in upper reaches (≥0.25 gradient) where colluvial processes dominated. Woody debris and sediment recruitment from regenerating riparian stands may have obscured any strong relationship between step geometry and channel gradient in young alder, young conifer, and recent clear-cut channels. Channel reaches are described as pool–riffles, step–pools, step–steps, cascades, rapids, and bedrock. Geometry of channel steps principally characterized channel reach types. We infer that fluvial processes dominated in pool–riffle and step–pool reaches, while colluvial processes dominated in bedrock reaches. Step–step, rapids, and cascade reaches occurred in channels dominated by both fluvial processes and

colluvial processes. Step–step reaches were transitional from cascades (upstream) to step–pool reaches (downstream). Woody debris recruited from riparian corridors and logging activities formed steps and then sequentially might modify channel reach types from step–pools to step–steps. Scour, runout, and deposition of sediment and woody debris from landslides and debris flows modified the distribution of reach types (bedrock, cascade, and step–pool) and the structure of steps within reaches.

43) Grotefendt, R.A. 1996. A pilot study utilizing low-altitude fixed base aerial photography for monitoring riparian and channel habitat conditions. Report written by Forest Consulting and Photogrammetry, North Bend, Washington. Written for Sealaska Corporation, Juneau, Alaska. 15pp. plus maps and photo plates. (A, D, F)

Compiler abstract: The purpose of this pilot study was to investigate the potential of low altitude aerial photography as a means to enhance the monitoring of riparian buffers and stream channel habitats on Sealaska Corporation lands in southeast Alaska. Monitoring of riparian habitats is normally conducted through ground surveys. However, obtaining large sample sizes and quantifying the complexity of riparian and channel habitats is difficult with ground surveys. Therefore, in 1995, low altitude aerial photographs (420 to 750 ft. flying heights) were obtained for about 3 miles of Cabin Creek, Prince of Wales Island, Alaska and for 2 miles of Sandstone Creek, Canyon River, and Wildcat Creek in Washington. The imagery was expected to: 1) provide multiple measurements of many riparian attributes, 2) document stream changes for historical review, 3) obtain detailed photographs to show the effectiveness of land management practices, and 4) provide the ability to repeat the measurements that were taken. Thirty riparian and stream characteristics were investigated using low altitude photos, including (but not all inclusive): diameter of downed trees, heights of standing trees, cut bank erosion volume, down tree count, down tree decay class, geomorphic zones, channel gradient (%), treefall direction, canopy closure (%), channel width, stem map, sand bar map, channel bank map, log debris position map. Results showed that photo measurements were accurate at quantifying many riparian characteristics, however, overhanging vegetation can obscure some dimensions. Therefore, low altitude photography may be used in conjunction with ground survey techniques to more fully quantify riparian area characteristics.

44) Halupka, K.C., M.F. Willson, M.D. Bryant, F.H. Everest, and A.J. Gharrett. 2003. Conservation of population diversity of Pacific salmon in southeast Alaska. North American Journal of Fisheries Management. 23: 1057-1086. (K)

Author abstract: We analyzed intraspecific variation in selected biological characteristics of five species of Pacific salmon *Oncorhynchus* spp. in southeast Alaska and adjacent areas of Canada with a particular interest in describing the variation among populations and suggesting conservation priorities to preserve existing variation. We identified traits that showed high levels of among-population variation, evaluated the interspecific consistency of variation patterns, and noted the relationship of these traits to potential adaptive variation. In addition, we graphically identified populations with distinctive phenotypic and demographic characteristics as outliers from the distribution of mean values of traits taken from populations throughout the region. We also reviewed allozyme surveys to identify populations that differed in terms of the geographic clustering patterns of allele frequencies. Approximately 9,000 salmon populations occur in the study area, and sufficient data were available from 2,062 (23%) of them to analyze at least one characteristic. We identified 47 populations represented by adequate data sets that have distinctive characteristics. An additional 35 populations, represented by limited samples or unusual nominal traits, may be regionally distinctive. Of the 47 adequately sampled, distinctive populations, 22 met our criteria for conservation consideration: (1) high potential for adaptive variation (including distinctive run timing), (2) a distinctive trait combined with high spawner abundance or allozyme frequencies that diverge from geographic clustering patterns, and (3) more than one distinctive characteristic or freshwater habitat shared with other distinctive populations. Freshwater habitats for 6 of those 22 populations are located in watersheds that do not have restrictive land use designations and warrant the highest conservation priority.

45) **Harding, R.D. 1993. Abundance, size, habitat utilization, and intrastream movement of juvenile coho salmon in a small southeast Alaska stream. M.S. Thesis, University of Alaska, Fairbanks. 109pp. (A, D)**

Author abstract: Aquatic habitat was measured, and juvenile coho salmon *Oncorhynchus kisutch* abundance and intrastream migrations were monitored in Kake Bake Creek, Alaska, between 1985 and 1986. Fry densities averaged 0.88, 0.33, and 0.11 fish/m^2 during August, November, and March, respectively; parr densities averaged 0.15, 0.09, and 0.05 fish/m^2, during August, November, and March respectively. Fry were distributed evenly between riffle, glide, and pool habitat types during August, but not during November or March. Parr were distributed evenly in riffle and glide habitats during August, November and March. Stream areas containing pools and large woody debris tended to have higher coho densities; habitat was generally a significant predictor of juvenile abundance despite low R^2 values.

Fall immigrants totaled 1,434 coho, with 764 immigrating into beaver ponds. Fall immigrants were bright silver in color and several had sea-lice *Calugus spp.* attached near their anal fins. Between April 1 and June 2, 1986, 586 coho smolts emigrated from Kake Bake Creek; 172 had been fall immigrants.

46) **Harris, A.S., and W.A. Farr. 1974. The forest ecosystem of southeast Alaska. 7. Forest ecology and timber management. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-25. 109pp. (K)**

Author abstract: Large-scale use of the timber resource of southeast Alaska began in 1953 after long efforts to establish a timber industry. Development and present status of the industry and present management of the timber resource are summarized, stressing the biological basis for timber management activities in southeast Alaska today. Ecological and silvicultural considerations related to timber harvest, reforestation, and stand development are discussed.

Published and unpublished information are brought together. Current management practices are discussed as a basis for a better understanding of how this information can be helpful in managing the timber resource and to point out where research is needed.

47) **Heifetz, J., M.L. Murphy, and K.V. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. North American Journal of Fisheries Management. 6: 52-58. (A, D)**

Electronic abstract: Effects of logging on preferred winter habitats of juvenile salmonids in southeastern Alaskan streams were assessed by comparing the area of preferred winter habitat in 54 reaches of 18 streams. Three types of streams were sampled at each of six locations: a stream in a mature, undisturbed forest; a stream in a clear-cut area but logged on at least one bank; and a stream in a clear-cut area with strips of forest (buffer strips) along the stream bank. To identify preferred winter habitats, we classified stream areas in 12 of 18 streams into discrete habitat types and compared the density of salmonids within these habitat types with average density of the entire reach. Most wintering Coho salmon (*Oncorhynchus kisutch*), Dolly Varden (*Salvelinus malma*), and steelhead (*Salmo gairdneri*) occupied deep pools with cover (i.e., upturned tree roots, accumulations of logs, and cobble substrate). Riffles, glides, and pools without cover were not used. Seventy-three percent of all pools were formed by large organic debris. Reaches in clear-cut areas without buffer strips had significantly less area of pool habitat than old-growth reaches. Buffer strips protected winter habitat of juvenile salmonids by maintaining pool area and cover within pools. In some cases, blowdown from buffer strips added large organic debris to the stream and increased the cover within pools.

48) Hennon, P., M. Wipfli, R. Deal, A. Johnson, T. De Santo, M. Schultz, T. Hanley, E. Orlikowska, G. Takashi, M. Bryant, and R. Edwards. 2002. Mixed alder-conifer forests: Managing upland ecosystems in southeast Alaska for wood products, wildlife, and fish. In: Congruent Management of Multiple Resources: Proceedings From the Wood Compatibility Initiative Workshop, 4-7 December 2001, Stevenson, Washington. A.C. Johnson, R.W. Haynes, and R. A. Monserud, Editors. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-563. Pages 51-58. (C, D)

Author abstract: Historically, red alder (*Alnus rubra*) Bong. has been viewed as an undesirable tree species and has been actively removed from managed forests. Several recent studies suggest that the presence of red alder may help alleviate some of the problems associated with fish and wildlife habitat that develop in the dense conifer-dominated young-growth forests that typically grow after clearcutting. Our study uses an integrated approach to evaluate to what extent red alder may influence trophic linkages and processes in managed young-growth ecosystems. Key components of this study include how logging and natural disturbance favor the regeneration of alder and how different mixtures of alder are associated with timber productivity, woody debris recruitment, terrestrial and aquatic invertebrate abundance, and fish and wildlife habitat. By using one independent variable in all components of this study (i.e., amount of red alder), we simultaneously contrasted many possible responses across this gradient to develop a general response model. Managers may use this model to choose a desirable level of red alder in a particular landscape to meet simple or multiple resource objectives. Both compatibility and tradeoffs among resources will be clearly evident. Active management (i.e., thinning with species bias or planting) can be used to achieve different amounts of alder in managed forests.

49) Hetrick, N.J., M.A. Brusven, W.R. Meehan, and T.C. Bjornn. 1998. Changes in solar input, water temperature, periphyton accumulation, and allochthonous input and storage after canopy removal along two small salmon streams in southeast Alaska. Transactions of the American Fisheries Society. 127: 859-875. (C, E, H, J)

Electronic abstract: Changes in solar radiation, water temperature, periphyton accumulation, and allochthonous inputs and storage were measured after we removed patches of deciduous, second-growth riparian vegetation bordering two small streams in southeast Alaska that produce Coho salmon *Oncorhynchus kisutch*. Solar radiation and leaf litter input were measured at the water surface at random locations dispersed through six alternating closed- and open-canopy stream sections. Water temperature, periphyton, and stored organic samples were collected near the downstream end of each section. Solar radiation intensity was measured with digital daylight integrators and pyronometers, periphyton biomass and chlorophyll a were measured on red clay tile substrates, allochthonous input was measured with leaf litter baskets, and benthic organic matter was measured with a Hess sampler. Average intensity of solar radiation that reached the water surface of open-canopy sections was significantly higher than in closed-canopy sections of two streams measured during daylight hours in summer 1988 and of one stream measured day and night in summer 1989.

50) Hetrick, N.J., M.A. Brusven, T.C. Bjornn, R.M. Keith, and W.R. Meehan. 1998. Effects of canopy removal on invertebrates and diet of juvenile Coho salmon in a small stream in southeast Alaska. Transactions of the American Fisheries Society. 127: 876-888. (C)

Electronic abstract: We assessed changes in availability and consumption of invertebrates by juvenile Coho salmon *Oncorhynchus kisutch* in a small stream in southeast Alaska where patches of dense second-growth riparian vegetation bordering the stream had been removed. Benthic invertebrate populations were assessed during summer 1988 and 1989 with a Hess sampler. Aerial invertebrates were sampled during summer 1989 with wire-mesh sticky traps hung just above the water surface and with floating clear-plastic pan traps. Invertebrate drift was assessed during summer 1989 with nets placed at the downstream end of closed- and open-canopy stream sections. Diets of age-0 and age-1 Coho salmon were sampled by flushing stomach contents of fish collected from closed- and open-canopy stream sections. Abundance and biomass of benthic invertebrates were larger in open- than in closed-canopy stream sections and were primarily Dipterans, Ephemeropterans, and Plecopterans. More insects were caught on sticky traps in open than in closed sections on two of four dates sampled, and composition of the catch was primarily dipterans (74% in both closed- and open-canopy sections).

51) Johnson, A.C., and P. Wilcock. 2002. Association between cedar decline and hillslope stability in mountainous regions of southeast Alaska. Geomorphology. 46: 129-142. (K)

Author abstract: Old-growth forests experiencing widespread decline of yellow-cedar (*Chamaecyparis nootkatensis*) in southeast Alaska have a 3.8-fold increase in the frequency of landslides. We report here on an investigation of the cause of this increased slope instability. Time since death of cedar was assessed using surveys around landslide sites. Root decay on dead trees was used to estimate the decline in the apparent soil strength provided by roots. Changes in soil hydrology were measured with 120 piezometers located in areas of healthy cedar, healthy spruce/hemlock, and sites with cedar decline. Relative influences on slope stability by changes in soil moisture and root strength were evaluated with a simple stability model. At most sites, soil depth is <0.7 m, and the loss of root strength has an important and possibly dominant influence on slope instability. In soils deeper than 1 m, changes in pore pressure have a proportionately larger influence on slope stability. Landslides appear most likely when cedar decline reaches snag class IV (approximately 50 years after tree death), when most of the cedar root strength is lost and root strength from secondary growth has yet to develop.

52) Johnson, A.C., and R.T. Edwards. 2002. Physical and chemical processes in headwater channels with red alder. In: Congruent Management of Multiple Resources: Proceedings From the Wood Compatibility Initiative Workshop, 4-7 December 2001, Stevenson, Washington. A.C. Johnson, R.W. Haynes, and R. A. Monserud, Editors. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-563. Pages 101-108. (E)

Author abstract: We investigated links between physical disturbance processes, vegetation type (alder or conifer), and stream nitrate concentrations in headwater streams in young-growth stands and old-growth forests within mountainous terrain in southeast Alaska. Alder coverage in upland headwater zones (areas with slopes > 15^{o}, or 27%) associated with landsliding was more extensive within young-growth stands than within old-growth forests. The highest nitrate concentrations occurred in streams within alder dominated young-growth forest. However, some streams with high alder coverage had low nitrate concentrations. These streams were larger and originated within alpine zones or ridge tops, suggesting that landform and source area may be important factors regulating nutrient concentrations. An understanding of the relationship among disturbance patterns, tree species establishment, and nutrient cycling may help managers better predict the effect of harvest practices on stream productivity.

53) Johnson, A.C., D.N. Swanston, and K.E. McGee. 2000. Landslide initiation, runout, and deposition within clearcuts and old-growth forests of Alaska. Journal of the American Water Resources Association. 36: 17-30. (K)

Electronic abstract: More than 300 landslides and debris flows were triggered by an October 1993 storm on Prince of Wales Island, southeast Alaska. Initiation, runout, and deposition patterns of landslides that occurred within clearcuts, second-growth, and old-growth forests were examined. Blowdown and snags, associated with cedar decline and "normal" rates of mortality, were found adjacent to at least 75 percent of all failures regardless of land use. Nearly 50 percent of the landslides within clearcuts occurred within one year following timber harvest; more than 70 percent of these sites had hydrophytic vegetation directly above failures. In following the runout paths of failures, significantly more erosion per unit area occurred within clearcuts than in old-growth forests on slopes with gradients from 9 to 28 degree (16 to 54 percent). Runout length, controlled by hillslope position within deglaciated valleys, was typically longer in old-growth forests than in second growth and clearcuts (median values were 334, 201, and 153 m, respectively). Most landslides and debris flows deposited in first- and second-order channels before reaching the main stem channels used by anadromous fish. Slide deposits in old-growth forests were composed of a higher proportion of woody debris than deposits derived from slides in second growth or clearcuts.

54) Johnson, S.W., and J. Heifetz. 1985. Methods for assessing effects of timber harvest on small streams. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest and Alaska Fisheries Center, Auke Bay Laboratory, Alaska, NOAA Technical Memorandum ABFL/NMFS. (A, C, E, G, I)

Electronic abstract: The methods used by the Northwest and Alaska Fisheries Center's Auke Bay Laboratory in assessing the effects of clear-cut logging on salmonid habitat and the effectiveness of buffer strips in protecting fish habitat during and after logging are described in detail. The methods have been used by the laboratory since 1982 to study fish populations and habitat in three different categories of streams in southeastern Alaska. The methods described include measurements of fish, periphyton, benthos, preferred fish habitats, and stream physical characteristics, such as discharge gradient, substrate, and water quality.

55) Johnson, S.W., J. Heifetz, and K.V. Koski. 1986. Effects of logging on the abundance and seasonal distribution of juvenile steelhead in some southeastern Alaska streams. North American Journal of Fisheries. 6: 532-537. (K)

Electronic abstract: Eighteen streams in six locations in Southeastern Alaska were examined for the effects of logging on juvenile steelhead (*Salmo gairdneri*) populations. Three types of streams were examined at each location: a stream in undisturbed old-growth forest; a stream in a clear-cut area with strips of forest (buffer strips) along the stream bank; and a stream in a clear-cut area logged on at least one bank. Within each stream type, three reaches were sampled. Few juvenile steelhead were found in reaches where juvenile cutthroat trout (*Salmo clarki*) were present, and no juvenile steelhead were found in streams with a low-flow discharge ($<0.06\ m^3/s$). Only two study sites, Prince of Wales Island and Mitkof Island, had juvenile steelhead in all three stream types. Fry (age 0) and parr (age 1 and older) were sampled in summer and winter at the Prince of Wales Island site; parr were sampled in summer at the Mitkof Island site. Logging appeared to affect the growth of steelhead fry and the abundance and distribution of both fry and parr. On Prince of Wales Island, fry were more abundant and larger in the clear-cut reaches than in the old-growth or buffered reaches. Parr density in summer was highest in the clear-cut reaches at both sites but, by winter, had decreased 91% in the clear-cut reaches and had increased 100 and 400%, respectively, in the old-growth and buffered reaches. Parr were migrating during fall and winter; therefore, the effects of logging on their growth could not be assessed.

56) Jones, S.H., R.J. Madison, and C. Zenone. 1978. Water resources of the Kodiak-Shelikof Subregion, south-central Alaska. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Hydrologic Investigations Atlas HA-612. (I)

Electronic abstract: Hydrologic data for the Kodiak-Shelikof subregion of south-central Alaska are summarized to provide a basis for planning water resources development, identifying water problems and evaluating existing water quality and availability. Average annual precipitation, measured at a few coastal locations in this maritime climatic zone, ranges from 23 to 127 inches. Mean annual runoff for the Kodiak Island group ranges from 4 to 8 cfs/sq mi. A maximum instantaneous runoff of 457 cfs/sq mi has been determined from a small basin on Kodiak Island. Lowest measured stream discharges range from no flow to 0.91 cfs/sq mi. Surface water is the primary source of water supplies for the city of Kodiak and other communities. The geology of the subregion is characterized by metamorphosed sedimentary and volcanic rocks with only a thin mantle of unconsolidated material. A few small, alluvium-filled coastal valleys offer the most favorable conditions for ground-water development, but moderate yields (50-100 gal/min) have been obtained from wells in fractured bedrock. Water in streams and lakes generally has a dissolved-solids concentration less than 60 mg/L, and the water varies from a calcium-bicarbonate type to a sodium-chloride type. The chemical composition of ground waters has a dilute calcium-bicarbonate type in unconsolidated materials and a sodium-bicarbonate type in bedrock. The dissolved solids in the groundwater ranges from 170 to 250 mg/L.

57) Keith, R.M., T.C. Bjornn, W.R. Meehan, N.J. Hetrick, and M.A. Brusven. 1998. Response of juvenile salmonids to riparian and instream cover modifications in small streams flowing through second-growth forests of southeast Alaska. Transactions of the American Fisheries Society. 127: 889-907. (D)

Electronic abstract: We manipulated the canopy of second-growth red alder *Alnus rubra* and instream cover to assess the effects on abundance of juvenile salmonids in small streams of Prince of Wales Island, southeast Alaska, in 1988 and 1989. Sections of red alder canopy were removed to compare responses of salmonids to open- and closed-canopy sections. At the start of the study, all potential instream cover was removed from the study pools. Alder brush bundles were then placed in half the pools to test the response of juvenile salmonids to the addition of instream cover. Abundance of age-0 Coho salmon *Oncorhynchus kisutch* decreased in both open- and closed-canopy sections during both summers, but abundance decreased at a higher rate in closed-canopy sections. More age-0 Dolly Varden *Salvelinus malma* were found in open-canopy sections than in closed-canopy during both summers. Numbers of age-1 and older Coho salmon and Dolly Varden were relatively constant during both summers, and there was no significant difference in abundance detected between open- and closed-canopy sections. Abundance of age-0 Coho salmon decreased in pools with and without additional instream cover during both summers. Abundance of age-1 and older Coho salmon and age-0 Dolly Varden did not differ significantly in pools with or without added cover during either summer. Abundance of age-1 and older Dolly Varden was higher in pools with added instream cover than in pools without cover during both summers. Age-0 Coho salmon decreased in abundance throughout the summer in both years. Emigration was measured in 1989 and accounted for most of the decrease in abundance. Age-0 Coho salmon emigrants were significantly smaller than age-0 Coho salmon that remained in the stream

58) Kessler, S.J., S.J. Paustian, and S. Russell. 1989. Modeling fish habitat and stream class using channel classifications. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Page 101. (A)

Author abstract: Channel type inventories of Tongass National Forest streams are used in a number of ways in the Revision of the Tongass Land Management Plan and other planning and implementation activities across the Forest. For the fish resource, three major uses of the channel type inventories are employed in conjunction with the ARC/INFO Geographical Information system (GIS). These uses are: 1) to model the quantity of timber available from riparian areas as

a result of application of different land management prescriptions, 2) to model the fish habitat capability of Forest streams, and to predict effects on the fish resource resulting from different land management allocations, and 3) to predict stream class, or display the extent of anadromous and resident fish habitat. We presented detailed information for the second two uses, while Wilsona and Kessler addressed the quantity of timber available in riparian areas in their presentation.

59) Kirchhofer, D.A. 1984. A stream ecosystem in an old-growth forest in southeast Alaska. Part III: Standing crop and drift of invertebrates in Porcupine Creek. 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 71-79. (C)

Author abstract: Abundance and composition of benthos and drift in Porcupine Creek, a small undisturbed stream in southeast Alaska, was sampled over a period of two years. Abundance of aquatic insects varied greatly from year to year. The density (number per sq m) was three to six times greater in 1978 than in 1977, ranging from a low of 307 insects/m^2 to a high of 48,418 insects/m^2. For freshwater reaches of Porcupine Creek, four taxa, two mayfly genera, *Baetis* and *Cinygmula*, one stonefly taxa, *Alloperla* complex, and the diteran family Chironomidae made up 64-81 percent of all insects in the benthos. The stream/estuary ecotone of Porcupine Creek, which as influenced by tides, had a greater density of macroinvertebrates than the freshwater reaches. Isopods and amphipods accounted for 93 percent of the benthos in the ecotone.

Drift was composed of the same major taxa as the benthos, but in different proportions. For the third-order section, two taxa, *Baetis* and Chironomidae, made up 66-98 percent of the total drift. *Baetis* was a greater percentage of drift than benthos at both second- and third-order reaches, whereas *Alloperla* made up a greater percentage of benthos than drift and did not drift in any numbers except during spring emergence.

60) Kirkpatrick, B., T.C. Shirley, and C.E. O'Clair. 1998. Deep-water bark accumulation and benthos richness at log transfer storage facilities. Alaska Fishery Research Bulletin. 5: 103-115. (K)

Author abstract: A small, manned submersible was used to determine the extent of bark accumulation and its effects on the epifaunal macrobenthos at depths from 20-130 m at log transfer facilities (LTFs) and log rafting facilities (LRFs) in Dora Bay, Prince of Wales Island, Alaska. Continuous videotaping from an external fixed camera was conducted along 6 transects located near LTFs and LRFs and along 3 transects in a similar, adjacent area not used as an LTF or LRF. Bark and woody debris accumulation and kinds and numbers of organisms were recorded by depth for 3 general habitat types (steep, rocky; moderate incline; cobble; flat, silty) with and without bark. Bark accumulation was found to 40-m depth on 6 dives, and to 70-m depth on 3 dives. Of 91 taxa observed during the study, most (69 species) were found on rocky, bark-free habitat; significantly reduced species richness was found in all bark-dominated habitats. Bark and debris from LTFs appeared to be displaced down slope into adjacent, deeper area; this is the first published account of bark and woody debris accumulation below 20-m depth. In suitable habitats, manned submersibles or remotely operated vehicles appear to be useful tools for monitoring bark accumulation and investigating the effects of logging facilities.

61) Kline, T.C., Jr., J.J. Goering, O.A. Mathisen, P.H. Poe, and P.L. Parker. 1990. Recycling of elements transported upstream by runs of Pacific salmon: 1. d ^{15}N and d ^{13}C evidence in Sashin Creek, southeastern Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 47: 136-144. (E)

Electronic abstract: Value of δ^{15}N and δ^{13}C (the per mil deviation from the recognized isotope standard) from biota of a southeastern Alaska stream (Sashin Creek) that receives an annual run of 30,000 anadromous pink salmon (*Oncorhynchus gorbuscha*) were measured to determine sources of nitrogen (N) and carbon (C). Marine-derived nitrogen (MDN) is the predominant source of N for food webs found in the lower 1,200 m of the stream which, due to a waterfall, is the only portion of the stream available to salmon returning to spawn. Comparable spawning section biota were enriched by about 5 per mil relative to the salmon-free control section, corresponding to the difference between 0 and 100% MDN in a mixing model. Food webs of resident rainbow trout (O. *mykiss*), at the outlet of one of the source lakes, Sashin Lake, have very low δ^{13}C, suggesting the importance of a respired C pool in the lake.

62) Konopacky Environmental. 1996. Fish collections in twelve unnamed and USFS-designated Class III streams on Prince of Wales Island, southeast Alaska, during late-June 1996. Annual Report – 1995, Volume 2 of 2. Konopacky Project No. 002-7 report written by Konopacky Environmental, Meridian, Idaho. Written for Ketchikan Pulp Company, Ketchikan, Alaska. Submitted to Alaska Department of Fish and Game, Juneau, Alaska. (A)

Author abstract: Konopacky Environmental staff used a Coffelt Mark X backpack electrofisher, set at 300 volts and variable amperage, to sample a 60-m long reach in each of 12 small unnamed USFS-designated Class III streams (i.e., fishless) on Prince of Wales Island, southeast Alaska, on June 25-26, 1996. Three streams were located in each of four study-defined quadrants (i.e., north, west, east, south) on the island. All streams were used in an ongoing multi-year water-air temperature/timber harvest study, funded by Ketchikan Pulp Company, on the island. A total of three Dolly Varden char *Salvelinus malma* were collected from two streams. One char (i.e., 126 mm total length [TL], 15 g live weight [LW]), was collected from a stream, located at T66S, R80E, SE1/4, in the north quadrant on the island. Two char (i.e., 97 mm TL, 7 g LW and 107 mm TL, 10 g LW) were collected from a stream, located at T71S, R80E, S02, NW1/4, in the west quadrant on the island. No fish of any species were collected in the sampled reaches of the other ten study streams. Given the small number of fish found in the two streams via the electrofishing efforts, the USFS method of labeling Class III streams appears acceptable for planning purposes associated with timber harvest.

63) Koski, K.V. 1981. Utilization of estuarine areas by salmonids in southeastern Alaska and the potential impact from logging. Estuaries. 4: 286-287. (K)

Electronic abstract: Southeastern Alaska is a complex of mountainous islands and fiords. Most of this archipelago is in the Tongass National Forest which contains the largest stand of old growth forest in the United States. Over 250,000 acres of the Tongass have been clearcut and logging is continuing at a rate of about 18,000 acres annually. Over 2,500 identified salmon streams flow from this Forest into adjacent estuaries; these ecosystems produce about 30% of the Nation's salmon resource. Physical and biological characteristics of these estuaries are variable and dependent upon adjacent watershed topography and geology.

64) Koski, K.V., and D.A. Kirchhofer. 1984. A stream ecosystem in an old-growth forest in southeast Alaska. Part IV: Food of juvenile coho salmon, *Oncorhynchus kisutch*, in relation to abundance of drift and benthos. 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 81-87. (C)

Author abstract: Stomach contents of juvenile coho salmon were collected from five study reaches in Porcupine Creek, southeast Alaska, using a flushing technique that did not injure the fish. The food consumed was compared with the apparent food availability as measured by samples of the invertebrate drift and benthos. The prey items found in the stomachs were ranked as to their relative dietary importance using the Index of Relative Importance (IRI). To determine what food was available or unavailable to coho salmon, the actual food consumed was compared with the apparent food availability using an Index of Food Selection (L). Total stomach contents were compared using a relative index of fullness. Food items with the highest values of IRI varied among all study reaches. Amphipods were the most important food in the stream / estuary ecotone, and Diptera was the dominant food in the freshwater reaches upstream. Pink salmon eggs were the most important food item in all reaches during September. Salmon eggs, amphipods, and Diptera were actively selected from the apparent availability of food, whereas Plecoptera, Ephemeroptera, and isopods were usually avoided or not available. The fullness of stomachs reflected the general abundance of food in the drift and benthos. Terrestrial insects were scarce in the diet and in the apparent food supply, possibly reflecting the low diversity of vegetation associated with old-growth forests in southeast Alaska. The stream / estuary ecotone is an important rearing habitat for coho salmon as shown by its higher density and growth as compared with areas upstream. Possible consequences of logging are discussed.

65) Koski, K.V., and M.L. Murphy. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal of Fisheries Management. 9: 427-436. (D)

Author abstract: Natural rates of input and depletion of large woody debris (LWD) in southeast Alaska streams were studied to provide a basis for managing streamside zones to maintain LWD for fish habitat after timber harvest. Debris was inventoried in a variety of stream types in undisturbed old- growth forest; 252 pieces of LWD were dated from the age of trees growing on them. Longevity of LWD was directly related to bole diameter: small LWD (10-30 cm diameter) was less than 110 years old, whereas large LWD (> 60 cm diameter) was up to 226 years old. Assuming equilibrium between input and depletion of LWD in streams in old-growth forests and exponential decay of LWD, input and depletion rates were calculated from mean age of LWD. Input and depletion rates were inversely proportional to LWD diameter and ranged from 1%/yr for large LWD in all stream types to 3%/yr for small LWD in large, high-energy, bedrock-controlled streams. A model of changes in LWD after timber harvest (which accounted for depletion of LWD and input from second-growth forest) indicated that 90 years after clear-cut logging without a stream-side buffer strip, LWD would be reduced by 70% and recovery to

prelogging levels would take more than 250 years. Because nearly all LWD is derived from within 30 m of the stream, the use of a 30-m wide, unlogged buffer strip along both sides of the stream during timber harvest should maintain LWD.

66) Landwehr, D. 1993. Soil disturbance monitoring transects: Thorne Bat Ranger District, Tongass National Forest. In: Proceedings of Watershed '91: Soil, Air, and Water Stewardship Conference, 16-17 April 1991, Juneau, Alaska. T. Brock, Editor. USDA Forest Service, Alaska Region, R10-MB-217. Page 58. (K)

Author abstract: One hundred ninety soil disturbance transects were completed in timber harvest units on the Thorne Bat Ranger District, Tongass National Forest in southeast Alaska. Mineral soil disturbance on individual transects varied from 0 to 39 percent of the transect. Average disturbance of all transects was 4.6 percent. Shovel yarding averaged slightly higher levels of disturbance, 5.1 percent, as compared to cable yarding systems which averaged 4.0 percent.

Comparisons were drawn between the Coffman Cove Administrative Area and the Thorne Bay Administrative Area. Shovel yarding on the Coffman Cove averaged 7.1 percent mineral soil disturbance whereas shovel yarding on the Thorne Bay Area averaged 3.3 percent.

Differences in mineral soil disturbance between the two administrative areas can be explained by differences in operator experience or awareness and differences in timber sale administration. Once operators on the Coffman Cove Area tried to reduce soil disturbance, conditions improved and total disturbance was reduced.

Shovel yarding appears to have the higher potential for exposing mineral soil. When done improperly, shovel yarding can result in high levels of disturbance. Standards and guidelines for overall mineral soil disturbance were met in all the units involved in the study. Three units are borderline on acceptable disturbance (i.e. Confidence intervals overlap the acceptable level). Most of the exposed [soil] in these areas resulted from rutting in shovel yarded areas and skid trails in the case of one downhill hi-lead unit.

67) Lisle, T.E. 1986. Effects of woody debris on anadromous salmonid habitat, Prince of Wales Island, southeast Alaska. North American Journal of Fisheries Management. 6: 538-550. (A, D)

Author abstract: The effects of woody debris on anadromous salmonid habitat in eight streams on Prince of Wales Island, southeast Alaska, were investigated by comparing low-gradient (1-9%) first- or second-order streams flowing through either spruce-hemlock forests or 6-10-year-old clearcuts, and by observing changes after debris was selectively removed from clear-cut reaches. Woody debris decreased the rate of shallowing as discharge decreased, thus helping to preserve living space for fish during critical low-flow periods. Debris dams were more frequent in clear-cut streams (14.9/100 m), which contained more debris, than in forested streams (4.2/100 m). As a result, total residual pool length (length when pools are filled with water but there is no flow) and length of channel with residual depth greater than 14 cm-the depth range occupied by 84% of coho salmon *(Oncorhynchus kisutch)*-were greater in clear-cut streams than in forested streams. Greater volumes of woody debris in clear-cut streams produced greater storage of fine sediment (<4-mm diameter) unless the stream gradient was sufficiently high to flush sediment from storage. One-half of the debris dams broke up or were newly formed over a

3-year period, which suggests that they usually released sediment and woody debris before the pools they formed were filled with sediment. Woody debris removal decreased debris-covered area, debris dam frequency, and hydraulic friction in some cases but, in others, these variables were unaffected or recovered within 2 years after erosion and adjustment of the streambed. No consistent differences in pool dimensions were found between treated and untreated clear-cut reaches. Comparisons of habitat in forested and clear-cut streams suggested that removing debris from clear-cut streams reduced salmonid carrying capacity. Retention and natural reformation of debris dams in cleared reaches prevented the expected deterioration of habitat. However, the removal and destabilization of existing woody debris may cause depletion of debris before riparian trees can regrow and furnish new material to the clear-cut streams.

68) Lohr, S.C., and M.D. Bryant. 1999. Biological characteristics and population status of steelhead (*Oncorhynchus mykiss*) in southeast Alaska. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-407. 20pp. (K)

Author abstract: We reviewed existing data to determine the range and distribution of steelhead (*Oncorhynchus mykiss*) in southeast Alaska, summarized biological characteristics, and determined population status of steelhead stocks. Unique or sensitive stocks that may require consideration in planning land management activities are identified within the data reviewed. Data sources were personal communications, reports, and unpublished data files of State and Federal agencies. Only eight winter-run stocks in southeast Alaska and two summer-run stocks in southwest Alaska had sufficient data to valuate biological characteristics. Age structure, sex ratio, incidence and frequency of repeat spawning, and body length were similar among winter-run stocks, and consistent with coastwide trends of increasing freshwater age and body size of steelhead stocks in the northern portion of their range. Winter-run stocks appeared to have a greater proportion of repeat spawners (kelts) than summer-run stocks, and juvenile steelhead in the summer-run stocks generally spent 1 year less in both fresh water and the ocean. Assessment of escapement trends, run timing, and stock status is hindered by lack of adequate data both in number of stocks with sufficient data and the number of years of data available. Incomplete weir counts during immigration and emigration of adult fish and low sample sizes of escapement indices, both within and among years, decrease the reliability of estimates. Although stocks with sufficient data are not at risk, small run sizes that are typical of most steelhead stocks may be more susceptible to poor land management practices and overharvest than larger stocks.

69) Lorenz, J.M., M.L. Murphy, and K.V. Koski. 1989. Classification and inventory of fish habitat in the Taku River, Alaska. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Pages 113-115. (A, G)

Author abstract: A system for classifying fish habitat in large glacial rivers was developed and used in a 1986 study of salmon in the Taku River, Alaska. Twelve distinct habitat types -- 7 within the river channel and 5 off-channel -- were identified on the valley floor (Table 1). Aerial photographs were used to differentiate habitat types by their channel geometry, hydraulic characteristics, and water source. Over 1,900 ha of fish habitat in the lower river, between the Canadian border and the river mouth (29 km), were classified by habitat type and verified with aerial and boat surveys. Random samples of fish abundance and physical characteristics, stratified by habitat type, were used to estimate fish density and habitat quality for each habitat type in the lower river. The two most abundant types (main channels and braids) were in the river channel and made up over 90% of the area. However, the most important habitats for juvenile sockeye, coho, and Chinook salmon (Table 2), those with low water velocity and easy access to main channels, made up less than 10% of the area. The total population of juvenile salmon in the lower Taku River was estimated at about one million. Juvenile salmon density in main channel habitats was similar along the entire length of the river (60 km), but species composition changed as sockeye became less abundant and chinook more abundant upstream. Sockeye salmon spawned in many habitat types, keying on specific reaches with good intragravel flow. The habitat classification system described here provided a good framework for identifying juvenile fish habitat in the Taku River and may be applicable to other large glacial rivers.

70) Martin, D.J. 1993. Fish habitat and channel conditions of nine streams in forested lands of southeast Alaska and Afognak Island. Project No. 44-005 final report written by Pentec Environmental, Inc., Edmonds, Washington. Written for Sealaska Corporation, Juneau, Alaska and the Alaska Forest Association, Ketchikan, Alaska. 37pp. plus Figures, Tables, and Appendix. (A, B, D, F, H, J)

Compiler abstract: Sealaska Corporation and the Alaska Forest Association initiated a monitoring program to determine the effectiveness of the 1990 Alaska Forest Resources and Practices Act BMPs in protecting fish habitat and water quality during and after timber harvest in southeast Alaska. The monitoring program included unharvested, currently harvested, and previously harvested watersheds. This report presents the results of stream surveys conducted on nine streams in southeast Alaska and on Afognak Island in 1992:

- Four sites were previously logged from 1990-1992 and retained riparian buffers (two were harvested with variations);
- Three sites had logging initiated during 1992 and concurrent with the initiation of the monitoring program;
- Two sites had not experienced logging and were not scheduled to be harvested in the immediate future.

Twenty parameters were characterized within each stream, including large woody debris (LWD), LWD source bank, pool depth, substrate composition, spawning area, cover type, total cover, bank erosion, shade, channel gradient, channel width, cobble embeddedness, and temperature. Monitoring results were presented for each surveyed creek. Potential BMP effectiveness was also discussed.

71) Martin, D.J. 1995. A preliminary assessment of fish habitat and channel conditions for streams on forested lands of southeast Alaska. Project 44-006 final report written by Pentec Environmental, Inc., Edmonds, Washington. Written for Sealaska Corporation, Juneau, Alaska and the Alaska Forest Association, Ketchikan, Alaska. 88pp. (A, B, D, F, G, I, J)

Compiler abstract: In 1992, Sealaska Corporation and the Alaska Forest Association initiated a monitoring program in southeast Alaska to evaluate the overall effectiveness of the BMPs specified by the revised 1990 Alaska Forest Resources and Practices Act (FRPA) with the intent to prevent significant adverse effects of timber harvest on fish habitat and water quality. The objectives of the monitoring program were to determine: (1) if fish habitat conditions changed following timber harvest, and (2) if fish habitat quality had been significantly affected (positive or negative) by timber harvest activities. This report presents results from the 1993 habitat survey and provides preliminary analyses of survey data collected in both 1992 and 1993.

Ten streams were surveyed in 1992 and 1993. Streams varied in size from 5.2 to 31.0 m wide. Streams were subdivided into reaches based on geomorphic channel types. Timber harvest activities in all watersheds except one had occurred or were planned to occur in accordance with the revised FRPA. Streams were surveyed beginning at the mouth and proceeding upstream until an anadromous fish barrier was encountered or to a point where fish utilization was known to be low. Fish habitat and channel conditions were characterized by measuring or characterizing reach length, channel type, channel bankfull width, channel gradient, streambed particle size, riparian vegetation, buffer width, buffer treatment (e.g. unmanaged, partial harvest, no buffer), channel disturbances (e.g. bank erosion, blowdown), channel depth, pool width and length, large woody debris (LWD), stream flows, water temperature. These data were used to calculate various factors known to be indicative of fish habitat and spawning habitat quality: relative amount of fast-water and slow-water habitat; relative amount of pool habitat; pool spacing; residual pool depth; LWD in channel; size distribution of the dominant substrate; dominant habitat cover type; and frequencies of occurrence of units with sand/gravel, gravel/sand, gravel/cobble, and cobble/gravel substrate. Comparisons of fish habitat and channel conditions for the various streams between 1992 and 1993 and between different timber harvest treatments are provided.

72) Martin, D.J. 1996. Fish habitat and channel conditions for streams on forested lands of coastal Alaska: An assessment of cumulative effects. 1995 Assessment. Project 51-002 review draft report written by Pentec Environmental, Inc., Edmonds, Washington. Written for Sealaska Corporation, Juneau, Alaska and the Alaska Forest Association, Ketchikan, Alaska. 37pp. plus Appendices. **(A, B, D, F, G)**

Author abstract (Author Summary of Current Findings): An experimental approach that uses comparisons of pre- and post-harvest conditions in multiple basins is proposed as the basis for testing the effectiveness of modern BMPs in protecting fish habitat. A suit of habitat measurements, which will provide measurement repeatability and are useful for documentation of habitat changes, have been tested and modified for this monitoring program. Power analyses have been performed on a number of habitat parameters to determine the level of detection of various statistical analyses. Sample sizes have been identified for most parameters that will enable an 80 percent level of power.

Some habitat conditions are changing more in the post-harvest basins than in the pre-harvest basins, and the changes are most likely a result of timber harvest activities. Recent LWD recruits to a stream and the percentage of recruits caused by blowdown show a definite response to timber harvest. Significant reductions in riparian canopy density may be associated with timber harvest in some basins. Changes in total LWD loading are difficult to interpret in terms assigning timber harvest effects except where blowdown is clearly documented. Large variability in LWD loading within a basin makes it difficult to test for differences between pre- and post-harvest conditions among groups of basins because not all of the basins are demonstrating the same

pattern under natural conditions. Following LWD trends within a basin over time is probably the best approach to detecting change. The substrate particle size analysis was the most sensitive analysis performed, yet the results do not provide any indication that timber harvest can be associated with the recorded changes. Changes in relative pool area and pool depth show no relationship to pre- or post- harvest conditions or anything else.

73) Martin, D.J. 2001. The influence of geomorphic factors and geographic region on large woody debris loading and fish habitat in Alaska coastal streams. North American Journal of Fisheries Management. 21: 429-440. (A, D)

Author abstract: Large woody debris (LWD) and channel data from three Alaska coastal regions with varying geomorphic channel types were analyzed to document regional variability in LWD abundance, define geomorphic characteristics affecting LWD abundance, and identify relationships between LWD abundance and the formation of pools and gravel bars in streams. Large woody debris abundance was significantly lower at the northern edge of the coastal coniferous forest than in Southeast Alaska and was significantly greater in alluvial gravel-bedded channels than in contained boulder-bedrock channels. More pools and gravel bars were formed by LWD in alluvial channels than in contained channels. Pool spacing (the number of channel widths between pools) decreased with increasing LWD abundance (pieces/km) and was significantly influenced by the interaction between LWD abundance and channel width. As channel width increased, pool spacing was more strongly influenced by changes in LWD abundance, but the relative change in pool spacing diminished with increasing LWD load. The percentage of stream area in pools was insensitive to changes in LWD abundance and was best predicted by channel type. The percentage of habitat units with gravel as the dominant substrate was positively related to LWD abundance and negatively related to stream gradient.

74) Martin, D.J., and A. Shelly. 2004. Status and trends of fish habitat condition on private timberlands in southeast Alaska: 2003 Summary. Alaska Clean Water Action Grant No. NA170Z2325 final report written by Martin Environmental and TerraStat Consulting Group, Seattle, Washington. Written for Sealaska Corporation and the Alaska Department of Natural Resources, Juneau, Alaska. 44pp. plus Appendices. (A, B, D)

Compiler abstract: In 2003 the Sealaska Corporation and the Alaska Department of Natural Resources initiated a habitat and channel conditions monitoring program through an Alaska Clean Water Action Grant. This project was a continuation from previous monitoring programs that were conducted from 1992-1997 and from 1998-2001. The objectives of the project were to expand the database for monitoring of streams on private lands in southeast Alaska and to examine trends in habitat condition using both previously gathered and newly gathered data. Analyses were conducted to identify factors besides logging that could be influencing habitat trends. A power analysis was also conducted to determine sample size for future monitoring. Results from this study were compared against habitat condition trends and data collected by the Tongass National Forest on streams without logging.

This study surveyed 19 stream reaches during 2003 that included 7 new reaches and 12 previously surveyed reaches. The surveyed reaches were located in three basins in the Hoonah area and in six basins in the Craig area. With the exception of four, all the reaches occurred in

timber harvest units and most had buffer zones along both sides of the stream. Trend analysis was also conducted on 13 stream reaches from the historical data. Data were divided by those with only post-harvest data and those with both pre- and post-harvest data. Results of the analysis suggest that there were no significant regional trends in habitat conditions at the post-harvest sites for 11 years following logging. Also, there was no discernable difference between average habitat conditions before and after logging at the pre- and post-harvest reaches on private lands. Results showed that habitat variability was partially caused by different responses in habitat to changes in recruitment of wood that were related to wood loading and channel width. Additional years of reach monitoring are needed.

75) Martin, D.J., and J.A. Kirtland. 1995. An assessment of fish habitat and channel conditions in streams affected by debris flows at Hobart Bay. Project 16-004 report written by Pentec Environmental, Inc., Edmonds, Washington. Written for Goldbelt, Inc., Juneau, Alaska. 40pp. plus Appendix. (A, B, D, G)

Compiler abstract: In 1993, several debris flows occurred in two small basins that drain into Laura's Creek and Salt Chuck Creek of Hobart Bay. Three debris flows were initiated by forest practice activities, which then deposited silt, sand and some debris into Gypo Creek. Two large debris flows were initiated by natural causes that then passed through a clearcut unit and deposited large quantities of sediment and debris in Nancy and Salt Chuck Creeks. Laura's Creek, Salt Chuck Creek, and their tributaries were subsequently listed as DEC impaired water bodies because of channel modifications and sedimentation caused by the debris flows.

Field surveys of Gypo Creek, Nancy Creek, and lower Salt Chuck Creek were conducted to assess fish habitat, channel conditions, and landslide occurrence. Landslides were inventoried using aerial photographs taken in 1979 (pre-harvest) and 1989-90 (post-harvest). Fish habitat and stream channel inventories were conducted both upstream and downstream of the debris flow entry locations. Channel types were used to delineate stream reaches, and each reach was further delineated into channel geomorphic units (e.g. pools, riffles, cascades). Within each channel, the following were measured or characterized: stream discharge, channel gradient, channel depth, thalweg depth, pool tail crest depth, pool width and length, pool forming elements, cover elements (e.g. large woody debris [LWD], slash, undercut banks), and substrate particle size. From these variables, various habitat parameters were calculated, such LWD and undercut bank area, pool spacing, pool volume, frequency of occurrence of pool forming elements, frequency of dominant and subdominant substrates, and total and inchannel LWD loading.

Study results were as follows:

- A total of 26 landslides were identified, all of which were shallow-rapid failures of the thin, semi-cohesionless soils of the area;
- All landslides were either debris avalanches or debris flows;
- Thirteen of the 26 landslides delivered sediment to streams; six of these originated in timber harvest areas;
- The majority (69%) of the landslides occurred in steep inner gorges along stream channels;
- Forty-six percent of the landslides occurred in old-growth forest;
- Fifty-four percent of the landslides originated in harvest units or road fill;
- It was not possible to determine if forest management activities increased the frequency of landsliding;

- Landslides in the Gypo Creek and Nancy Creek watersheds were largely confined to small tributaries and did not transfer significant amounts of sediment to higher order channels;
- Channel characteristics and fish spawning and rearing habitat conditions were described;
- Channel modifications and sedimentation of Hobart Bay streams result from naturally occurring debris flows that create favorable and unfavorable fish habitat conditions that vary with the size and frequency of mass wasting events. Timber harvest may have influenced the timing and magnitude of some events.

76) Martin, D.J., and L.E. Benda. 2001. Patterns of instream wood recruitment and transport at the watershed scale. Transactions of the American Fisheries Society. 130: 940-958. (D)

Author abstract: A wood budget was constructed for the Game Creek basin (132 km^2) in southeast Alaska to identify spatial and temporal controls on the abundance and distribution of large woody debris (LWD). Field measurements of wood storage, size, and age were used to estimate volumetric rates of LWD recruitment and transport. Mortality recruitment did not follow a spatial pattern and ranged from 0.1 to 8.1 $m^3 \cdot km^{-1} \cdot year^{-1}$ (recruitment corresponded to forest mortality rates of 0.1 - 2.6% per year). Wood recruitment by bank erosion increased with increasing drainage area and ranged from 1 $m^3 \cdot km^{-1} \cdot year^{-1}$ at the smallest drainage areas to about 16 $m^3 \cdot km^{-1} \cdot year^{-1}$ at 60 km^2. Bank erosion recruitment exceeded the maximum mortality recruitment at a drainage area of approximately 20 km^2 (about 10-m-wide channel). Recruitment from land-sliding was only locally significant. The contribution of fluvial transport (flux) to total LWD storage increased with drainage area to an asymptotic maximum of 50% at about 50 km^2 (about 20-m-wide channel). Mean predicted transport distances for mobile LWD over the lifetime of individual pieces ranged from about 200 m in small, jam-rich streams to about 2,500 m in larger channels with fewer jams. Fluvial transport of LWD increased interjam spacing and jam size and decreased jam age with increasing distance downstream. Constructing LWD budgets at the watershed scale has numerous geomorphic and ecological implications, including identifying spatial controls on the abundance and diversity of aquatic habitats. In addition, information on LWD budgets may be useful for determining how and where to protect LWD sources to streams.

77) Martin, D.J., M.E. Robinson, and R.A. Grotefendt. 1997. Fish habitat and riparian stand composition for streams on forested lands of coastal Alaska: 1996 assessment. Review draft report written by Martin Environmental, Seattle, Washington, and Grotefendt Photogrammetric Services, Inc., North Bend, Washington. Written for Sealaska Corporation, Juneau, Alaska. 43pp. plus Appendices. (A, D, F, H)

Compiler abstract: The overall objective of this study was to document the effects of forestry practices on fish habitat. Specific objectives were to 1) determine if timber harvest is changing fish habitat, 2) determine if timber harvest is affecting habitat quality, and 3) identify the specific categories of best management practices that are not protecting fish habitat. Surveys of streams were conducted for 4 years in 20 stream systems in southeast Alaska. Comparisons were made among habitat features in pre- and post-harvest basins, as well as between pre- and post-harvest habitat features within each basin. Low-altitude aerial photographs were taken of the riparian zones and stream channels. Twelve sets of variables were measured from the photographs, including: channel area; length of stream reach; down tree decay; treefall direction; standing tree type (conifer, deciduous, snag); and distance from a stream to standing trees, down trees, and stumps. Fish habitat and channel morphology data were also collected, and included: channel depth, velocity, and width; channel surface gradient; channel cross-sectional area; channel type; pool spacing; sizes of stream bed substrates; numbers and types of large woody debris (LWD) structures; channel forming functions of LWD structures (e.g. pool scour, pool damming, bar stabilization, sediment storage, channel deflection); riparian canopy density; and location and length of unstable banks.

Results showed most LWD is recruited from areas immediately adjacent the streams. Comparisons at pre- and post- harvest basins showed that canopy density was not significantly different, the amount of change in LWD was larger in post-harvest reaches than pre-harvest reaches, and that there is an increase in LWD recruitment following logging in the post harvest basins. Pool depths changes were significant in 50% of the reaches in both pre- and post-harvest basins. Results also showed that pool habitat is strongly affected by channel type and that significant changes in the amount of LWD in streams can cause changes in pool habitat depending on channel type, LWD loading, and initial pool spacing.

78) Martin, D.J., M.E. Robinson, and R.A. Grotefendt. 1998. The \ for protection of salmonid habitat in Alaska coastal streams. Report written by Martin Environmental, Seattle, Washington, and Grotefendt Photogrammetric Services, Inc., North Bend, Washington. Written for Sealaska Corporation, Juneau, Alaska and the Alaska Forest Association, Ketchikan, Alaska. 85pp. plus Appendices. **(A, D)**

Compiler abstract: The purpose of this study was to evaluate the cumulative effectiveness of the Alaska Forest Resources and Practices Act by determine the effectiveness of 20 m wide riparian buffers for supplying LWD to streams and for protecting fish habitat. Low-elevation aerial photographs were used to identify potential large woody debris (LWD) sources in 15 watersheds (36 study reaches) in southeast Alaska. Annual channel survey data from 1994-1997 were used to monitor changes in LWD recruitment and to examine interactions between LWD, channel morphology, and fish habitat. Thirteen variables were measured from the aerial photographs, including: channel area, length of down trees, height of standing trees, treefall direction, and down tree decay class. Fish habitat and channel inventories were also conducted.

Some of the study results were:

- LWD is important for pool formation and for retention of gravels for salmonid spawning habitat;

Relative effectiveness of LWD to form fish habitat is a function of stream channel type and the amount of LWD in the stream;

- Nearly all of the recruitable size trees occurred within 20 m of stream,
- Selective timber harvest in the buffers, in addition to windthrow following logging, did not significantly reduce the potential supply of LWD from the 0-10 m zone;
- A 20-m wide buffer zone is more effective for providing LWD than a wider buffer or an unlogged area;
- Windthrow may reduce potential long-term supply of LWD in a small percentage of riparian buffers;

- Quantity and quality of fish habitat in streams with naturally low supplies of LWD could be improved by planning buffer zones to increase the supply of LWD.

79) Martin, D.J., M.E. Robinson, S.J. Perkins, and R.A. Grotefendt. 1997. Monitoring the effects of timber harvest activities on fish habitat in streams of coastal Alaska 1992-1997. Project status report written by Martin Environmental, and S.J. Perkins, Seattle, Washington, and Grotefendt Photogrammetric Service, Inc., North Bend, Washington. Written for Sealaska Corporation, Juneau, Alaska. 13pp. (A, D, I)

Compiler abstract: Sealaska Corporation and the Alaska Forest Association initiated a monitoring program in 1992 to determine the short-term and long-term effects of modern forest practices on fish habitat and water quality. This report provides a summary of the monitoring program objectives, approach, and findings from 1992-1997.

The objectives of the monitoring program were to: (1) determine if fish habitat conditions have been altered by timber harvest; (2) determine if habitat quality has been significantly affected, positively or negatively, by timber harvest; and (3) identify specific types of BMPs, such as riparian buffers or roads, that are not protecting fish habitat.

Stream surveys were conducted from 1992 to 1997 in 32 basins located in coastal forests of southeast Alaska, on the Kenai Peninsula, and on Afognak Island. In order to determine if fish habitat conditions have changed due to timber harvest, two study approaches were used: (1) comparing pre- and post-harvest habitat conditions in multiple basins, and (2) comparing pre- and post-harvest habitat conditions in each of the basins. Conclusions are presented for the buffer zone and mass wasting studies.

80) Martin, D.J., W.M. Young, Jr., S.D. Edland, T.S. Lin, and R.B. Morrow. 1990. An inventory of fish habitat conditions on seven southeast Alaska streams identified by the EPA Section 304(I) Long List. Project No. 00044-001 interpretive report written by Pentec Environmental, Inc., Edmonds, Washington. Written for Sealaska Corporation, Juneau, Alaska. 14pp. plus Figures, Tables, and Appendix. (A, B, D, F, H)

Compiler abstract: Streams that are suspected of being degraded by timber harvest and other activities are listed as impaired water bodies by the Environmental Protection Agency (EPA) and the Alaska Department of Environmental Conservation (DEC). Water quality data for forested streams in southeast Alaska are almost non-existent, so the so called "long list" of degraded streams is developed primarily through professional judgment. As a result, EPA requested comments from all interested parties concerning the need for inclusion or deletion of specific streams from the "long list."

Seven streams on Sealaska Corporation land in southeast Alaska that appeared on the "long list" were measured in 1990 to assess the quality and quantity of salmonid spawning and rearing habitat, to determine if they met applicable water quality standards. Cobble embeddedness and stream bank stability were measured to infer conditions related to sediment loads and turbidity. Large woody debris (LWD) was quantified as an indicator of channel stability and habitat quality for rearing fish. Riparian tree frequency was measured as an index of stream shading and future LWD sources. Sixteen environmental parameters were measured or visually estimated in each study reach and along transects within each reach. Transect characteristics that were quantified were: habitat type, width and depth, pool size, pool depth, pool cover, pool quality, pool creator (bedrock, boulders, gravel/cobbles, LWD), substrate composition, cobble embeddedness, and potential LWD. Characteristics of stream reaches between transects that were quantified were: bank stability, riparian condition (old growth, buffer > or < 30 m, second growth, clearcut), large woody debris, spawning area, spawning quality, and gradient.

Study results indicated that general habitat characteristics of the seven streams were characterized as follows:

- Riffles and runs were the dominant habitat types;
- Pools were relatively small, shallow, and had limited cover;
- Riparian condition varied along all streams, with sections of clearcuts, riparian buffers, second growth, and old growth forest;
- Clearcut was the dominant riparian condition along all streams except Humpback and Gunnuck creeks;
- Stream bed substrate was predominantly gravel and cobble;
- Spawning area ranged from <500 m^2 to 10,000 m^2.

Cobble embeddedness, bank stability, LWD and potential LWD were discussed in detail. The relationships between environmental conditions and water quality standards were also discussed.

81) Martin Environmental. 1997. A summary of stream water quality monitoring data: South Fork Michael Creek, Admiralty Island, Alaska. Draft report written by Martin Environmental, Seattle, Washington. Written for Koncor Forest Products, Inc., Anchorage, Alaska, and the Alaska Department of Environmental Conservation and Alaska Department of Natural Resources, Juneau, Alaska. 10pp. plus Figures and Tables (I)

Compiler abstract: The South Fork of Michael Creek in the Lake Florence Watershed, Admiralty Island was monitored from 1993-1996 to determine the effect of 66 ft wide riparian buffer strips with variation treatments on water temperature and turbidity. The stream was monitored for two years prior to timber harvest, and continued during the logging phase (1995 and 1996). Stream stage, turbidity, and water temperature were monitored at five stations, and riparian canopy density was measured between stream monitoring stations. The partial-cut buffers and associated BMPs effectively maintained stream turbidity near pre-harvest levels. Pre-treatment canopy densities were not measured, but comparisons of canopy densities among treated and untreated areas suggested some places were affected by timber harvest. Canopy density was reduced in all sampled areas in the winter of 1995-1996 as a result of blowdown. The effectiveness of the partial-harvest buffers and associated BMPs on maintenance of water temperature was not clearly demonstrated.

82) Martin, J.R. 1993. Influence of roads on wetland vegetation in southeast Alaska. In: Proceedings of Watershed '91: A Conference on the Stewardship of Soil, Air, and Water Resources, 16-17 April 1991, Juneau, Alaska. T. Brock, Editor. USDA Forest Service, Alaska Region, R10-MB-217. Page 33. (K)

Author abstract: The Tongass is the largest National Forest (over 17 million acres) in the United States and encompasses most of southeast Alaska. Approximately, 1.6% of the land is classified as forested wetlands; 9.5% peatland, 3.7% scrub wetlands; 2.3% lacustrine wetlands;

0.2% estuarine wetlands; and 42,429 miles of riverine wetlands for a total of over 4.7 million acres. Road building has been a major activity since the early 1950's. Over 2,600 miles of forest roads currently exist on the Tongass N.F. It's been expected that this mileage will double over the next 50 years. Most of these roads are built by overlaying pit-run rock on organic soils generally on gentle to flat topography. Because of the high rainfall, much of this flat topography is dominated by wetland vegetation. Consequently, a large percentage of the roads have been built on peatland and forest wetlands and to a lesser extent estuarine wetlands. Vegetation response to this development is highly variable in both direction and rate depending on how the hydrologic function was disrupted. Previously wet areas have become dryer and are progressing towards forest conditions as indicated by increased tree growth and regeneration. Conversely, wet areas have become wetter and shifts are seen from Sphagnum and short sedge dominated peatlands with highly stagnant water towards tall sedge fresh water marsh communities. In alluvial riparian forests, where terrace building and degradation is an active process, roads have caused some sites to become more stable and other sites to degenerate to alder or gravel bar conditions. Roads built in estuaries which have reduced the extent of saltwater inundation have caused formally grass dominated communities to become forested. The importance of considering changes in hydrologic function and subsequent shifts in resource production in road management planning is emphasized. Opportunities to utilize these concepts in road management planning and restoration are discussed.

83) McGreer, D.J. 2000. Effects of forest harvesting and roads on streamflow processes and application to watersheds of southeast Alaska. Report written by Western Watershed Analysts, Lewiston, Idaho. Written for Sealaska Corporation, Juneau, Alaska. 10pp. (G)

Compiler abstract: Timber harvest and related road construction can have important effects on hydrologic processes such as total water yield, timing of yield, seasonal low flows, peak flows and floods. This paper presents a review of scientific studies of the potential effects of timber harvest and roads on hydrologic processes in cool, wet forests—mostly from the western slopes of the Pacific Northwest—similar to those typically found in southeast Alaska. The author concludes that clearcut harvesting of forests in southeast Alaska will result in increased annual streamflow as well as increased flows at all times of the year, including low flows. In addition, the author concludes that peak flows may potentially increase following extensive clearcut logging, with further increases due to forest roads. These effects can be minimized by regulating the amount of acreage harvested and by minimizing compacted road surfaces and the amount of road mileage that discharges water directly to streams or gullies that are linked to streams. Road system water discharge can be minimized by carefully locating roads and by designing road drainage systems to minimize discharge of road surface sediments.

84) McNeil, W.H. 1966. Effect of the spawning bed environment on reproduction of pink and chum salmon. University of Washington, College of Fisheries, Seattle, Fishery Bulletin. 65: 495-523. (G, I)

Electronic abstract: The pink *Oncorhynchus gorbuscha* and chum *O. keta* are the only Pacific salmon in North American streams using fresh water solely for spawning. The young of other species remain in fresh water for many months. Post work on spawning bed mortality and fieldwork in streams of the Kasaan Bay region of Prince of Wales Island in Southeast Alaska are reviewed. There was 75-99% mortality between spawning and fry emergence connected with low and high stream discharge, freezing air temperatures, low dissolved oxygen levels during and after spawning or movement of gravel.

85) Meehan, W.R. 1970. Some effects of shade cover on stream temperature in southeast Alaska. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-113. 9pp. (H, J)

Electronic abstract: Water temperature differences measured with a precision resistance thermometer over 20-yard intervals show that on clear summer days, shade-producing streamside vegetation is important in cooling or maintaining coolness of small streams. The average temperature increase in unshaded reaches of streams in the Haines Juneau area was 0.071 deg c. and in the Petersburg Wrangell area it was 0.164 deg c. in shaded reaches the average temperature decrease was 0.060 deg c. and 0.081 deg c., respectively. Under overcast skies, the effects of shade were very small and the trend was for a slight temperature increase over 20-yard stream reaches--0.011 deg c. and 0.009 deg c., in the two areas. The reasons for the significantly different temperature responses in the two geographic areas are not yet known.

86) Meehan, W.R. 1971. Effects of gravel cleaning on bottom organisms in three southeast Alaska streams. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Program Fish Cultivation. 33: 107-111. (B, C)

Electronic abstract: Excessive sediment in the spawning gravels of salmon streams is believed to be a factor limiting salmon production. A riffle sifter designed for 'cleaning' streambed gravels is described. It is self-powered and amphibious, and stirs up streambed gravel sucking up fine materials and spraying them out onto the stream banks. The effects of using the riffle sifter in 3 streams in S.E. Alaska is evaluated. The 3 streams were Fish Creek, Slocum Creek and Lover's Cove Creek. Lover's Cove Creek was the best cleaned after development of the equipment. The bottom types and pre-treatment levels of sedimentation were similar. Samples were taken 3 days before, approx 3 days after, 3 months after and 12 months after treatment. All showed noticeable decreases in bottom fauna immediately after cleaning. There was a decrease of approx 30 percent in materials less than 0.4 mm in Slocum Creek and 65 percent less in Lover's Cove Creek which was the most thoroughly cleaned. In Lover's Cove Creek recruitment of bottom organisms was back to pre-treatment levels after 12 months and differences in fauna were negligible.

87) Meehan, W.R. 1974. The forest ecosystem of southeast Alaska. 3. Fish habitats. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-15. 41pp. (B, D, G, I, J)

Author abstract: The effects of logging and associated activities on fish habitat in southeastern Alaska are discussed, and fish habitat research applicable to southeast Alaska is summarized. Requirements of salmonids for suitable spawning and rearing areas are presented. Factors associated with timber harvest which may influence these habitats are discussed in detail; e.g., sediment, stream temperature, streamflow, logging debris, and chemicals. Recommendations for further research are made.

88) Meehan, W.R., F.B. Lotspeich, and E.W. Mueller. 1975. Effects of forest fertilization on two southeast Alaska streams. Journal of Environmental Quality. 4: 50-55. (I)

Electronic abstract: 4 streams in southeast Alaska were studied to determine the effects of forest fertilization with urea on basic productivity and water quality. An initial, short-term increase in ammonia-N_2 was observed in the treated streams, and nitrate-N_2 levels increased and remained high compared to control stream levels during the yr following treatment. Conclusions did not approach those considered toxic to aquatic life or unsafe for human consumption. Changes in biomass of periphyton and benthic fauna as a result of fertilization were not detected.

89) Milner, A.M. 1987. Colonization and ecological development of new streams in Glacier Bay National Park, Alaska. Freshwater Biology. 18: 53-70. (C, G, I, J)

Author abstract: Colonization and ecological development of post-glacial freshwater communities were investigated in Glacier Bay National Park, south-eastern Alaska, following the rapid recession of a Neo-glacial ice sheet within the last 250 years. Environmental variables shown to be most significant in stream development were temperature, flow regime and sedimentation. The Chironomidae (Diptera) were the pioneer invertebrate colonizers of newly emergent streams arising as meltwater from receding ice sheets and displayed a distinct pattern of succession with stream maturity. Ephemeroptera and Plecoptera colonized warmer clearwater streams, but Trichoptera had a minimal role in invertebrate community development. Establishment and production of salmonid fish populations in the new streams related principally to stream flow and sediment characteristics. Future pathways along which the streams may develop is probably dependent on the degree of large organic debris input. Stream development, structure and function are summarized including references to theories of ecosystem development, ecological succession and community stability.

90) Milner, A.M. 1996. Data analysis and summary of the use of rapid bioassessment metrics to evaluate the use of a partial buffer zone in timber harvest in a Lake Florence watershed, Admiralty, Island. White paper, Institute of Arctic Biology, University of Alaska, Fairbanks. 13pp. (C, I)

Compiler abstract: The report summarizes three years of macroinvertebrate data collected in Michael Creek to analyze the application of rapid bioassessment for evaluating timber harvest effects with a partial buffer strip on the macroinvertebrate community. The data represent a two year pre-harvest period (1993-1994), and the first year of post-harvest (1995). Four bioassessment metrics were used to determine possible differences in the macroinvertebrate community between a portion of the creek with a partial buffer and a control area. The four metrics were: 1) EPT genera (orders Ephemeroptera, Trichoptera, and Plecoptera); 2) EPT Individuals/Total Individuals Ratio; 3) percent dominant taxa; and 4) Family Biotic Index of Hilsenoff. Overall, no significant effects of timber harvest on the macroinvertebrate community were detected using the chosen bioassessment metrics. However, the bioassessment technique described may not detect timber harvest effects on aquatic systems that are not linked to macroinvertebrate community structure. Likewise, timber harvest effects that cause an overall decrease in macroinvertebrate populations, but do not alter their community structure will also not be detected.

91) Milner, A.M. and G.S. York. 2001. Factors influencing fish productivity in a newly formed watershed in Kenai Fjords National Park, Alaska. Archiv fuer Hydrobiologie. 151: 627-647. (C, E, I)

Electronic abstract: Delusion Creek in McCarty Fjord, southcentral Alaska, was studied over three field seasons from 1992 to 1994 to investigate the factors influencing salmonid colonization and productivity of a new stream system formed by glacial ice recession within the last 40 years. Stream discharge was extremely variable during the summer months. Frequent spate events were a major factor in maintaining an unstable channel and in raising turbidity levels, which limit primary production and the abundance and diversity of invertebrates in the main stream channel available to rearing fish. However, in less than 40 years, Coho (*Oncorhynchus kisutch*), pink (*O. gorbuscha*), and sockeye (*O. nerka*) salmon have colonized Delusion Creek, and over 1,000 sockeye salmon were observed to spawn along the margin of the upper lake in 1993. Ninety-three percent of juvenile sockeye salmon remained in the lakes for two years prior to smolting. Kettle ponds, formed after ice recession, were also found to be important rearing areas for juvenile Coho salmon. In the main stream channel, Dolly Varden (*Salvelinus malma*) char were the most abundant juvenile rearing fish. Water chemistry of the lakes indicated that nitrogen was likely a limiting nutrient to primary production. Experiments with artificial channels showed that enrichment with nitrogen and phosphorus increased chlorophyll-*a* levels and macroinvertebrate drift was significantly reduced from enriched channels. We suggest that primary productivity and invertebrate abundance may be enhanced by the colonization of spawning anadromous salmon which may, thus, act as a positive feedback to productivity of this new stream.

92) Milner, A.M., and R.G. Bailey. 1989. Salmonid colonization of new streams in Glacier Bay National Park, Alaska. Fisheries and Aquaculture Management. 20: 179-192. (G, I, J)

Electronic abstract: Following the rapid recession of a neoglacial ice sheet within the last 250 years, colonization of recently deglaciated streams by salmonid fishes was investigated in Glacier Bay National Park, south-eastern Alaska. The primary factors governing the establishment, species diversity composition and abundance of salmonids in Glacier Bay streams were water temperature, sediment loading and stream discharge. No salmonids were found in the turbid meltwater streams emerging from retreating ice. Coho, *Oncorhynchus kisutch* (Walbaum), and sockeye, *Oncorhynchus nerka* (Walbaum), salmon and Dolly Varden, *Salvelinus malma* (Walbaum), charr were the first salmonids to colonize the youngest clearwater stream.

93) Milner, A.M., D.M. Bishop, and L.A. Smith. 1985. The influence of water temperature and streamflow on sockeye salmon fry emergence and migration in Black Bear Creek, southeastern Alaska. In: Proceedings of the Symposium on Small Hydropower and Fisheries, 1-3 May 1985, Aurora, Colorado. F.W. Olson, R.G. White, and R.H. Hamre, Editors. The American Fisheries Society. Pages 54-58. (G, J)

Author abstract: Accumulated temperature unit and discharge information collected for sockeye salmon embryos from spawning to downstream migration over two successive incubation periods are evaluated with reference to possible impacts of an altered thermal or flow regime from the development of a small hydropower facility.

94) Montgomery, D.R., J.M. Buffington, R.D. Smith, K.M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. Water Resources Research. 31: 1097-1106. (A, D)

Electronic abstract: Field surveys of stream channels in forested mountain drainage basins in southeast Alaska and Washington reveal that pool spacing depends on large woody debris (LWD) loading and channel type, slope, and width. Mean pool spacing in pool-riffle, plane-bed, and forced pool-riffle channels systematically decreases from greater than 13 channel widths per pool to less than 1 channel width with increasing LWD loading, whereas pool spacing in generally steeper, step-pool channels is independent of LWD loading. Although plane-bed and pool-riffle channels occur at similar low LWD loading, they exhibit typical pool spacings of greater than 9 and 2-4 channels widths, respectively. Forced pool-riffle channels have high LWD loading, typical pool spacing of <2 channel widths, and slopes that overlap the ranges of free-formed pool-riffle and plane-bed channel types. While a forced pool-riffle morphology may mask either of these low-LWD-loading morphologies, channel slope provides an indicator of probable morphologic response to wood loss in forced pool-riffle reaches. At all study sites, less than 40% of the LWD pieces force the formation of a pool. We also find that channel width strongly influences pool spacing in forest streams with similar debris loading and that reaches flowing through previously clear-cut forests have lower LWD loading and hence fewer pools than reaches in pristine forests.

95) Murphy, M.L. 1985. Die-offs of pre-spawn adult pink salmon and chum salmon in southeastern Alaska. North American Journal of Fisheries Management. 5: 302-308. (K)

Author abstract: About 300 pre-spawn adult pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) died in August 1981 in the intertidal reach of Porcupine Creek, a small stream in an old-growth forest. A combination of low stream flow and neap tides triggered the die-off, and about 1% of the pink salmon and chum salmon spawners died upon returning to Porcupine Creek in 1981. Anoxia, rather than temperature, caused most of the deaths because the maximum stream temperature was 19 C--well below lethal temperatures. Conditions similar to those in 1981 recur in Porcupine Creek about once every 8 years. This type of die-off also appears to be common in other streams in southeastern Alaska and can be predicted from the number of salmon returning, amount of precipitation, and height of the tide.

96) Murphy, M.L., and K.V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Page 99. (D)

Author abstract: Natural rates of input and depletion of large woody debris (LWD; fragments >10 cm diameter and >3 m long) in southeast Alaska streams were studied to provide a basis for managing streamside zones to maintain LWD for fish habitat after timber harvest. Large woody debris was inventoried by size and decay classes in 32 reaches of a variety of channel types in undisturbed old-growth forest, and more than 250 pieces were dated from the age of trees growing on them. Longevity of LWD in the streams was directly related to bole diameter. Small pieces (<30 cm diameter) were all less than 100 yr old, whereas large pieces (>90 cm diameter) were up to 226 yr old. Assuming steady-state conditions in old-growth forest, LWD depletion rate was assumed to equal input rate which was calculated from the percentage abundance and average age of LWD in the decay classes. Annual depletion ranged from 1.2% of large pieces in all channel types to 3.0% of small pieces in C2 channels (fourth-order, bedrock-controlled streams). A model of LWD changes after logging, which accounted for LWD depletion, LWD input from second-growth trees, and distance from the stream to LWD sources, indicated that clearcutting without buffer strips along streams reduces LWD >60 cm diameter by 75%, and the minimum level of LWD is reached 90-100 years after logging. Because almost all LWD in streams comes from within 30 m of the stream bank, a 30-m buffer on both sides of the stream should maintain LWD levels in the stream after logging.

97) Murphy, M.L., J.F. Thedinga, K.V. Koski, and G.B. Grette. 1984. A stream ecosystem in an old-growth forest in southeast Alaska. Part V: Seasonal changes in habitat utilization by juvenile salmonids. 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 89-98. (A, D)

Author abstract: Seasonal changes in distribution and habitat selection by juvenile salmonid fishes were studied in Porcupine Creek, a small coastal stream in an old-growth forest in southeast Alaska. During summer, coho salmon (*Oncorhynchus kisutch*) were distributed in both stream/estuary ecotone and freshwater reaches, and biomass (g per m^2) was directly related to total pool volume. Trout (*Salmo gairdneri* and *S. clarki*) and Dolly Varden char (*Salvelinus malma*) were not common in the stream/estuary ecotone but were common in freshwater. Total salmonid biomass during summer was directly related to the amount of large organic debris in the stream. Tagged salmonids showed little movement during summer but redistributed themselves within the Porcupine Creek system before winter. Coho moved out of the stream/estuary ecotone to upstream freshwater areas to overwinter. In late autumn, coho used primarily large mainstream pools, backwater pools, and secondary-channel pools, and trout and char used primarily debris or undercut banks on the edges of riffles. Resource managers need to take into account seasonal changes in habitat requirements when assessing effects of logging or other land uses on fish habitat in streams.

98) Murphy, M.L., J. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989. Habitat utilization by juvenile Pacific salmon (*Oncorhynchus*) in the glacial Taku River, southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 46: 1677-1685. (A)

Electronic abstract: Habitat utilization by juvenile Pacific salmon (*Oncorhynchus*) was determined in summer 1986 by sampling 54 sites of nine habitat types: main channels, backwaters, braids, channel edges, and sloughs in the river; and beaver ponds, terrace tributaries, tributary mouths, and upland sloughs on the valley floor. Physical characteristics were measured at all sites, and all habitats except main channels (current too swift for rearing salmon) were seined to determine fish density. Each species of *Oncorhynchus* was absent from about one-quarter of the seining sites of each habitat type. The lower Taku River provides important summer habitat for juvenile salmon, but many suitable areas were unoccupied possibly because of their distance from spawning areas and poor access for colonizing fish.

99) Murphy, M.L., J. Heifetz, S.W. Johnson, K.V. Koski, and J.F. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Sciences. 43: 1521-1533. (A, C, D, F, H)

Author abstract: To assess short-term effects of logging on juvenile *Oncorhynchus kisutch*, *Salvelinus malma*, *Salmo gairdneri*, and *Salmo clarki* in southeastern Alaska, we compared fish density and habitat in summer and winter in 18 streams in old-growth forest and in clear-cuts with and without buffer strips. Buffered reaches did not consistently differ from old-growth reaches; clear-cut reaches had more periphyton, lower channel stability, and less canopy, pool volume, large woody debris, and undercut banks than old-growth reaches. In summer, if areas had underlying limestone, clear-cut reaches and buffered reaches with open canopy had more periphyton, benthos, and coho salmon fry (age 0) than old-growth reaches. In winter, abundance of parr (age >0) depended on amount of debris. If debris was left in clear-cut reaches, or added in buffered reaches, coho salmon parr were abundant (10-22/100 m^2). If debris had been removed from clear-cut reaches, parr were scarce (<2/100 m^2). Thus, clear-cutting may increase fry abundance in summer in some streams by increasing primary production, but may reduce abundance of parr in winter if debris is removed. Use of buffer strips maintains or increases debris, protects habitat, allows increased primary production, and can increase abundance of fry and parr.

100) Myren, R.T., and R.J. Ellis. 1984. Evapotranspiration in forest succession and long-term effects upon fishery resources: A consideration for management of old-growth forests. 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 183-186. (G)

Author abstract: Evapotranspiration of rapidly growing forests may markedly reduce the minimum streamflows during the summer. In many streams of southeast Alaska, the minimum summer streamflows limit spawning success of pink and chum salmon and may limit the habitat of species such as coho salmon that rear in streams. Extrapolating from the literature leads to the conclusion that converting significant portions of old-growth watersheds to rapidly growing second-growth forests risks permanently reducing summer low flows of the streams and, thus, their ability to produce salmon. It is recommended that this risk be considered in managing the forests and that effects on streamflow of converting old-growth forests to second-growth forests be included in studies of logging in southeast Alaska.

101) Orlikowska, E.H. 2004. The role of red alder in riparian forest structure along headwater streams in southeastern Alaska. Northwest Science. 78: 111-123. (K)

Author abstract: We assessed the influence of red alder on tree species composition, stand density, tree size distribution, tree mortality, and potential for producing large conifers, in 38-42 yr old riparian forests along 13 headwater streams in the Maybe so and Harris watersheds on Prince of Wales Island, Alaska. Red alder ranged from 0 to 53% of the total live basal area of the stands. Tree density, basal area of live and dead trees, and mean diameter of live conifers were not significantly related to the percent of alder as a proportion of total stand live basal area within these riparian forests. The mean diameter of the 100 largest conifers per hectare (the largest trees) was similar among different sites and appeared unrelated to the amount of alder in the stands. The mean diameter of dead conifers increased slightly with increasing proportion of red alder. Most dead trees were small and died standing. Red alder was much more concentrated immediately along stream margins (within 0-1 m distance from the stream bank vs. > 1 m). The presence of red alder did not inhibit the production of large-diameter conifers, and both alder and conifers provided small woody debris for fishless headwater streams in southeastern Alaska. Red alder is an important structural component of young-growth riparian stands.

102) Paustian, S.J. 1987. Monitoring nonpoint source discharge of sediment from timber harvesting activities in two southeast Alaska watersheds. In: Water Quality in the Great Land—Alaska's Challenge. Proceedings: Alaska Section, American Water Resources Association. R.G. Huntsinger, Technical Chairman. Water Research Center, Institute of Northern Engineering, University of Alaska, Fairbanks. Pages: 153-168. (I)

Author abstract: Sediment discharge measurements taken on the mainstem of Indian River near Tenakee Springs in Southeast Alaska showed no significant change in sediment delivery following logging and road building that affected 8% of an 11 mi^2 watershed. More discrete sediment sources from road building were measured below road crossings on three first and second order tributaries to Kadashan River also located in Tenakee Inlet. Short term impacts of road building in Kadashan resulted in increased suspended sediment yield equivalent to 2% of the estimated annual sediment yields. Potential increases in total estimated sediment yield over a two year post-road construction period ranged from 20% to 66% in the three Kadashan study streams. The results of these monitoring studies have important implications for assessment of water quality management goals and objectives in the forested watersheds of coastal Alaska.

103) Pentec Environmental, Inc. 1991. Factors affecting pink salmon pre-spawning mortality in southeast Alaska. Technical Report 91-01 written by Pentec Environmental, Inc., Edmonds, Washington. Written for the Alaska Working Group on Cooperative Forestry/Fisheries Research. 81pp. (G, I, J)

Compiler abstract: In February 1990, the Working Group on Cooperative Forestry/Fisheries Research decided to initiate a two phase study to address three questions:

1. "What environmental factors cause pre-spawner mortality?"
2. "What watershed characteristics or other causative factors or both result in lethal conditions for migrating adult salmon?"

3. "What is the effect of logging on factors that cause pre-spawner mortality?"

This document reports on the first phase of the study, which addressed two objectives:

1. Identification of factors causing low dissolved oxygen (DO) in streams during the pre-spawner migration period, and
2. Verification that low DO causes adult salmon pre-spawner mortality.

Data were collected in seven streams in the central portion of Prince of Wales Island, southeast Alaska. Streams with varying levels of timber harvest, some with a history of fish kills, were selected. DO concentrations were determined by taking diel measurements at the head and tail of typical salmon holding pools, both before and during the time when adult spawning salmon were present. Background DO concentrations were those that were measured without the presence of spawners. The effects of spawner oxygen demand were determined by measuring DO when spawners were present.

Conclusions of the study were:

1. Significant reductions of DO concentrations during summer low flows can result from respiration of adult spawners;
2. Fish respiration can cause reductions in DO concentrations at water temperatures well below lethal levels;
3. The primary factors controlling DO levels during spawner migration were stream discharge and fish abundance, but fish activity level may also be important;
4. The most likely factor causing pre-spawner mortality is low DO concentration resulting from fish respiration in holding pools;
5. Water temperature increases will decrease potential availability of DO while increasing DO uptake by fish—stream discharge will determine how these factors affect DO concentrations.

The greatest potential effect of timber harvest on pre-spawner mortality is most likely related to logging effects on stream discharge. The magnitude of changes in stream discharge and spatial characteristics of these changes relative to salmon holding pools needs to be investigated in second growth basins.

104) Pentec Environmental, Inc. 1993. Fish habitat and channel conditions of nine streams in southeast Alaska and Afognak Island 1992 survey results. Technical Report 93-01 written by Pentec Environmental, Inc., Edmonds, Washington.Written for the Alaska Working Group of Cooperative Forestry/Fisheries Research. 37pp., plus Tables, Figures, and Appendices. (A, B, D, F)

Compiler abstract: A monitoring program was developed by Sealaska and Alaska Forest Association to produce a database of fish habitat and conditions of channels for forested lands that were previously harvested and for those that will be harvested in the future. The purpose was to evaluate the overall effectiveness of new forest practices and best management practices. This was accomplished by developing a multiyear monitoring program to collect data before and after timber harvest in nine streams in Southeast Alaska and Afognak Island for comparative studies between harvested and unharvested basins. Creeks included in the study were: Coon, Coco, Frosty, East Tolstoi,Cabin, Eagle, East Eagle, Little Afognak, and East Fork Little Afognak River. Parameters that were sampled for each creek, that are highly sensitive to and would be affected by BMPs included: LWD size and number, distribution and number of habitat units by type, pool residual depth, bank stability, shade, channel width, and spawning gravel sediment.

Parameters that were sampled for each creek that are indicative of general quality and quantity of fish habitat included: habitat unit area, dominant and subdominant substrate composition, cover type and area, spawning area, cobble embeddedness, riparian type and treatment, and channel gradient. Results are presented separately for each creek.

105) Perkins, S.J. 1999. Landslide inventory and sediment response study for monitored Sealaska streams. Report written by Martin Environmental, Seattle, Washington. Written for Sealaska Corporation, Juneau, Alaska. 27pp plus Appendices and maps. (B, I)

Author abstract (Author Introduction): This report presents the results of a landslide inventory and sediment-response study of twelve streams that are the subject of ongoing studies of forest practices effectiveness by Sealaska and the Alaska Forest Association. The purpose of this was to 1) estimate relative sediment supply levels to the study streams, 2) determine the relative importance of landslides in supplying sediment to each stream, and 3) compile a history of sediment supply changes and historic channel responses to changes in bedload. The results of this study will provide the context for a second study phase: analysis of monitoring data to examine the effects of sediment supply changes on channel substrate and morphology.

The scope of this study consisted of inspection of aerial photographs, topographic maps, and supplemental information from timber harvest managers.

106) Piccolo, J.J., and M.S. Wipfli. 2002. Does red alder (*Alnus rubra*) in upland riparian forests elevate macroinvertebrate and detritus export from headwater streams to downstream habitats in southeastern Alaska? Canadian Journal of Fisheries and Aquatic Sciences. 59: 503-513. (C)

Author abstract: We assessed the influence of riparian forest canopy type on macroinvertebrate and detritus export from headwater streams to downstream habitats in the Tongass National Forest, southeastern Alaska. Twenty-four fishless headwater streams were sampled monthly, from April to August 1998, across four riparian canopy types: old growth, clearcut, young-growth alder, and young-growth conifer. Young-growth alder sites exported significantly greater count (mean = 9.4 individuals·m^{-3} water, standard error (SE) = 3.7) and biomass (mean = 3.1 mg dry mass·m^{-3} water, SE = 1.2) densities of macroinvertebrates than did young-growth conifer sites (mean = 2.7 individuals·m^{-3} water, SE = 0.4, and mean = 1.0 mg dry mass·m^{-3} water, SE = 0.2), enough prey to support up to four times more fish biomass if downstream habitat is suitable. We detected no significant differences in macroinvertebrate export between other canopy types or in detritus export among different canopy types. Roughly 70% of the invertebrates were aquatic; the rest were terrestrial or could not be identified. Although we do not recommend clearcutting as a means of generating red alder, maintaining an alder component in previously harvested stands may offset other potentially negative effects of timber harvest (such as sedimentation and loss of coarse woody debris) on downstream, salmonid-bearing food webs.

107) Rickman, R.L. 1998. Effects of ice formation on hydrology and water quality in the lower Bradley River, Alaska--Implications for salmon incubation habitat. USDI Geological Survey, Anchorage, Alaska, Water-Resources Investigations Report 98-4191. 50pp. (G, I, J)

Electronic abstract: A minimum flow of 40 cubic feet per second is required in the lower Bradley River, near Homer, Alaska, from November 2 to April 30 to ensure adequate salmon egg incubation habitat. The study that determined this minimum flow did not account for the effects of ice formation on habitat. An investigation was made during periods of ice formation. Hydraulic properties and field water-quality data were measured in winter only from March 1993 to April 1995 at six transects in the lower Bradley River. Discharge in the lower Bradley River ranged from 42.6 to 73.0 cubic feet per second (average 57 cubic feet per second) with ice conditions ranging from near ice free to 100 percent ice cover. Stream water velocity and depth were adequate for habitat protection for all ice conditions and discharges. No relation was found between percent ice cover and mean velocity and depth for any given discharge and no trends were found with changes in discharge for a given ice condition. Velocity distribution within each transect varied significantly from one sampling period to the next. Mean depth and velocity at flows of 40 cubic feet per second or less could not be predicted. No consistent relation was found between the amount of wetted perimeter and percent ice cover. Intragravel-water temperature was slightly warmer than surface-water temperature. Surface and intragravel-water dissolved-oxygen levels were adequate for all flows and ice conditions. No apparent relation was found between dissolved-oxygen levels and streamflow or ice conditions. Excellent oxygen exchange was indicated throughout the study reach. Stranding potential of salmon fry was found to be low throughout the study reach. The limiting factors for determining the minimal acceptable flow limit appear to be stream-water velocity and depth, although specific limits could not be estimated because of the high flows that occurred during this study.

108) Roberston, A.L., and A.M. Milner. 2001. Coarse particulate organic matter: A habitat or food resource for the meiofaunal community of a recently formed stream? Archiv fuer Hydrobiologie. 152: 529-541. (C)

Electronic abstract: We examined the role of CPOM as food and/or habitat for lotic meiofauna in Wolf Point Creek, a recently formed stream in Glacier Bay, south-eastern Alaska. Meiofaunal communities in the stream substratum and those colonising mesh bags containing leaf or plastic substrata were compared on 3 occasions during the summer of 1997. MANOVA indicated that the communities of the stony and mesh bag substrata were significantly different but there were no significant differences between the communities occupying the plastic or leaf substrata. Measures of FPOM and biofilm were significantly higher on the leaf than on the plastic substrata. The responses of meiofaunal densities to date and substratum type were taxon specific. CPOM availability in this recently formed stream has had a marked impact on the meiofaunal community; densities increased significantly with CPOM enhancement and its main role appeared to be as habitat. This finding differs from those of similar studies on lotic macroinvertebrate communities. Future increases in allochthonous inputs and stream retention in Wolf Point Creek (following vegetation succession) will lead to an increase in meiofaunal densities. It is likely that the establishment of the riparian zone adjacent to new streams formed following press disturbances will be a significant influence in the succession of resident meiofaunal communities.

109) Robison, E.G., and R.L. Beschta. 1990. Characteristics of coarse woody debris for several coastal streams of southeast Alaska, USA. Canadian Journal of Fisheries and Aquatic Sciences. 47: 1684-1693. (A, D)

Electronic abstract: Coarse woody debris (> 0.2 m in diameter and 1.5 m long) was measured along five undisturbed low-gradient stream reaches; volume, decay class, and horizontal orientation in relation to channel flow of first-, second-, third-, and fourth-order coastal streams were determined. Debris was also classified into four influence zones based on stream hydraulics and fish habitat. Average debris length, diameter, and volume per piece increased with stream size. Eighty percent of debris volume of the first-order and the smaller second-order streams was suspended above or lying outside the bankfull channel, while less than 40% was similarly positioned in the fourth-order stream.

110) Robison, E.G., and R.L. Beschta. 1990. Coarse woody debris and channel morphology interactions for undisturbed streams in southeast Alaska, U.S.A. Earth Surface Processes and Landforms. 15: 149-156. (A, D)

Author abstract: Coarse woody debris and channel morphology were evaluated for five low-gradient streams that ranged from first to fourth order (0-7 to 55 km^2 watershed area). Debris volumes were directly related to variations in bankfull width. Woody debris was associated with 65 to 75 per cent of all pools and the relative proportion of types of pools (i.e. plunge, lateral scour, etc.) varied with stream size. High variability in channel depths and widths was common. The results provide benchmark values of woody debris loadings and channels morphology for undisturbed coastal Alaska stream systems.

111) Savard, C.S., and D.R. Scully. 1984. Surface-water quantity and quality in the lower Kenai Peninsula, Alaska. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water Resources Investigations Report 84-4161. 62 pp. (G, I, J)

Electronic abstract: New information on stream discharge and quality were collected over a 2-year period in the lower Kenai Peninsula. This new information improved understanding of the area's surface-water hydrology. Average annual runoff ranges from 11 inches in the lowland portions of the peninsula to 100 inches in the Seldovia area. For drainage basins in the Kenai Lowland, maximum flood runoff rates range from about 10 to 82 cubic feet per second per square mile. In the Seldovia area maximum peak discharges range from about 65 to 280 cubic feet per second per square mile. Low-flow discharges are higher in the Seldovia area than on the lower peninsula. Calcium and bicarbonate ions dominate the water in streams draining the study area; the water is soft and has a low dissolved-solids content. Measured stream water temperatures range from 0 to 23 degrees Celsius in the Kenai Lowland and from 0 to 11.5 degrees Celsius in the Seldovia area.

112) Schmiege, D.C, A.E. Helmers, and D.M. Bishop. 1974. The forest ecosystem of southeast Alaska. 8. Water. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-28. 26pp. (G, I, J)

Author abstract: One of the most striking characteristics of southeast Alaska is the abundance of water. Large glaciers, icefields, and thousands of streams result from heavy precipitation throughout the year.

Published and unpublished data on water regimen, temperature, sedimentation, and chemistry are combined. These serve as a basis for understanding how this valuable resource may be used and protected so that high quality water may always be abundant and available. A brief section on needed research is included

113) Schult, D.T., and D.J. McGreer. 2001. Effects of forest harvest and roads on water quality and application to watersheds of southeast Alaska. Report written by Western Watershed Analysts, Lewiston, Idaho. Written for Sealaska Corporation, Juneau, Alaska. 12pp. (E, F, I, J)

Compiler abstract: Timber harvest and related road construction can have important effects on water quality in forest streams by affecting sediment, nutrients, dissolved oxygen, and water temperature. This paper presents a review of scientific studies of the potential effects of timber harvest and roads on water quality in cool, wet forests—mostly from the western slopes of the Pacific Northwest—similar to those typically found in southeast Alaska. The authors apply their conclusions to management of Alaska's coastal forests with application of the Alaska Forest Resources and Practices Act.

114) Sedell, J.R. and W.S. Duval. 1985. Influence of forest and rangeland management on anadromous fish habitat in western North America: Water transportation and storage of logs. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-186. 68pp. (C, I)

Electronic abstract: Environmental effects of water transportation of logs in western North America include the historical driving of logs in rivers and streams, and the present dumping, rafting, and storage of logs in rivers and estuaries in British Columbia and southeastern Alaska. The historical perspective focuses on habitat losses and volumes of logs transported by water, both freshwater and marine. The environmental impacts of log handling on the physical habitat, water quality, plant communities, benthic and intertidal invertebrates, and fish are reviewed. Information gaps and research recommendations age given. In general, the environmental impacts of log handling are localized.

115) Seitz, H.R. 1989. The U.S. Geological Survey data base: Streamflow and water quality in southeast Alaska. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Page 93. (G, I)

Author abstract: Stream gauges for determination of streamflow have been operated in Southeast Alaska – Yakutat south to the Canadian border – since 1909. Records range in length from 1 to 70 years at 132 gauging sites. The oldest operating stream gauge is Fish Creek near Ketchikan, beginning in 1915. The present gauging network consists of 22 gauge sites. Continuous stream temperature records, less than 5 years in length, have been collected at 43 sites. Chemical analysis of the waters of Southeast Alaska has been sparse and limited to determination of common ions. Streamflow sediment determinations have been limited in areal coverage and range of river stage. Sediment loads carried by streams at peak flows greater than mean annual peaks have not been determined.

116) Sheridan, W.L. 1961. Temperature relationships in a pink salmon stream in Alaska. Ecology. 42: 91-98. (J)

Author abstract (Author Conclusions and Summary): The temperature regimen in 2 pink salmon spawning riffles in Cabin creek, southeast Alaska were studied for a period of 14 months in 1949-50. These studies were undertaken because little was known of the temperature regimens of streams in the area and because survival of both adult and young pink salmon in freshwater depends in part upon suitable water temperatures.

Temperatures of the air, stream water, intragravel water, and bank groundwater were measured. A multiple thermocouple system was installed in each of 2 spawning riffles to measure temperatures in the gravel and in the banks.

Analyses of temperature data showed the following:

1. Although the extent of relationship between temperatures of the various media varied with the season, air temperatures were found to dominate and govern all water temperatures during a large part of the climatic year. During the summer and fall months, the closest relationship existed between temperatures of stream water and intragravel water ($r = 0.99$); the least between air and groundwater temperatures ($r = 0.63$). because of close agreement between air and stream and intragravel water temperatures, abnormal air temperatures can affect pink salmon adult spawners as well as eggs and larvae.
2. Winter stream temperatures depend to a large extent on whether the stream is covered with ice and snow. If the stream is clear of ice, stream temperatures are usually higher than when the stream is covered. If the stream is covered, temperatures in the stream are less influenced by air temperatures. The protective influence of an ice and snow layer was evident in Cabin Creek during one of the coldest winters on record.
3. In the spring, melting snow subdues the effect of high air temperatures on water temperatures. Variable yearly water temperatures in the spring, caused by an interaction of air temperatures and accumulated snow, can influence the number of temperature units available to developing pink salmon larvae, hence may cause fry to migrate to sea at unfavorable times.
4. Temperature gradation was more pronounced in groundwater of the banks than in water within the gravel of the streambed, and was more marked in the intertidal zone than in the stream above tidal influence. In the intertidal zone, temperature gradation was the result of ebb and flow of warmer saltwater over the area. Temperature changes in the intertidal zone depend mainly on tide level, temperatures of stream and saltwater, and permeability of streambed gravels.

Saltwater bathing intertidal zones may give salmon eggs and larva protection against freezing during extremely cold winters and may accelerate developmental rate because of higher temperatures than in the stream above the tides. Pink salmon eggs reared in dilute saltwater also have a higher survival than eggs reared in freshwater controls.

117) Sheridan, W.L. 1962. Relation of stream temperatures to timing of pink salmon escapements in southeast Alaska. In: Symposium of Pink Salmon. H.R. Mac Millan Lectures in Fisheries. Symposium held at the University of British Columbia, 13-15 October 1960, Vancouver, British Columbia. N.J. Wilimovsky, Editor. Pages 87-101. (J)

Author abstract (Author Summary): 1. Fisheries Research Institute stream surveys (conducted from 1949 through 1957) in Southeast Alaska clearly established that (1) pink salmon in this region return and spawn in different streams at different times, and (2) some spawning streams are consistently colder than others, especially during the summer and fall spawning season. 2. Correlation analyses of data on timing of the runs and temperatures of the streams indicate that in most in stances cold streams are entered and spawned in earlier in the season than warmer streams. 3. We suggest that coordination of time of spawning with following temperatures during incubation is necessary for highest survival of the species because a: there is an optimum sequence of temperatures during development of eggs and larvae. Deviations from the normal temperature pattern can cause mortality. b. There is presumably on "best" period of time for the fry to enter saltwater. For fry to migrate to sea during this "best" period eggs must be deposited at a specific time and temperatures during incubation must follow a relatively restricted pattern. c. the normal time of Seward migration (April and May) may be the "best" time because of (1) food availability and (2) saltwater temperatures and salinities or other factors about which very little is known.

118) Sheridan, W.L., M.P. Perensovich, T. Faris, and K. Koski. 1984. Sediment content of streambed gravels in some pink salmon spawning streams in Alaska. 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 153-165. (B)

Author abstract: Composition of gravel was measured in selected pink salmon spawning riffles in several streams in southeast Alaska, one stream in Yakutat, and one stream in Prince William Sound, during the period 1963-1971. Over 2,000 streambed samples were analyzed for fine particulate matter. The point measurement, percent < 0.83 mm in diameter, was used throughout. There was good agreement between percent < 0.83 and the "fredle index," and between results of analyzing gravel samples by the volumetric (wet) method and gravimetric (dry) method.

The mean percent particle size < 0.83 mm for 18 streams was 8.9. Separation of streams in logged watersheds from those in unlogged watershed resulted in means of 9.1 percent for streams in logged drainages and 7.1 percent for streams in unlogged watersheds, but tests with a nested Analysis of Variance showed no significant difference in percent fines < 0.83 between six streams in logged watersheds and six streams in unlogged watersheds. Tests for differences between sediment levels sampled during different seasons showed significant differences in some cases, and none in others.

119) Sidle, R.C., and A.J. Campbell. 1983. Suspended sediment regime of Bambi Creek, Chichagof Island, Alaska. Transactions of the American Geophysical Union. 64: 700. (F, G, I)

Electronic abstract: Sedimentation is a major concern to anadromous fish streams because of the potential for reducing oxygen and nutrient transport within stream gravels and forming a barrier to fry emergence. The supply of sediment to forest steams in coastal Alaska is primarily related to the inherent stabilities of landforms and stream channels. Suspended sediment monitoring during the fall storm season at Bambi Creek, a small, second-order stream in the Trap Bay watershed, began in 1980. Over the 3-yr. period from 1980 to 1982, nine storms were sampled including all major storms in 1982. Regression relationships developed for total suspended sediment (TSS) versus discharge for the combined nine storms, indicate that less than 29% of the variation in TSS can be explained by selecting streamflow as the only independent variable. Detailed analysis of sediment data for the five storms sampled in 1982 revealed seasonal and within-storm patterns of transport.

120) Sidle, R.C., and A.J. Campbell. 1985. Patterns of suspended sediment transport in a coastal Alaska stream. Water Resources Bulletin. 21: 909-917. (I)

Electronic abstract: Suspended sediment data from a 154 ha watershed on northeast Chichagof Island, Alaska, were collected over three fall storm seasons from 1980 to 1982. Sediment rating curves for nine pooled storms explained less than 34% of the variation in total suspended solids (TSS). Significantly higher concentrations of suspended sediment occurred during the rising limb of storm hydrographs than for similar flows on the falling limb, accounting for hysteresis loops in TSS versus streamflow plots for individual storms. These hysteresis loops were wider during early season storms, indicating that easily transportable fine sediment may have been flushed from the upper portion of channel banks and from behind large organic debris during early season peak flows. Turbidity correlated well (r=0.94) with TSS for all stormflow data combined. Organic matter constituted an average of 35% of TSS for all water quality samples.

121) Sidle, R.C., and A.M. Milner. 1989. Stream development in Glacier Bay National Park, Alaska, U.S.A. Arctic and Alpine Research. 21: 350-363. (A, F, G)

Electronic abstract: Examines effects of hydraulics, sediment supply, channel condition, and riparian vegetation on stream development over time. Field studies conducted on five streams.

122) Smith, R.D., and J.M. Buffington. 1993. Effects of large woody debris on channel unit distribution in southeast Alaska. In: Proceedings of Watershed '91: A Conference on the Stewardship of Soil, Air, and Water Resources, 16-17 April 1991, Juneau, Alaska. T. Brock, Editor. USDA Forest Service, Alaska Region, R10-MB-217. Pages 43-44. (A, D)

Author abstract: The importance of large woody debris (LWD) in stream channels in forested areas is documented by research conducted over the past several years. As a result, the practice of removing LWD from streams in managed areas has generally been discarded. More information is needed however to refine guidelines, including effective designs for buffer strips for management within riparian zones. Information is also needed to improve guidelines for rehabilitation of streams impacted by outdated management practices. Presumably, the riparian zone must be relied upon to provide the stream channel with a sustained supply of debris necessary for maintenance of channel morphologic characteristics that provide fish habitat. The amounts, sizes, and types of debris required to provide adequate fish habitat are not well known. We are addressing these information needs by conducting studies of the distribution of stream channel units in both undisturbed streams and streams where loading of LWD has been reduced. Channel units are spatial divisions of a stream channel distinguished by local hydraulics and channel morphology and are generally analogous to fish habitat units.

Preliminary results clearly indicate that LWD loading and characteristics are among the most important variables controlling the distribution of channel units, in particular various types of pools.

123) Smith, R.D., R.C. Sidle, and P.E. Porter. 1993. Effects of bedload transport of experimental removal of woody debris from a forest gravel-bed stream. Earth Surface Processes and Landforms. 18: 455-468. (A, D, F, I)

Author abstract: Experimental removal of woody debris from a small, gravel-bed stream in a forested area resulted in a four-fold increase in bedload transport at bankfull discharge. This was caused by increased transportability of sediment previously stored upslope of debris buttresses or in low-energy hydraulic environments related to debris. Bank erosion delivered additional sediment to the channel, and transport energy was increased by an inferred increase in the component of total boundary shear stress affecting grains on the bed. Increased transport following debris removal in May 1987 continued throughout the entire autumn storm season through late November 1987, indicating persistent adjustment of the stream bed and banks despite marked response to earlier flows as large as bankfull. Stream bed adjustments included development of a semi-regular sequence of alternate bars and pools, many of which were spaced independently of former pool locations.

124) Starostka, V.J. 1994. Use of the geographic information system in aquatic habitat management. Northeast Pacific Pink and Chum Salmon Workshop. Pages 171-172. (A)

Electronic abstract: The channel type, an inventory and mapping tool for stream classification based on stream reaches, was incorporated into the geographic information system (GIS) to facilitate manipulation and storage of stream inventory data. The basic component of the channel type is the fluvial process group which describes the interrelationship between runoff, landform relief, geology, and glacial or tidal influences on erosion and depositional processes. Channel type inventories provide key information on fish habitat utilization, habitat capability and enhancement options. Most Tongass National Forest, state, and native corporation streams in Southeast Alaska have been mapped using the channel type method.

125) Stednick, J.D., L.N. Tripp, and R.J. McDonald. 1982. Slash burning effects on soil and water chemistry in southeastern Alaska. Journal of Soil and Water Conservation. 37: 126-128. (I)

Electronic abstract: Timber harvest followed by slash burning in the coastal hemlock-spruce forests of Chicagof Island in southeastern Alaska did not produce significant long-term effects on soil or water resources. A 13 ha site, logged in 1977 and burned in June 1978, was monitored by collecting daily stream water samples from above and below the burn during the snow-free months of 1978 and 1979. Soil samples were also analyzed. Suspended sediment levels were higher in the water below the burn (116.8 mg per liter) than above the burn (35.4 mg per liter). Fourteen of the 16 water quality parameters were not significantly different when above-burn and below-burn sample results were compared. However, total P and K levels were higher in below-burn stream water. In soil samples slash burning produced no significant differences in litter depth, pH, N, P, and Ca levels. However, K and Mg concentrations in the burned soil were about half of the control concentrations.

126) **Still, P.J. 1980. Index of streamflow and water-quality records to September 30, 1978, southeast Alaska. USDI Geological Survey, Anchorage, Alaska, Open-File Report 80-698. 26pp. (G, I)**

Electronic abstract: This report, which is one of a series of reports for Alaska, lists stations in southeast Alaska at which streamflow and water quality data have been collected by the U.S. Geological Survey. Included are a hydrologic subregion map of southeast Alaska and a table listing the types of data collected and periods of record.

127) **Swanson, F.J., M.D. Bryant, G.W. Lienkaemper, and J.R. Sedell. 1984. Organic debris in small streams, Prince of Wales Island, southeast Alaska. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-166. 12pp. (D)**

Author abstract: Quantities of coarse and fine organic debris in streams flowing through areas clearcut before 1975 are 3 and 6 times greater than quantities in streams sampled in old-growth stands in Tongass National Forest, central Prince of Wales Island, southeast Alaska. The concentration of debris in streams of clearcut Sitka spruce-western hemlock forests in southeast Alaska, however, is about half that in streams of clearcut Douglas-fir-western hemlock forests in western Oregon. Management guidelines for maintaining natural debris conditions include minimizing the addition of fresh material to a channel during management activities, leaving natural accumulations of debris, and managing streamside areas for production of a continuous, long-term supply of large debris for channels. Considerations in planning stream cleanup include the length of time the debris has resided in the channel and the stability of debris, which is a function of its size, orientation, and degree of burial and decay.

128) **Swanston, D.N. 1969. Mass wasting in coastal Alaska. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Paper PNW-83. 15pp. (K)**

Author abstract: Mass wasting, a dominant form of erosion in coastal Alaska, is common where slopes are oversteepened by glacial erosion, soils are newly developed and shallow, and there is abundant rainfall. Presently, the most practical policy for the forest-land manager is avoidance of susceptible areas during timber harvest. Old debris avalanche and flow scars are visible on aerial photos, but a more accurate identification of these areas can be made from a slope-gradient map, which can be used to (1) delineate potential slide areas, (2) determine percentage of slide-prone ground, and (3) establish cutting patterns causing minimum disturbance.

129) Swanston, D.N. 1974. The forest ecosystem of southeast Alaska. 5. Soil mass movement. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-17. 22pp. (K)

Author abstract: Research in southeast Alaska has identified soil mass movement as the dominant erosion process, with debris avalanches and debris flows the most frequent events on characteristically steep, forested slopes. Periodically high soil water levels and steep slopes are controlling factors. Bedrock structure and the rooting characteristics of trees and other vegetation exert a strong influence on relative stability of individual sites.

Timber harvesting operations have a major impact on initiation and acceleration of these movements. The cutting of timber itself has been directly linked with accelerated mass movements, and the accumulation of debris linked with accelerated mass movements, and the accumulation of debris in gullies and canyons has been identified as a major contributor to the formation of large-scale debris flows or debris torrents. The limited road construction on steeper slopes thus far has had a relatively small impact.

Effective management practices on such terrain consist of identification and avoidance of the most unstable areas and careful control of forest harvesting operations in questionable zones.

130) Swanston, D.N., and R. Erhardt. 1993. Short-term influence of natural landslide-dams on the structure of low-gradient channels: An extended abstract. In: Proceedings of Watershed '91: A Conference on the Stewardship of Soil, Air, and Water Resources, 16-17 April 1991. T. Brock, Editor. USDA Forest Service, Alaska Region, R10-MB-217. Pages 34-38. (A, D, F)

Author abstract: Landslides, one of the principal processes of sediment and large woody debris transport from uplands to anadromous fish streams in southeast Alaska, tend to enter low-gradient channels at nearly right angles. Rapid deceleration from impact of debris with the opposing bank, coupled with a substantial reduction in gradient, causes dewatering and deposition of a debris wedge at and immediately downstream from the point of entry of the landslide. The persistence of the wedge, both as a dam and temporary base-level for the channel, is largely determined by composition of material and the size of flows carried by the channel during storms. Subsequent flows over and around the deposit tend to be sediment poor and energy rich, resulting in more rapid downcutting, increases in downstream channel scour, and the frequent shifting of the channel bed for several hundred meters downstream. In this dynamic environment, the large woody debris piles downstream of the wedge serve as focal points for formation and persistence of habitat elements such as pools, riffles, and side channels. These habitat elements remain viable until occurrence of additional landslides or flood flows with power great enough to remobilize the debris.

131) Swanston, D.N, W.R. Meehan, and J.A. McNutt. 1977. A quantitative geomorphic approach to predicting productivity of pink and chum salmon streams in southeast Alaska. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Paper PNW-227. 16pp. (K)

Author abstract: Twenty-one quantitative geomorphic variables, measured from aerial photographs and topographic and geologic maps of 78 watersheds, were tested for significance in differentiating between good and poor producers of pink and chum salmon. A discriminant model was then constructed. Using this model, the decision maker can make a qualititative estimate of potential pink and chum salmon production for any southeast Alaska watershed with minimum field investigation.

132) Swanston, D.N., C.G. Shaw III, W.P. Smith, K.R. Julin, G.A. Cellier, and F.H. Everest. 1996. Scientific information and the Tongass Land Management Plan: Key findings from the scientific literature, species assessments, resource analyses, workshops, and risk assessment panels. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-386. (D, F, I)

Author abstract: This document highlights key items of information obtained from the published literature and from specific assessments, workshops, resource analyses, and various risk assessment panels conducted as part of the Tongass land management planning process. None of this information dictates any particular decision; however, it is important to consider during decision making or when the consequences of any particular decision are evaluated.

133) Thedinga, J.F., M.L. Murphy, J. Heifetz, K.V. Koski, and S.W. Johnson. 1989. Effects of logging on size and age composition of juvenile Coho salmon (*Oncorhynchus kisutch*) and density of presmolts in southeast Alaska streams. Canadian Journal of Fisheries and Aquatic Sciences. 46: 383-391. (C)

Electronic abstract: Short-term effects of logging on age composition and size of juvenile coho salmon (*Oncorhynchus kisutch*) were studied in 18 streams in Southeast Alaska in 1982 and 1983; studies were in old-growth and clear-cut reaches with or without buffer strips. The number of fry (age 0) in summer and winter was proportionately higher in buffered and clear-cut reaches than in old-growth reaches, and all treatments averaged a 20% decrease in fry from summer to winter. Fry length and condition factor were greater for buffered and clear-cut reaches than for old-growth reaches, whereas parr (age 1 and older) size did not differ among treatments. Fry and parr were larger in the southern than in the northern regions and their length and weight were directly related to periphyton biomass and benthos density.

134) Thomas, R.E., J.A. Gharrett, M.G. Carls, S.D. Rice, and A. Moles. 1986. Effects of fluctuating temperature on mortality, stress, and energy reserves of juvenile Coho salmon. Transactions of the American Fisheries Society. 115: 52-59. (J)

Author abstract: The effects of fluctuating diel temperature cycles on survival, growth, plasma cortisol and glucose concentrations, liver weight, and liver glycogen of juvenile coho salmon

(*Oncorhynchus kisutch*) were determined. Temperature cycles (10-13, 9-15, 8-17, and 6.5-20 C) were selected to simulate observed temperatures in clear-cuts of southeastern Alaska. Different levels of feeding, including starvation, were used in each test. LT50s were 28 C for age-0 fish (350 mg) and 26 C for age-II fish (22-g presmolts). Cyclic temperatures for 40 d, averaging 11 C daily, did not influence growth of age-0 fish on any food ration as compared to controls held at a constant 11 C. Plasma cortisol and glucose concentrations were significantly greater in fish maintained for 20 d in the 6.5-20 C cycle, but not different in fish in 10-13 and 9-15 C cycles or a constant 11 C. These elevated concentrations may be indicators of long-term stress. Plasma cortisol concentrations were lower in starved fish than in fed fish at all temperature regimes; however, fluctuating temperature did not enhance starvation effects on cortisol levels. Diel temperature cycles did not affect liver weights or liver glycogen concentrations. It is concluded that temporary high temperatures above lethal limits, even if only for 1-2 h, may be more harmful than long-term fluctuating temperatures.

135) USDA Forest Service, Alaska Region. 2002. A summary of technical considerations to minimize the blockage of fish at culverts on the national forests of Alaska. A supplement to the Alaska Region's June 2, 2002 briefing paper titled Fish Passage on Alaska's National Forests. (K)

Author abstract (Author Introduction): This is a general technical review of the process undertaken by the USDA Forest Service, Region 10 interagency fish passage task force, to address the issue of fish blockage at road crossings. This review will answer the following questions:

1. Why is it important to provide fish passage at road crossings?
2. What is a "blockage" of fish movement at road culverts?
3. How were existing road culverts evaluated to determine if they blocked fish?
4. How are new and reinstalled culverts being designed to ensure fish passage?
5. What additional information is needed to better address fish passage issues?

Providing for fish passage at stream and road intersections is an important consideration when constructing or reconstructing forest roads. Improperly located, installed or maintained stream crossing structures, primarily culverts, can restrict fish movement, thereby adversely affecting fish populations. These structures may present a variety of obstacles to fish migration. The most common obstacles are culvert outlet vertical barriers, debris blockages, and excessive water velocities.

136) Walter, R.A. 1984. A stream ecosystem in an old-growth forest in southeast Alaska. Part II: Structure and dynamics of the periphyton community. 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 57-69. (C, E, H)

Author abstract: Average net primary production of periphyton in a small undisturbed stream in southeast Alaska ranged from 1 to 354 mg ash-free dry weight (AFDW).m^{-2}.day^{-1} over a 1 year period. Annual production was 13.2 gAFDW / m^2 for the entire creek. Third-order sections were twice as productive as second-order sections, and the stream / estuary ecotone was more productive than freshwater sections. Primary production was probably limited by light in freshwater and by nutrients or grazing in the stream / estuary ecotone. Weighted mean annual standing crop of chlorophyll *a* for the entire creek was 7.2 mg/m^2. Diatoms dominated volume but not abundance of total algal cells. The filamentous chlorophyte *Ulothrix* dominated production in summer. Many of the dominant species appear to be poorly known or not described. The comparatively high net primary production and unusual species composition of periphyton in Porcupine Creek may be due to the stream's relatively large salmon runs, low gradient, and long intertidal area. If the watershed were logged, nutrients would probably replace light as the factor limiting primary production and standing crop of filamentous chlorophytes could be expected.

137) Wipfli, M.S. 1997. Terrestrial invertebrates as salmonid prey and nitrogen sources in streams: Contrasting old-growth and young-growth riparian forests in southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 54: 1259-1269. (C)

Author abstract: Terrestrial-derived invertebrate (TI) inputs into streams and predation on them by salmonids (40.180 mm fork length) were measured in six coastal Alaska stream reaches from April through October 1993.1994; riparian habitat of three stream reaches contained conifer-dominated old-growth (no timber harvesting) and three were alder-dominated young-growth (31 years postclearcutting). Data from pan-traps placed on stream surfaces showed that TI biomass and nitrogen inputs averaged up to 66 and 6 mg×m^{-2}×day^{-1}, respectively, with no significant difference between habitats. Stomach contents from coho salmon (*Oncorhynchus kisutch*), cutthroat trout (*O. clarki*), and Dolly Varden (*Salvelinus malma*) revealed that TI and aquatic-derived invertebrates (AI) were equally important prey. Additionally, salmonids from young-growth systems ingested a greater TI proportion than those from old-growth systems. There were trends but no significant differences between habitats of TI and AI biomass ingested; however, statistical power was <0.30. These results showed that TI were important juvenile salmonid prey and that a riparian overstory with more alder and denser shrub understory may increase their abundance. Riparian vegetation management will likely have important consequences on trophic levels supporting predators, including but not limited to fishes.

138) Wipfli, M.S., and D.P. Gregovich. 2002. Export of invertebrates and detritus from fishless headwater streams in southeastern Alaska: Implications for downstream salmonid production. Freshwater Biology. 47: 957-969. (C)

Author abstract: 1. We examined the export of invertebrates (aquatic and terrestrial) and coarse organic detritus from forested headwaters to aquatic habitats downstream in the coastal mountains of southeast Alaska, U.S.A. Fifty-two small streams (mean discharge range: 1.2-3.6 L S-I), representing a geographic range throughout southeast Alaska, were sampled with 250-µm nets either seasonally (April, July, September) or every 2 weeks throughout the year. Samples were used to assess the potential subsidy of energy from fishless headwaters to downstream systems containing fish.
2. Invertebrates of aquatic and terrestrial origin were both captured, with aquatic taxa making up 65-92% of the total. Baetidae, Chironomidae and Ostracoda were most numerous of the aquatic taxa (34, 16 and 8%, respectively), although Coleoptera (mostly Amphizoidae) contributed the

greatest biomass (30%). Mites (Acarina) were the most numerous terrestrial taxon, while terrestrial Coleoptera accounted for most of the terrestrial invertebrate biomass.
3. Invertebrates and detritus were exported from headwaters throughout the year, averaging 163 mg invertebrate dry mass $stream^{-1}$ day^{-1} and 10.4 g detritus $stream^{-1}$ day^{-1}, respectively. The amount of export was highly variable among streams and seasons (5-6000 individuals $stream^{-1}$ day^{-1} and <1-22 individuals m^{-3} water; <1-286 g detritus $stream^{-1}$ day^{-1} and <0.1-1.7 g detritus m^{-3} water). Delivery of invertebrates from headwaters to habitats with fish was estimated at 0.44 g dry mass m^{-2} $year^{-1}$. We estimate that every kilometre of salmonid-bearing stream could receive enough energy (prey and detritus) from fishless headwaters to support 100-2000 young-of-the-year (YOY) salmonids. These results illustrate that headwaters are source areas of aquatic and terrestrial invertebrates and detritus, linking upland ecosystems with habitats lower in the catchment.

139) Wipfli, M.S., and J. Musslewhite. 2004. Density of red alder (*Alnus rubra*) in headwaters influences invertebrate and detritus subsidies to downstream fish habitats in Alaska. Hydrobiologia. 520: 153-163. (C)

Author abstract: We investigated the influence of red alder (*Alnus rubra*) stand density in upland, riparian forest on invertebrate and detritus transport from fishless headwater streams to downstream, salmonid habitats in southeastern Alaska. Red alder commonly regenerates after soil disturbance (such as from natural landsliding or timber harvesting), and is common along streams in varying densities, but its effect on food delivery from headwater channels to downstream salmonid habitats is not clear. Fluvial transport of invertebrates and detritus was measured at 13 sites in spring, summer, and fall during two years (2000-2001). The 13 streams encompassed a riparian red alder density gradient (1-82% canopy cover or 0-53% basal area) growing amongst young-growth conifer (45-yr-old stands that regenerated after forest clearcutting). Sites with more riparian red alder exported significantly more invertebrates than did sites with little alder (mean range across 1-82% alder gradient was about 1-4 invertebrates m^{-3} water and 0.1-1 mg invertebrates m^{-3} water, respectively). Three-quarters of the invertebrates were of aquatic origin: the remainder was of terrestrial origin. Aquatic taxa were positively related to the alder density gradient, while streams with less alder (mean range across 1-82% alders gradient was 0.01-0.06g detritus m^{-3} water). Based on these data, we predict that headwater streams with more riparian alder will provide more invertebrates and support more downstream fish biomass than those basins with little or no riparian alder, provided these downstream food webs utilize this resource subsidy.

140) Wipfli, M.S., J. Hudson, and J. Caouette. 1998. Influence of salmon carcasses on stream productivity: Response of biofilm and benthic macroinvertebrates in southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences. 55: 1503-1511. (C, E)

Author abstract: This study was conducted to determine if salmon carcasses (from spawning adults) increased stream biofilm ash-free dry mass (AFDM) and benthic macroinvertebrate abundance in southeastern Alaska, U.S.A. Thirty-six once-through artificial streams were situated along, and received water and drifting invertebrates from, a natural stream. Two treatments (salmon carcass, control) were sampled six times during a 3-month period in a randomized incomplete block design with a 2 x 6 factorial treatment structure. Additionally, two natural stream sites were sampled once for biofilm and macroinvertebrates, one site receiving 75 000 adult salmon migrants during 1996 and the other upstream of spawning salmon. While biofilm AFDM was 15 times higher in carcass-enriched reaches of Margaret Creek, there were no detectable treatment differences in the artificial streams. Total macroinvertebrate densities were up to eight and 25 times higher in carcass-enriched areas of artificial and natural streams, respectively; Chironomidae midges, Baetis and Cinygmula mayflies, and Zapada stoneflies were the most abundant taxa. The increased biofilm in Margaret Creek and macroinvertebrate abundance in both systems suggests that salmon carcasses elevated freshwater productivity. This marine-based positive feedback mechanism may be crucial for sustaining aquatic-riparian ecosystem productivity and long-term salmonid population levels.

141) Wipfli, M.S., J.P. Hudson, D.T. Chaloner, and J.P. Caouette. 1999. Influence of salmon spawner densities on stream productivity in southeast Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 56: 1600-1611. (C, E)

Author abstract: We conducted this study to determine the relationship between salmon spawner abundance and stream biofilm and benthic macroinvertebrate abundance in Southeast Alaska. Experiments took place in outdoor artificial and natural streams. Six pink salmon (*Oncorhynchus gorbuscha*) carcass treatments (0.00, 1.45, 2.90, 4.35, 5.80, and 7.25 kg wet mass) placed in artificial channels were subsampled repeatedly for biofilm ash-free dry mass (AFDM), chlorophyll *a*, and macroinvertebrates. In a small (nonanadromous) forest stream, we sampled benthos throughout a 66-m reach 17 days after distributing 60 carcasses along the lower half of that reach. All response variables significantly increased in response to carcass additions in both artificial and natural streams. Chlorophyll *a* continued to increase across all loading rates, while AFDM and total macroinvertebrate densities showed no further response to loading beyond the first treatment (1.45 kg) in artificial streams. In the natural stream, AFDM and chironomid densities continued increasing across loading levels. These results indicated that increased spawner densities increased lower trophic level abundance until a trophic capacity was reached. Salmon escapement goals should consider food web effects, especially on trophic levels that support juvenile salmonids, that ultimately affect freshwater salmon production.

142) Wipfli, M.S., R.L. Deal, P.E. Hennon, A.C. Johnson, T.L. De Santo, T.A. Hanley, M.E. Schultz, M.D. Bryant, R.T. Edwards, E.H. Orlikowska, and T. Gomi. 2002. Managing young upland forests in southeast Alaska for wood products, wildlife, aquatic resources, and fishes: Problem analysis and study plan. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-558. 64pp. (C, E)

Author abstract: Red alder (*Alnus rubra* Bong.) appears to influence the productivity of young-growth conifer forest and affect the major resources (timber, wildlife, and fisheries) of forested ecosystems in southeast Alaska. We propose an integrated approach to understanding how alder influences trophic links and processes in young-growth ecosystems. The presence of red alder is expected to increase understory biomass, and aquatic, riparian, and terrestrial invertebrate abundance, providing more food for herbivores, fish, and birds. We predict that most red alder trees will die standing, and woody debris will be small and mobile in streams. Nitrogen fixation by red alder in mixed stands may result in larger, more commercially valuable conifers. Inclusion of red alder in the regenerating stand may therefore mitigate some negative impacts of clearcutting, and may increase total wood production form the landscape.

143) Wood-Smith, R.D., and J.M. Buffington. 1996. Multivariate geomorphic analysis of forest streams: Implications for assessment of land use impacts on channel condition. Earth Surface Processes and Landforms. 21: 377-393. (A, D)

Author abstract: Multivariate statistical analyses of geomorphic variables from 23 forest stream reaches in southeast Alaska result in successful discrimination between pristine streams and those disturbed by land management, specifically timber harvesting and associated road building. Results of discriminant function analysis indicate that a three-variable model discriminates 10 disturbed from 13 undisturbed reaches with 90 per cent and 92 per cent correct classification respectively. These variables are the total number of pools per reach, the ratio of mean residual pool depth to mean bankfull depth, and the ratio of critical shear stress of the median surface grain size to bankfull shear stress. The last variable can be dropped without a decrease in rate of correct classification; however, the resulting two-variable model may be less robust. Analysis of the distribution of channel units, including pool types, can also be used to discriminate disturbed from undisturbed reaches and is particularly useful for assessment of aquatic habitat condition. However, channel unit classification and inventory can be subject to considerable error and observer bias. Abundance of pool-related large woody debris is highly correlated with pool frequency and is an important factor determining channel morphology. Results of this study yield a much needed, objective, geomorphic discrimination of pristine and disturbed channel conditions, providing a reference standard for channel assessment and restoration efforts.

144) Ziemer, R.R., and D.N. Swanston. 1977. Root strength changes after logging in southeast Alaska. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-306. 10pp. (K)

Author abstract: A crucial factor in the stability of steep forested slopes is the role of plant roots in maintaining the shear strength of soil mantles. Roots add strength to the soil by vertically anchoring through the soil mass into failures in the bedrock and by laterally tying the slope together across zones of weakness or instability. Once the covering vegetation is removed, these roots deteriorate and much of the soil strength is lost.

Measurements of change in strength of roots remaining in the soil after logging at Staney Creek on Prince of Wales Island, southeast Alaska, indicate that loss of strength in smaller roots occurs rapidly for all species the first 2 years. Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) roots are more resistant to loss of strength than are Sitka spruce *(Picea sitchensis* (Bong.) Carr.) roots. By 10 years, even the largest roots have lost appreciable strength.

Alaska—FRPA Region II

(Interior Spruce/Hardwood Forest, South of the Alaska Range)

145) Ashton, W.S. 1983. Determination of fish passage discharge for design of hydraulic structures on Little Tonsina River, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 51pp. (G)

Author abstract: The flow regime of the Little Tonsina River, Alaska, was analyzed to determine the peak and low flows during periods of fish migration. Seven methods of predicting the Critical Migration Discharge for use in designing hydraulic structures for fish passage were evaluated. These methods were evaluated to determine which method provided the most accurate prediction of streamflow during periods of fish migration. Three periods of analysis were considered: spring, April 1 to June 30; summer, July 1 to August 31; and fall, September 1 to October 31. For the Little Tonsina River the spring period 12-hour duration discharge with a 2-year return period and the fall period 7-day, 5-year return period low-flow were considered critical for the design of culverts for fish passage. The Critical Migration Discharge determined using floods predicted by regional regression equations overestimated the spring and fall design discharges by 51% and 8%, respectively.

146) Feulner, A.J. 1971. Water-resources reconnaissance of a part of the Matanuska-Susitna Borough, Alaska. USDI Geological Survey Hydrologic Investigations Atlas HA-364. (G, I)

Electronic abstract: This one-sheet hydrologic atlas consisting of maps, graphs, tables of data, and a descriptive text summarizes the groundwater and surface water resources of the Matanuska-Susitna borough, Alaska. Average cumulative discharge of all measured streams in the study area was about 28,000 cfs. The greatest yields of groundwater (more than 100 gpm) comes from wells in the flood plains and lowland areas adjacent to streams and rivers. These areas are underlain by glacial and alluvial deposits of sand and gravel. Groundwater in the study area has a greater chemical-quality variation than the surface water. It generally is harder than surface water, except in areas adjacent to streams where the water quality of both is similar. Much of the groundwater obtained from shallow wells drilled in the alluvium contains objectionable concentrations of iron, most of which could be easily removed by aeration and filtration of the water prior to storage or use. Groundwater ranges from about 50 to more than 200 mg/liter in hardness and is of the calcium bicarbonate type.

147) Freeman, M.W., and J. Durst (Editors). 2004. Region II forest resources & practices riparian management annotated bibliography. Report by the Alaska Department of Natural Resources Division of Forestry, and Alaska Department of Natural Resources Office of Habitat Management & Permitting. Report to the Alaska Board of Forestry. 136pp. plus an alphabeticasl list of references (A, B, C, D, E, F, G, H, I, J)

Compiler abstract: This annotated bibliography is a compilation of published research relevant to riparian management issues in the spruce/hardwood forests of southcentral Alaska (i.e. Region II). The bibliography is separated into eleven topics: 1) overwintering and spawning ecology of fishes in cold climates; 2) adult anadromous fish use in the Susitna River; 3) fluvial processes with special emphasis on glacial river; 4) forestry slope and stability; 5) temperature effects in brownwater streams; 6) effects of beetle epidemics and harvesting on stream flow; 7) the use of winter roads in forest practices, and the relationship with ATV use; 8) riparian areas, logging roads, and invasive species; 9) riparian area function and management in headwaters and small streams; 10) riparian area function and management in lakes; and 11) revegetation in Alaska using native plants, and soils in riparian areas/wetlands and interpretations for use. A brief summary of the referenced literature for each topic is provided at the beginning of each section of the bibliography.

148) Knott, J.M., S.W. Lipscomb, and T.W. Lewis. 1986. Sediment transport characteristics of selected streams in the Susitna River Basin, Alaska, October 1983 to September 1984. USDI Geological Survey Open-File Report 86-424W. 73pp. (G, I)

Author abstract: The upper reaches of the Susitna River have been considered for development of a large power generation system for south-central Alaska. This report presents a summary and discussion of sediment and hydraulic data obtained from October 1983 to September 1984 at ten sites on the Susitna, Chulitna, Talkeetna, and Yentna Rivers. Sediment data include measurements of suspended sediment and bedload discharge and analyses of particle size distribution of suspended sediment, bed-load, and bed material; hydraulic data include measurements of width, average depth and velocity, and water surface slope. Relations between water and sediment discharge are developed for selected sites. Sediment loads for the 1984 water year were estimated for the Yentna, Chulitna, and Talkeetna Rivers and for four sites on the Susitna River. About 25 million tons of sediment was transported by the Susitna River at Susitna Station during the 1984 water year. The Yentna and Chulitna Rivers contributed more than 20 million tons of sediment to the Susitna River. About 90% of suspended material (silt, clay, and sand) transported past upstream sites reached Susitna Station during the same period.

149) Knott, J.M., S.W. Lipscomb, and T.W. Lewis. 1987. Sediment transport characteristics of selected streams in the Susitna River Basin, Alaska: Data for water year 1985 and trends in bedload discharge, 1981-85. USDI Geological Survey Open-File Report 87-229. 51pp. (G, I)

Author abstract: The upper reaches of the Susitna River have been considered for development of a large power generation system for south-central Alaska. Sediment and hydraulic data obtained from October 1984 to September 1985 (water year 1985) at selected sites on the Susitna, Chulitna, Talkeetna and Yentna Rivers are summarized. Sediment data include measurements of suspended sediment and bedload discharge, and analyses of particle size distribution of suspended sediment, bedload, and bed material; hydraulic data include measurements of channel width, average depth and velocity of water, and water surface slope. Relations between water and sediment discharge are developed for each site. Sediment loads for water year 1985 were estimated for the Yentna , Chulitna, and Talkectna Rivers and for three sites on the Susitna River. About 31 million tons of sediment were transported to the Susitna River at Susitna Station during the year. The Yentna and Chulitna Rivers contributed about 21 million tons of sediment to the Susitna River.

150) Kyle, R.E., and T.B. Brabets. 2001. Water temperature of streams in the Cook Inlet Basin, Alaska, and implications of climate change. USDI Geological Survey Water-Resources Investigations Report 01-4109. Anchorage, Alaska. 24pp. (J)

Author abstract: Water-temperature data from 32 sites in the Cook Inlet Basin, south-central Alaska, indicate various trends that depend on watershed characteristics. Basins with 25 percent or more of their area consisting of glaciers have the coldest water temperatures during the open-water season, mid-May to mid-October. Streams and rivers that drain lowlands have the warmest water temperatures. A model that uses air temperature as input to predict water temperature as output was utilized to simulate future trends in water temperature based on increased air temperatures due to climate warming. Based on the Nash-Sutcliffe coefficient, the model produces acceptable results for 27 sites. For basins with more than 25 percent glacial coverage, the model was not as accurate. Results indicate that 15 sites had a predicted water-temperature change of 3 degrees Celsius or more, a magnitude of change that is considered significant for the incidence of disease in fish populations.

151) Martin, D.C. 1988. Aquatic habitat of the Tiekel River, southcentral Alaska, and its utilization by resident Dolly Varden (*Salvelinus malma*). M.S. Thesis, University of Alaska, Fairbanks. 179pp. (C, J)

Author abstract: The Tiekel River is a third order stream in southcentral Alaska and contains stream-resident Dolly Varden (*Salvelinus malma*) that are small in size. The purpose of this project was to compile baseline aquatic habitat data, determine which habitats were the most important to the Dolly Varden and should be protected from future development, and develop management recommendations. Habitat data suggested that the Tiekel River drainage contained a wide variety of habitats that could fulfill the life requirements for a number of fish species. Habitat suitability index graphs were constructed for the important habitat variables and should be used in the planning of future habitat alterations to assure that habitat quality does not suffer. The beaver ponds were found to have a greater probability of producing large fish than the stream habitats. Fish size was positively correlated with August water temperatures and chlorophyll *a* concentrations.

152) Martin, D.J. 1996. Spawning gravel quality in selected streams of the Ninilchik Area, Kenai Peninsula, Alaska. Project No. 51-004 revised draft data report written by Pentec Environmental, Inc., Edmonds, Washington. Written for the Alaska Department of Natural Resources and Klukwan Forest Products. 20pp. plus Appendices. (B)

Compiler abstract: This report describes sample locations, sample methods, and 1995 sample results for a monitoring program to measure spawning gravel quality in areas of the Ninilchik area of the Kenai Peninsula where future timber harvest was planned. The monitoring program was initiated to establish baseline (i.e. pre-harvest) conditions which would later be compared against conditions after timber harvest was conducted.

Spawning gravel samples were collected from 13 locations of the North Fork Ninilchik River, Clam Creek, and Stariski Creek. Sample locations were located downstream from forest stands scheduled for timber harvest. Stream channels were characterized by measuring bankfull channel width, average channel depth, and gradient at three consecutive riffles at each gravel sample location. For each gravel sample, spawning gravels were characterized by determining particle size composition by volume and dry weight. The percentage of fines was used as an indicator of habitat quality.

The mean percentage of fines was highly variable among streams, and significant differences in mean levels if fines occurred among the stations within each stream. The 1995 data indicated that pre-harvest levels of fines were relatively high at all stream locations, primarily because Ninilchik area streams are located in old glacial outwash channels and drain an area with low topographic relief composed of sand and small gravels.

153) Mauger, S. 2004. A preliminary water quality assessment of lower Kenai Peninsula salmon bearing streams: August 1998 – June 2004. Homer Soil and Water Conservation District and Cook Inlet Keeper, Homer, Alaska. 71pp. (G, E, I, J)

Compiler abstract: This report presents a preliminary water quality assessment of four salmon bearing creeks on the lower Kenai Peninsula—Ninilchik River, Deep Creek, Stariski Creek, and Anchor River. Water quality data were collected from August 1998 through June 2004, and consisted of the following variables: streamflow, water temperature, dissolved oxygen, pH, total dissolved solids, conductivity, nutrients (nitrogen, phosphorus), turbidity, suspended solids, settleable solids, and color.

154) Schulz, B.K. 1993. Movement of Metasystox-R2 in an Alaskan landscape soil. M.S. Thesis, University of Alaska, Fairbanks. 79pp. (I)

Author abstract: Metasystox-R2 is a systemic insecticide that is injected into the soil to control aphids on ornamental birch trees. Its active ingredient is oxydemeton-methyl (ODM), a highly water soluble organophosphate. Soils in south-central Alaska are frozen for up to six months a year. When not frozen, soils are cold and permeable to water movement. Concerns have been expressed by home owners and pesticide applicators over the potential of Metasystox-R2 to contaminate groundwater under local soil and climatic conditions. An application of Metasystox-R2 was made to five individual birch trees in a landscape setting. Soil samples were collected to a depth of 61 centimeters over a 78-day period following application. Residues of the active ingredient and its toxic sulfone metabolite were recovered at the maximum depth sampled. Results suggest that downward transport of ODM and its toxic sulfone metabolite can be minimized by limiting depth of soil saturation during post-application irrigation.

155) Scott, K.M. 1982. Erosion and sedimentation in the Kenai River, Alaska. US Geological Survey Professional Paper 1235. United States Government Printing Office, Washington, D.C. 35pp. (A, F, G)

Author abstract: The Kenai River is the most important freshwater fishery in Alaska. The flow regime is characterized by high summer flow of glacial melt water and periodic flooding caused by sudden releases of glacier-dammed lakes in the headwaters. Throughout most of its 50-mi course across the Kenai Peninsula Lowlands to Cook Inlet, the river meanders within coarse bed material with a median diameter typically in the range 40-60 mm. Every nontidal section of the stream is a known or potential salmon-spawning site.

The stream is underfit, a condition attributed to regional glacial recession and hypothesized drainage changes, and locally is entrenched in response to geologically recent changes in base level. The coarseness of the bed material is explained by these characteristics, combined with the reservoir like effects of two large morainally impounded lakes, Kenai and Skilak Lakes, that formed as lowland glaciers receded. Throughout the central section of the river the channel is effectively armored, a condition that may have important long-term implications for the ability of this section of channel to support the spawning and rearing of salmon.

The 3.8-river-mile channel below Skilak Lake contains submersed, crescentic gravel dunes with lengths of more than 500 ft and heights of more than 15 ft. Such bed forms are highly unusual in streams with coarse bed material. The dunes were entirely stable from 1950 to at least 1977, so much so that small details of shape were unmodified by a major glacial-outburst flood in 1974. The features are the product of a flood greatly in excess of any recorded discharge.

The entrenched section of the channel has been stable since 1950-51 or earlier; only negligible amounts of bank erosion are indicated by sequential aerial photographs. Bank erosion is active both upstream and downstream from the entrenched channel, however, and erosion rates in those reaches are locally comparable to rates in other streams of similar size. Although erosion rates have been generally constant since 1950-51, evidence suggests a possible recent decrease in bank stability and an increase in erosion that could be related to changes in river use.

The high sustained flow of summer encourages a variety of recreation-related modification to the bank and flood plain—canals, groins, boat ramps, slips, embankments, as well as commercial developments. As population and recreational use increase, development can pose a hazard to the productivity of the stream through increased suspended-sediment concentration resulting directly from construction and, with greater potential for long-term impact, indirectly from bank erosion. A short-term hazard to both stream and developments is the cutoff of meander loops, the risk of which is increased by canals and boat slips cut in the surface layer of cohesive, erosion-resistant sediment on the flood plain within nonentrenched meander loops. A significant long-term hazard is an increase in bank erosion rates resulting from the loss of stabilizing vegetation on the high (as high as 70 ft) cutbanks of entrenched and partly entrenched sections of channel. Potential causes of erosion and consequent vegetation loss are river-use practices, meander cutoffs, and groin construction.

156) Shelby, B., B.P. Van Haveren, W.L. Jackson, D. Whittaker, and D. Prichard. 1990. Resource values and instream flow recommendations: Gulkana National Wild River, Alaska. USDI Bureau of Land Management, Denver, Colorado, Technical Paper. 191pp. (G)

Electronic abstract: The Gulkana River, a clear-water tributary to the Copper River in south-central Alaska, was designated a National Wild River by Congress on December 2, 1980. Inclusion into the Wild and Scenic Rivers System was based partially on its location in a wilderness environment with a variety of wildlife, excellent water quality, excellent habitat for resident and anadromous fish, and outstanding opportunities for recreational boating. The goal of the project was to identify the amount of water necessary to preserve and protect the natural values of the Gulkana National Wild River and its immediate corridor environs and to recommend a legal mechanism through which those recommended flow regimes can be recognized and protected.

157) Tydingco, T.A. 1999. The effects of timber harvest practices on fish habitat in Kenai Peninsula streams. M.S. Thesis, University of Alaska, Fairbanks. 53pp. (B, D, J)

Electronic abstract: The effects of logging on fish habitat in streams of the lower Kenai Peninsula, Alaska during the summers of 1997 and 1998 were evaluated. Large woody debris, riffle particle composition, and temperature were chosen as variables that would reflect fish-related changes in habitat that might result from logging. Only temperature was significantly different (higher) in treatment areas. The logging operations that were investigated provided greater habitat protection than required by the Alaska Forest Resources and Practices Act.

158) Wilson, W.J., M.D. Kelly, and P.R. Meyer. 1987. Instream temperature modeling and fish impact assessment for a proposed large scale Alaska hydroelectric project. In: Regulated Streams: Advances in Ecology. J.F. Craig and J.B. Kemper, Editors. Plenum Press, New York. Pages 183-206. (J)

Electronic abstract: The State of Alaska is proposing to construct a two dam, 1620 megawatt hydroelectric project (U.S. Federal Energy Regulatory Commission N. 7114) on the Susitna River approximately 190 km NNE of Anchorage. A study is underway to determine the effects this project may have on the indigenous aquatic resources of the Susitna drainage. Reported on here are the studies of the expected alteration of the instream temperature regime of the Susitna River. Twenty species of fish are known to inhabit the Susitna basin. This study focuses on the most numerous and economically valuable Pacific salmon species, approximately two million of which annually enter this river to spawn. Analysis of expected effects on salmon from altered water temperatures due to operation of the Susitna Hydroelectric Project is based on a comparison of available predictions from the Stream Network Temperature Simulation Model (SNTEMP) model with fish thermal tolerance criteria. Based on the SNTEMP model results, salmon thermal tolerance criteria, Susitna stock life history information, and professional judgment, the authors conclude that no direct mortality is anticipated to occur from with-project temperatures, although unquantifiable, indirect mortality to some species may occur.

Alaska—FRPA Region III

(Interior Spruce Hardwood Forest, North and West of the Alaska Range)

159) Aldrich, J.W., and C.W. Slaughter. 1983. Soil erosion on subarctic forest slopes. Journal of Soil and Water Conservation. 38: 115-118. (K)

Author abstract: Investigations of sheet-rill erosion in a permafrost-free subarctic setting indicated that stripping all vegetation from the soil surface increased rainfall erosion 16 times over that produced from an undisturbed forest, from a rate of 0.008 ton per acre per year to 0.13 ton per acre per year. Removing the trees from a forested area, with only minor disturbance of ground cover, did not increase erosion. Very low erosion, 0.03 ton per acre per year, was measured from a vehicle trail on permafrost terrain. Comparison of measured erosion with erosion predicted by the universal soil loss equation indicated that the equation overestimated annual rainfall erosion by an average of 21 percent and overestimated individual storm erosion by an average of 174 percent.

160) Aldrich, J.W., and R.A. Johnson. 1979. Surface erosion and sedimentation associated with forest land use in interior Alaska: Completion report. Institute of Water Resources, University of Alaska, Fairbanks, Report No. IRW-99. 87pp. (K)

Author abstract: The magnitude of sheet-rill erosion associated with various landscape manipulations is presented. The Universal Soil Loss Equation's usefulness for predicting annual sheet-rill erosion within interior Alaska is confirmed. Investigations of sheet-rill erosion indicate that removing trees from forested areas with only minor ground cover disturbance did not increase erosion. Removing the ground cover, however, increased erosion 18 times above that on forested areas. Erosion is substantially reduced when disturbed areas are covered with straw mulch and fertilizer. Comparison of the actual erosion and the quantity of erosion predicted with Universal Soil Loss Equation indicates that the equation overestimates annual erosion by an average of 21 percent. It overestimates individual storm erosion by an average of 174 percent. Data are also presented concerning sheet-rill erosion in a permafrost trail, distribution of the rainfall erosion index, and suggested cover and management factor values.

161) Anderson, G.S. 1970. Hydrologic reconnaissance of the Tanana Basin, central Alaska. USDI Geological Survey Hydrologic Investigations Atlas HA-319. 4 sheets. (G)

Electronic abstract: The Tanana basin in interior Alaska covers approximately 44,500 square miles with 576 square miles of its headwaters in Canada. This report is intended to define in broad terms the hydrology of the Tanana basin. Although basic data are limited, sufficient information is available to formulate a framework for further collection of basic data, preliminary development planning, and identification of problems. The Tanana basin is entirely within the discontinuous permafrost zone of Alaska. Groundwater in the Tanana basin occurs under unconfined and artesian conditions. Unconfined groundwater generally is found in unconsolidated alluvium in the valleys and in fractured bedrock beneath high slopes and ridges. Artesian conditions generally occur in the lower slopes where permeable beds are confined by permafrost or by impermeable sedimentary beds. Along the lower hillslopes, flowing artesian wells are common. The thermal effects of water exert a dominant control on the permafrost regimen. Deeper lakes and rivers and the circulation of groundwater cause the degradation of permafrost and limit its distribution both vertically and aerially. The average streamflow of the Tanana River near its mouth is estimated as 37,000 cfs. Approximately 85% of this discharge originates in the Alaska Range; approximately 50% of the discharge is contributed by 4 tributaries from the south side, the Kantishna, Nenana, Nabesna, and Delta Rivers.

162) Ashton, W.S., and S.R. Bredthauer. 1986. Riverbank erosion processes on the Yukon River at Galena, Alaska. In: Proceedings of the Cold Regions Hydrology Symposium, University of Alaska, July 1986, Fairbanks. D.L. Kane, Editor. American Water Resources Association Technical Publication Series TPS-86-1. American Water Resources Association, Bethesda, Maryland. Pages 415-423. (A, F)

Author abstract: Periodic measurements of riverbank recession on the Yukon River at Galena, Alaska have been made since 1946. Intensive studies of channel shape and riverbank erosion were conducted in 1959, 1984 and 1985. Erosion rates varied from 0.3 m/yr (1.0 ft/yr) at banks with developed vegetative protection (peat or bank debris) to 10.8 m/yr (35.5 ft/yr) at steep banks with active thermoerosional niching. Comparison of channel profile measurements from June 1984 and June 1985 indicate that the thalweg did not significantly change location or elevation during a 10-year recurrence interval flood.

163) Brabets, T.P., B. Wang, and R.H. Meade. 2000. Environmental and hydrologic overview of the Yukon River Basin, Alaska and Canada. USDI Geological Survey, Anchorage, Alaska, Water-Resources Investigations Report 99-4204. 106pp. (G, I)

Author abstract: The Yukon River, located in northwestern Canada and central Alaska, drains an area of more than 330,000 square miles, making it the fourth largest drainage basin in North America. Approximately 126,000 people live in this basin and 10 percent of these people maintain a subsistence lifestyle, depending on the basin's fish and game resources. Twenty ecoregions compose the Yukon River Basin, which indicates the large diversity of natural features of the watershed, such a climate, soils, permafrost, and geology.

Although the annual mean discharge of the Yukon River near its mouth is more than 200,000 cubic feet per second, most of the flow occurs in the summer months from snowmelt, rainfall, and glacial melt. Eight major rivers flow into the Yukon River. Two of these rivers, the Tanana River and the White River, are glacier-fed rivers and together account for 29 percent of the total water flow of the Yukon. Two others, the Porcupine River and the Koyukuk River, are underlain by continuous permafrost and drain larger areas than the Tanana and the White, but together contribute only 22 percent of the total water flow in the Yukon.

At its mouth, the Yukon River transports about 60 million tons of suspended sediment annually into the Bering Sea. However, an estimated 20 million tons annually is deposited on flood plains and in braided reaches of the river. The waters of the main stem of the Yukon River and its tributaries are predominantly calcium magnesium bicarbonate waters with specific conductances generally less than 400 microsiemens per centimeter. Water quality of the Yukon River Basin varies temporally between summer and winter. Water quality also varies spatially among ecoregions.

164) Burrows, R.L. 1980. Cross-section, velocity, and bedload data at two erosion sites on the Tanana River near Fairbanks, Alaska, 1979. USDI Geological Survey, Anchorage, Alaska, Open-File Report 80-699. 32pp. (F, G, I)

Author abstract: In an effort to relate river processes to vertical and lateral erosion at two sites on the Tanana River in the vicinity of Fairbanks, measurements of depth, velocity, and bedload-transport rates were made at several sections at each site.

To facilitate comparison of the river processes and ongoing erosion, compilation and graphic presentation of the velocity distributions and bedload-transport rates are presented in conjunction with cross-section configuration immediately adjacent to the area of erosion.

Dry sieve analyses of the bedload samples give particle-size distribution. Approximately 85-95 percent of the material in transport at both sites was in the sand range (>0.062 millimeter <2.0 millimeters).

165) Burrows, R.L., and P.E. Harrold. 1983. Sediment transport in the Tanana River near Fairbanks, Alaska, 1980-81. USDI Geological Survey, Anchorage, Alaska, Water Resources Investigations Report 83-4064. 116pp. (G, I)

Author abstract: Suspended-sediment and bedload-transport rates for the Tanana River near Fairbanks, Alaska can be related to water discharge, and annual sediment loads can be computed using these relations. For a site at Fairbanks, the annual loads in 1980 were 22.0 million metric tons of suspended sediment and 272,000 metric tons of bedload; in 1981, 27.3 million metric tons of suspended sediment and 333,000 metric tons of bedload passed the Fairbanks site. Data collected at five other locations within a 40-kilometer reach of the river indicate very similar suspended-sediment-transport relations, but bedload-transport relations varied from site to site and between 1980 and 1981. For all sites bedload is usually 1 to 1.5 percent of suspended-sediment load.

Particle-size distribution for suspended sediment is similar at all six sites. Median particle size is generally in the silt range; only occasionally is it in the very fine sand range.

Median particle size of bedload varied from the gravel range to the medium sand range for five of the six sampling sites in both years. At the sixth site, the farthest downstream location, median particle size of bedload was in the sand range.

Bed material particles were somewhat coarser at the upstream sites than at the downstream sites. Coarser particles dominated the deeper portions of the channels and finer material was predominant on the bars and overflow parts of the channels. Median particle size of bed material was generally in the coarse gravel range, but was in the medium sand range at the farthest downstream site.

Water-surface profiles show that at all discharges the water-surface slope was steeper at the upstream sites than at the downstream sites.

166) Burrows, R.L., B. Park, and W.W. Emmett. 1979. Sediment transport in the Tanana River in the vicinity of Fairbanks, Alaska, 1977-78. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Open-File Report 79-1539. 37pp. (G, I)

Electronic abstract: Measurements of the sediment load of the Tanana River in the vicinity of Fairbanks, Alaska, show that suspended-sediment transport rate in tons per day, relates to water discharge, in cubic feet per second, as: Suspended-sediment transport rate (tons/day) = 5.717 x 10 to the minus 8th power x water discharge (cubic feet/second) to the 2.713 power, (where the correlation coefficient squared = 0.967). The bedload-transport rate is approximately 1 to 2 percent of the suspended-sediment transport rate. Data collected at Fairbanks and upstream from Fairbanks near North Pole, Alaska, show little difference in size distribution of suspended sediment between the two locations. The median particle size distribution of suspended sediment is generally in the silt range, but at some low-water discharges, the median particle size is in the very fine sand range. The median particle size is in the very fine sand range. The median particle size of bedload near North Pole is generally in the gravel range, but at some low transport rates, the median particle size is in the medium sand range. At Fairbanks, data collected in 1977 indicate median particle sizes of bedload comparable to those of the upstream location, whereas data collected in 1978 indicate a marked decrease in median particle size of bedload between the two locations. For both locations and at all water discharges and sediment transport rates, particles constituting the suspended load are significantly smaller than particles constituting the bedload.

167) Burrows, R.L., W.W. Emmett, and B. Parks. 1981. Sediment transport in the Tanana River near Fairbanks, Alaska, 1977-79. USDI Geological Survey, Anchorage, Alaska, Water-Resources Investigations Report 81-20. 56pp. (G, I)

Author abstract: Suspended-sediment- and bedload-transport rates for the Tanana River near Fairbanks, Alaska, can be related to water discharge, and annual sediment loads can be computed using these relations. For a site near Fairbanks, the average annual (1974-79) load is 24 million metric tons of suspended sediment and 321,000 metric tons of bedload. Upstream, near North Pole, the average annual load is 20.7 million metric tons of suspended sediment and 298,000 metric tons of bedload. For both sites bedload is usually 1 to 1.5 percent of suspended-sediment load. Particle-size distribution for suspended sediment is similar at Fairbanks and North Pole. Median particle size is generally in the silt range, but at some low-water discharges, it is in the very fine sand range. Median particle size of bedload near North Pole is generally in the gravel range, but at some low transport rates, it is in the medium sand range. In 1977 median bedload particle size was comparable at the two sites, but in 1978 the median size was markedly smaller at Fairbanks. In 1979 generally coarser material was transported at both sites, but the difference in bedload particle size was even greater between the sites. At both locations and all water discharges and sediment-transport rates, suspended-load particles are significantly smaller than bedload particles. At North Pole in 1979, median bed-material particle size was in the coarse gravel range; at Fairbanks it was in the medium gravel range in the main channel but in the fine sand range in the overflow part of the channel.

168) Chikita, K.A., R. Kemnitz, and R. Kumai. 2002. Characteristics of sediment discharge in the subarctic Yukon River, Alaska. Catena. 48: 235-253. (G, I, J)

Electronic abstract: The characteristics of sediment discharge in the Yukon River, Alaska were investigated by monitoring water discharge, water turbidity and water temperature. The river-transported sediment, 90 wt.% or more, consists of silt and clay (grain size =62.5 µm), which probably originated in the glacier-covered mountains mostly in the Alaska Range. For early June to late August 1999, we continuously measured water turbidity and temperature near the estuary and in the middle of Yukon River by using self-recording turbidimeters and temperature data loggers. The water turbidity (ppm) was converted to suspended sediment concentration (SSC; mg/l) of river water, using a relation between simultaneous turbidity and SSC at each of the two sites, and then, the suspended sediment discharge, approximately equal to water discharge times SSC, was numerically obtained every 1 or 2 h. It should be noted that the sediment discharge in the Yukon River is controlled by SSC rather than water discharge. As a result, a peak sediment discharge occurred in mid or late August by local sediment runoffs due to glacier-melt (or glacier-melt plus rainfall), while a peak *water* discharge was produced by snowmelt in late June or early July. Application of the "extended Shields diagram" indicates that almost all the river-transported sediments are under complete suspension.

169) Clark, R.A. 1992. Influence of stream flows and stock size on recruitment of Arctic grayling (*Thymallus arcticus*) in the Chena River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 49: 1027-1034. (G)

Author abstract: The hypothesis that recruitment of Arctic grayling (*Thymallus arcticus*) in the Chena River is influenced by streamflow and stock size was tested using population data collected from 1976 through 1990. Recruitment may be influenced by streamflow during the initial weeks of life of Arctic grayling, namely during spawning, emergence, and the larval stage. Using correlation and regression analyses, streamflow during the time-frame was found to be a significant descriptor of variability in recruitment ($r = -0.751$, $p = 0.005$). Although streamflow was implicated in recruitment variation, creation of an environment-dependent, stock-recruitment model was not possible because estimates of measurement error were lacking. This was because of bias due to the relation between residuals and subsequent stock size, and because of the presumed autocorrelation of stock size. An alternative analysis was conducted to investigate the influence of stock size on recruitment when streamflow was thought to minimally affect recruitment. Using an estimate of natural mortality rate, and assuming no fishing mortality, the theoretical contribution of recruits to the spawning stock exceeded the maximum observed stock size. It was concluded that the maximum observed stock size failed to negatively influence recruitment, and the level of stock size that might influence recruitment is greater than the maximum observed stock size.

170) Clay, J.R. 1973. The drift of benthic invertebrates in Goldstream Creek, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 83pp. (C, G, H, J)

Electronic abstract: The objectives were to determine if there was any diurnal variation in the amount of drift; what organisms were present in the drift; and to evaluate several physical parameters, including light intensity, water temperature and stream discharge with respect to their influence on the drift of macro-invertebrates in Goldstream Creek. Ephemeroptera (mayflies) and Diptera (two-winged flies) were the only orders represented consistently within the drift. Ephemeroptera exhibited a definite diurnal periodicity during the second, third and fourth (of four) sampling periods, while Diptera exhibited a similar periodicity during the third and fourth sampling days. Both orders peaked in abundance, as caught with a drift net, after

sunset. The greatest numbers of both orders captured during the study were collected on the sampling day during which the highest water temperature was measured.

171) Collins, C.M. 1990. Morphometric analyses of recent channel changes on the Tanana River in the vicinity of Fairbanks, Alaska. US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, CRREL Report 90-4. 54pp. (A, F)

Author abstract: Long-term bank erosion rates and channel changes in 1 14-km stretch of the Tanana River centered on Goose Island were documented using historical aerial photography from 1938 through 1982. The construction effects of a causeway partially blocking the river and the time required to return to equilibrium after construction were studied. Erosion, averaged over the entire study reach, was not significantly different following causeway construction compared to that prior to construction. Significant short-term increases in localized erosion rates during post- vs pre-construction time periods were documented in south channels and islands downstream of the causeway. Deposition upstream of the river constriction formed by the causeway was dramatic. The Tanana River returned to near equilibrium by 1980, five years after the construction of the causeway, with some effects continuing in 1982. Due to additional in-river construction downstream of the study area in 1981, the separate effects from the causeway could not be monitored beyond 1982.

172) Cowan, C.A. 1983. Phenology of benthic detritus input, storage and processing in an Alaskan subarctic stream. M.S. Thesis, University of Alaska, Fairbanks. 98pp. (C)

Author abstract: Allochthonous leaf litter input, storage of benthic detritus, processing rates of leaf litter, and macroinvertebrate standing crop were measured in Monument Creek, a second-order stream in interior Alaska. Litter input and storage of benthic detritus was very low in comparison to temperate streams. Processing rates of 5 g experimental leaf packs of birch and willow were moderate, while alder was processed very rapidly. Insect densities on leaf packs were relatively high, and approached domination by shredders (consumers of whole leaf tissue) as processing progressed. Associations between size classes of benthic detritus and standing crop of invertebrate feeding groups were generally positive but very weak, despite high shredder densities and low detritus storage. Productive capacities of high latitude streams may be fundamentally limited by low allochthonous input.

173) Cowan, C.A., and M.W. Oswood. 1983. Input and storage of benthic detritus in an Alaskan subarctic stream. Polar Biology. 2: 35-40. (C)

Electronic abstract: Allochthonous leaf litter input and storage of benthic detritus were measured in Monument Creek, a second-order interior Alaskan stream. Litter input was very low, totaling 62.5 g ash-free dry weight (AFDW) $\cdot$ m^{-2} $\cdot$ y^{-2} in 1980. Peak input coincided with autumnal leaf fall. Benthic detritus storage was similarly low. CPOM (coarse particulate organic matter, > 1 mm) ranged from 2.8 to 28.9 g AFDW $\cdot$ m^{-2}, peaking in mid-September, MPOM (medium particulate organic matter, 250 µm - 1 mm) ranged from 3.7 to 10.9 g AFDW $\cdot$ m^{-2}, peaking in May. SPOM (small particulate organic matter, 80 - 250 µm) ranged from 2.0 to 9.0 g AFDW $\cdot$ m^{-2} and also peaked in May. Compared to streams in temperate regions, Monument Creek is receiving and storing less energy from the surrounding forest.

174) Cowan, C.A., and M.W. Oswood. 1984. Spatial and seasonal associations of benthic macroinvertebrates and detritus in an Alaskan subarctic stream. Polar Biology. 3: 211-215. (C)

Electronic abstract: Seasonal and spatial patterns of benthic invertebrate abundance were examined in relation to benthic detritus in Monument Creek, an Alaskan subarctic stream. The total macroinvertebrate fauna showed a mid-summer low in abundance, increasing to seasonal highs in winter/early spring (November/May). Shredders were a small portion of the benthic fauna or leaf pack fauna in summer but increased rapidly (in biovolume) following autumnal leaf fall to dominate the fauna by early winter (October/November). Abundance was strongly correlated with quantity of detritus in the sample. Each unit of benthic detritus in Monument Creek is associated with a relatively large number of small (low individual biomass) shredders compared to streams in temperate regions. Detrital resources in this subarctic stream were meager, compared to temperate streams, and appeared to strongly influence the spatial and temporal patterns of detritivores.

175) Dingman, S.L. 1971. Hydrology of the Glenn Creek watershed, Tanana River Basin, central Alaska. US Army Corps of Engineers, Cold Regions Research and Engineering Lab, Hanover, New Hampshire, Research Report 297. 112pp. (G)

Author abstract: The results of a four-summer (1964-1967) hydrologic study of the watershed of Glenn creek, about 8 miles north of Fairbanks, Alaska, in the Yukon-Tanana uplands physiographic province, are presented. This work was initiated to provide initial base line hydrologic data for a small subarctic watershed. The stream is second-order, and drains an area of 0.70 square mile. Basin elevations are from 842 to 1,618 ft. about half of the 12.3-in. normal annual precipitation is runoff. The remainder is the actual evapotranspiration, which equals only about 30% of estimated potential evapotranspiration. For individual storms, runoff-rainfall proportions were from 0.03 to 0.42, and were positively correlated with antecedent discharge of the stream. Peak discharges for individual storms were estimated by an equation including antecedent discharge, total precipitation and storm duration, and average recession constant. These results represent the first detailed hydrologic data from the discontinuous permafrost zone of the North American taiga and should be of significance to the international hydrological decade and international biological program.

176) Emmett, W.W., R.L. Burrows, and B. Parks. 1978. Sediment transport in the Tanana River in the vicinity of Fairbanks, Alaska, 1977. USDI Geological Survey, Anchorage, Alaska, Open-File Report 78-290. 28pp. (G, I)

Author abstract: Measurements of suspended- and bedload-sediment transport for the Tanana River in the vicinity of Fairbanks, Alaska, show that suspended-sediment load, G_s in tons per day, relates to water discharge, Q, in cubic feet per second as:

$$G_s = 1.66 \times 10^{-8} Q^{2.83}$$

The bedload transport rate is approximately one percent of the suspended-sediment transport rate.

The median particle size of suspended sediment is generally silt (<0.062 mm), but at some low-water discharges, the median particle size is very fine sand. The median particle size of bedload is generally gravel (>2.0 mm, and often in the range of 10 to 20 mm), but at some low transport rates, the median particle size is medium sand. At all water discharges and sediment-transport rates, the particles constituting the suspended load are significantly smaller than the particles constituting the bedload.

177) Fox, J.D., Jr. 1989. Simulating vegetation-water yield relations in interior Alaska. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Pages 179-189. (G)

Author abstract: Spring runoff in cold climates is affected by the complex interaction of snowmelt rate and soil infiltration capacity. The former is affected by all factors influencing the snowpack energy balance, while the latter is affected by soil texture and the combination of autumn soil moisture, snowpack depth and air temperature that determines soil freezing and thawing. These complex relationships are also influenced by vegetative cover. Accordingly, a hypothesis has been made that runoff will increase after timber harvest, not only due to increased snowmelt rates and decreased transpiration, but also due to increased fall soil moisture and subsequent formation of concrete frost. Since no vegetation-water yield field experiments have been done in interior Alaska, a watershed model designed to study vegetation-water yield relations was modified to include a soil freeze-thaw algorithm (Stefan-St. Paul equations) and used to simulate the interaction of forest cover, soil moisture, soil frost, infiltration, and spring runoff. Simulation results support the hypothesis outlined above but also indicate the conditional nature of the vegetation-water yield connection. Simulations also indicate that the drier the initial soil conditions, the longer may be the delay in runoff response to harvest. The model does appear to realistically simulate the great variability in spring runoff patterns observed in interior Alaska and provides direction for further research. These results, as well as the general approach, should be useful to watershed managers in explaining the variability of spring runoff events and in estimating potential impacts of vegetation changes on water yield.

178) Freeman, M.W. (Editor). 2000. Region III forest resources & practices riparian management annotated bibliography. Report by the Alaska Department of Natural Resources Division of Forestry, and the Alaska Department of Fish and Game Habitat & Restoration Division. Report written for the Alaska Board of Forestry. 152pp. (A, D, F, I)

Compiler abstract: This annotated bibliography is a compilation of published research relevant to riparian management issues in interior Alaska. The bibliography is separated into seven topics: 1) buffer function and design; 2) factors affecting stream bank and river bank stability, with an emphasis on vegetation influences; 3) large woody debris; 4) permafrost and silty soils; 5) winter fish use of glacial streams; 6) fish use of upwellings; and 7) ice thickness and ice bridges. A brief summary of the referenced literature for each topic is provided at the beginning of each section of the bibliography.

179) Frey, P.J., E.W. Mueller, and E.C. Berry. 1970. The Chena River, the study of a subarctic stream. Federal Water Quality Administration, Alaska Water Lab, Fairbanks, Alaska. Reference FWQA project no 1610--10/70. 96pp. (C, I)

Electronic abstract: The Chena River is a subarctic stream flowing westerly from the low mountains of eastern Alaska to the Tanana River near Fairbanks. It is typical of many interior Alaska rivers with the exception that its lower reaches are highly polluted by domestic and industrial wastes from the Fairbanks area. The purpose of this 3-year study of the river was to understand the physical, chemical, and biological limnology of the river system and what effect man's influence--past, present and future--has on the river. Dissolved oxygen was one of the most critical parameters determined. In the summer it is close to saturation. During winter, in the lower river, the concentration approaches 1 mg/1. The biological community was studied through both quantitative and qualitative plant and animal collections. The upper reaches of the river are much richer in number of kinds of organisms than the lower reaches. Coliform bacteria counts range from very low in the upper river to over 500,000 per 100/m1 below Fairbanks. A flood control dam is planned for the river above the city of Fairbanks. Significant modification of the water quality and biota of the river can be expected following the construction of the dam. Proper management of the flow from the impoundment can reduce the objectionable effects of this dam on the river system.

180) Gatto, L.W. 1984. Tanana River monitoring and research program: Relationships among bank recession, vegetation, soils, sediments and permafrost on the Tanana River near Fairbanks, Alaska. US Army Corps of Engineers, Cold Regions Research & Engineering Laboratory, Special Report 84-21. 53pp. (A, F)

Author abstract: The objective of this analysis was to determine if available data are useful in identifying the characteristics that contribute to erodibility of the banks along two reaches of the Tanana River. Existing data on bank vegetation, soils, sediments and permafrost were used. Because these data were general and not collected for the purpose of site-specific analysis, my analytical approach was simple and did not include any statistical tests. The data were visually compared to the locations and estimated amounts of historical recession to evaluate if any relationships were obvious. The results of this analysis showed no useful relationships. Vegetation was similar in eroded and uneroded areas and its distribution did not show any obvious relationship to the locations of bank recession. Surface sediments and soils in the eroded areas had little, if any, effect on bank erodibility because the river erodes the bank over its entire depth, which is well below this surface zone. The subsurface sediment from eroded and uneroded well and along transects with high and low measured recession was similar. Permafrost occurrences are about equal in eroded and uneroded sites, although it appears that recession can be higher where permafrost is common than where it is absent. In most cases the existing data are either too general or not properly located to be useful in anticipating future locations of bank erosion. In order to predict future erosion, a field project should be initiated to evaluate the influence of bank characteristics and hydraulic forces on bank erosion rates.

181) Harrold, P.E., and R.L. Burrows. 1983. Sediment transport in the Tanana River near Fairbanks, Alaska, 1982. USDI Geological Survey, Anchorage, Alaska, Water-Resources Investigations Report 83-4213. 53pp. (G, I)

Author abstract: Suspended-sediment and bedload-transport rates for the Tanana River near Fairbanks can be related to water discharge and annual sediment loads can be computed using these relations. For a site at Fairbanks the annual loads in 1982 were 26.1 million metric tons of suspended sediment and 227,000 metric tons of bedload. Data collected at five other sites within a 40-kilometer reach of the river indicate very similar suspended-sediment-transport relations but bedload-transport relations varied from site to site. For all sites bedload is on the order of 1 percent of suspended-sediment load.

Particle-size distribution for suspended sediment is similar at all six sites. Median particle size is generally in the silt range; only occasionally is it in the very fine sand range.

Median particle size of bedload varied from the gravel range to the medium sand range at four of the six sampling sites. At the farthest downstream location, Byers Island, and the farthest upstream location, above Chena River Floodway, median particle size of bedload was always in the sand range.

Water-surface profiles show that at all discharges, the water surface slope was steeper at the upstream sites than at the downstream sites.

182) Hemming, C.R., and W.A. Morris. 1999. Fish habitat investigations in the Tanana River watershed, 1997. Alaska Department of Fish and Game, Habitat and Restoration Division, Juneau, Alaska, Technical Report No. 99-1. 83pp. (I)

Author abstract (Author Executive Summary): This report contains the results from 1997, the second year of a two-year field investigation undertaken in 1996 of juvenile fish and juvenile fish habitat in the Tanana River system. The goal of this study was to identify habitats used by juvenile fish and to describe the physical and water quality characteristics of these areas. We expanded the study in 1997 to include a sample area near Delta Junction, and continued sampling the Tanana River near Fairbanks (Ott et al. 1998). We captured fish in minnow traps and beach seines, and collected water samples at selected locations with each sample area. Water samples were analyzed for turbidity and total suspended solids.

Minnow traps were set at various locations within each sample area and left to fish overnight for about 24 hour intervals; sampling occurred monthly from May through August 1997. Minnow traps were set at up to 20 sites in the Fairbanks area, during the four sample periods, yielding 79 trap days of effort. Minnow traps were set at up to 15 locations during the four sample periods, for 58 trap days of effort in the Delta area. We captured 51 fish that included 7 species in the Fairbanks sample reach, and 179 fish included 5 species in the Delta area. We organized the minnow trap fish capture data into five water classes based on visual characteristics of the water. We tested the five water classes using turbidity and total suspended solids measurements and found a significant difference in water quality measurements between each of the five classes. We evaluated minnow trap fish capture results by water class and found the greatest number of species and the largest catches in groundwater and tannic-stained runoff habitats.

Beach seining was conducted at various sites in both sample areas. All seine sites occurred in turbid-water areas with similar velocities, depths, and water quality characteristics. Seining in the Fairbanks area yielded 1,642 fish including 12 species. Delta-area sampling captured 930 fish of 9 species. Beach seine results identified temporal and spatial patterns of fish use in each sample area. Fish species found in each area were similar, but catch numbers varied between the two

areas. Juvenile salmon were captured during the May and June sampling periods in both the Fairbanks and Delta areas; however, chum salmon (*Oncorhynchus keta*) fry were more frequently captured in the Delta sample area. Groundwater upwelling areas produced the largest catches of chum salmon fry in the Delta area. In the Fairbanks sample area we found a similar pattern to that found in 1996, with lake chubs (*Couesius plumbeus*) and longnose suckers (*Catostomus catostomus*) captured most frequently. Slimy sculpin (*Cottus cognatus*) and Chinook salmon (*Oncorhynchus tschawytscha*) were most often captured in association with gravel substrate areas.

183) Hughes, N.F. 1991. The behavioral ecology of Arctic grayling distribution in interior Alaskan streams. Ph.D. Thesis, University of Alaska, Fairbanks. 124pp. (K)

Author abstract: During the summer months Arctic grayling in interior Alaskan streams get bigger as you travel from downstream reaches to the headwaters. On a smaller scale, within individual pools, the largest fish holds position in the middle of the current, near the deepest part of the pool, and smaller fish hold positions progressively further downstream or to the side of the pool. The results of this study support the hypothesis that a single process – competition for profitable feeding positions – produces both the whole-stream and within-pool distribution pattern.

Field experiments showed that competition for desirable positions is responsible for the distribution patterns adopted by groups of fish sharing a pool, and for the size-gradient of fish over the length of the stream. In both cases large fish excluded smaller ones from the most desirable positions. Modeling work suggested that Arctic grayling locate and rank positions on the basis of profitability. Within pools this conclusion was supported by a close fit between the positions predicted by a foraging model and the positions actually selected by Arctic grayling. Over the length of the whole stream this conclusion was supported by the model's prediction that feeding positions become more profitable as you go upstream.

184) Irons, J.G., III, and M.W. Oswood. 1992. Seasonal temperature patterns in an arctic and two subarctic Alaskan (USA) headwater streams. Hydrobiologia. 237: 147-157. (J, H)

Electronic abstract: Monument Creek (MC) and Little Poker Creek (LPC) are subarctic streams in interior Alaska; LPC is in a permafrost-dominated valley. Imnavait Creek (IC) is an arctic tundra beaded stream in the northern foothills of the Brooks Range. Water temperatures were recorded with automated dataloggers hourly. Water temperature rose in the spring about twice as fast in MC as in LPC, and again about twice as fast in IC as in MC. A similar pattern was observed during the autumnal decline in water temperature. Maximum daily amplitude followed a similar pattern. Although it is about 450 km north of the other streams, the tundra stream (IC) accumulated more degree-days, had higher maximum and mean temperatures, greater daily temperature amplitude, and steeper slopes of vernal temperature rise and autumnal temperature decline than the subarctic streams (LPC and MC). The absence of a canopy of riparian plants, channel morphology, and continuous sunlight during the arctic mid-summer accounted for these higher temperatures. Beaded tundra streams provide a highly seasonal (< 120 d ice-free) and spatially and temporally complex thermal environment.

185) Irons, J.G., III, and M.W. Oswood. 1997. Organic matter dynamics in 3 subarctic streams of interior Alaska, USA. Journal of the North American Benthological Society. 16: 23-28. (G, I)

Electronic abstract: The predominant biome in interior Alaska is known as the taiga, or northern boreal forest. In these high latitude forests (about 60 degree N-67 degree N in Alaska), the angle of solar radiation with respect to the land surface is a major factor controlling ecological processes, including those relevant to organic matter dynamics in streams. Sun angle determines mean annual air temperature, which in interior Alaska is about -3.3 degree C. Temperature extremes in this continental climate can range from -50 to +35 degree C. One result of this harsh thermal regime is the presence of permafrost in the colder microclimates. Indeed, much of interior Alaska is in the zone of discontinuous permafrost, in which south-facing slopes are generally permafrost-free, and cold north-facing slopes and poorly drained valley bottoms are generally underlain by permafrost. Soil carbon densities reflect the balance between input (organic matter production) and decomposition. In the cold and often water-saturated soils common at high latitudes, decomposition is reduced and soil carbon may accumulate as peat over very long time periods. Thus there is often a positive relationship between the amount of soil organic matter and the amount of permafrost in a watershed. Permafrost affects the hydrological regimes of subarctic streams. Streams dominated by permafrost are more "flashy" than those that are relatively permafrost-free. Snowmelt runoff is later and greater in a permafrost-dominated basin than snowmelt runoff from a permafrost-free basin. Likewise, peak stormflow discharge from a permafrost-dominated basin is much higher than in a non-permafrost stream; but during rain-free periods and in winter, flow is much lower. This pattern is a result of the flow-paths of precipitation as it travels to the stream. On permafrost-dominated north-facing slopes, precipitation enters the thick organic layer and flows above the permafrost to the stream. On permafrost-free south-facing slopes, precipitation enters the groundwater and is released much more slowly to the stream. Differences in discharge result in different patterns of carbon and sediment flux from basins with differing amounts of permafrost.

186) Irons, J.G., J.P. Bryant, and M.W. Oswood. 1991. Effects of moose browsing on decomposition rates of birch leaf litter in a subarctic stream. Canadian Journal of Fisheries and Aquatic Sciences. 48: 442-444. (C, E)

Electronic abstract: The effects of moose browsing on decomposition rates of paper birch leaves was examined in Monument Creek, a subarctic headwater stream near Fairbanks, Alaska. Leaves from birch trees previously browsed by moose differed from leaves from unbrowsed trees in food quality for stream detrivores in an Alaskan subarctic stream. Leaves from previously browsed plants decomposed faster. Effects of browsing were tested by collecting leaves from previously browsed and unbrowsed trees and measuring loss of mass over time in an Alaskan subarctic stream. The browsing history of birch trees was associated with increased leaching rate of tannin, foliar nitrogen concentration , and rate of mass loss. All three factors were higher for leaves from trees previously browsed than for unbrowsed ones. Faster loss of tannin through leaching and higher foliar nitrogen concentration apparently caused birch detritus to be processed more rapidly by stream biota, potentially increasing secondary production of stream consumers. Hence, moose browsing was associated with important changes in the food quality of birch leaf litter, linking terrestrial herbivory and aquatic food webs.

187) Irons, J.G., S.R. Ray, L.K. Miller, and M.W. Oswood. 1989. Spatial and seasonal patterns of streambed water temperatures in an Alaskan subarctic stream. In: Proceedings of the Symposium on Headwaters Hydrology. W.W. Woessner and D.F. Potts, Editors. American Water Resources Association, Bethesda, Maryland. Pages 381-390. (J)

Author abstract: Streambed temperature profiles were determined for two years (October 1986 to October 1988) in Monument Creek, a second order subarctic stream. Hourly temperature recordings were made at two vertical profiles (near-bank and mid-channel). Air temperatures ranged from -41.6 C to +22.5 C, (mean = 3.8 C). Streambed surface temperatures (as measured in mid-channel) ranged between -0.1 and 13.0 C (year one), and -12.8 to 12.7 C (year two). In the first winter, the near-bank streambed repeatedly froze and thawed during the winter, while the mid-channel streambed never froze. In spite of very cold air temperatures, the coldest temperature reached in frozen stream sediments was -2.5 C. However, in the second winter, both profiles remained frozen (minimum -12.8 C) for most of the winter, although stream flow was still present. Spatial and temporal patterns in water temperature were complex and indicated that streambed water was derived from both streamwater and groundwater. Amount of rain (especially in late fall) was correlated with the hydrology and temperature dynamics of the streambed. In years with late autumn rains, stream sediments may remain unfrozen through the winter as groundwater slowly discharges to the stream; in drier years, sediments may freeze deeply, with profound effects on the availability of unfrozen 'refugia' for overwintering stream invertebrates and immature fishes.

188) Jackson, W.L., and B.P. Van Haveren. 1987. Predicting channel responses to changing flow regimes: Beaver Creek, Alaska. In: Erosion and Sedimentation in the Pacific Rim. International Association of Hydrological Sciences, Washington, DC, IAHS Publication No. 165. Pages 393-394. (A, G)

Electronic abstract: Beaver Creek is a north-flowing tributary to the Yukon River in central Alaska. The river is characterized by a gravel and cobble bed, numerous large meanders, oxbows, sloughs, bars, and multiple channels on certain low-sinuosity reaches. In 1986, a project was initiated (1) to determine the minimum quantity of water necessary to protect the outstanding recreation, aesthetic , and fishery values that made Beaver Creek a component of the Wild Rivers System, and (2) to recommend a legal strategy to protect the recommended instream flow regime. Beaver Creek streamflows were synthesized using regional techniques, indirect methods, and direct stream gaging. Hydraulic geometry relationships and indirect discharge rating curves were developed at 17 cross-sections. Relationships between bankfull discharge and bankfull width, depth, velocity, and wetted perimeter were also developed. Beaver Creek Wild River channel slopes range from 0.30 to 0.03 percent and occur in four distinct slope classes. Based upon the bankfull hydraulic geometry relationships and descriptions of channel morphology, uniform 10, 20 and 30% reductions in Beaver Creek's flood-frequency relationship will result in corresponding reductions of 5, 9, and 14% in bankfull width, depth and wetted perimeter.

189) Kane, D.L., and C.W. Slaughter. 1973. Seasonal regimes and hydrological significance of stream icings in central Alaska. In: The Role of Snow and Ice in Hydrology. Proceeding of the Banff Symposium, September 1972. International Association of Hydrological Sciences, Publication 107, Volume 1. Pages 528-540. (G)

Electronic abstract: Many streams in arctic and subarctic regions have accumulations of ice in the channel and nearby flood plain during the winter months. Field data on the rates of growth of these icings and on various climatic factors were collected at a small research watershed near Fairbanks, Alaska. The volume of icing growths was estimated from aerial photographs. Hydrologic implications were derived by comparing the volume of these icings with other elements of the hydrologic cycle. Water involved in icing formation is diverted from winter streamflow; this same water is released from storage by melt in late spring, augmenting streamflow after peak snowmelt runoff. Water yielded by melt of icing is largely available for streamflow, and does not contribute moisture to the soil mantle away from stream channels as does snowpack meltwater. Stream icing in the subarctic, upland research watershed constituted 4% of yearly runoff volume, but amounted to nearly 40% of winter streamflow. Melt occurred over a 4-week period, largely following ablation of the seasonal snowpack.

190) Kane, D.L, and P.M. Wellen. 1985. A hydraulic evaluation of fish passage through roadway culverts in Alaska. Report No. FHWA-AK-RD-85-24. Final report written by the Institute of Water Resources, Engineering Experiment Station, University of Alaska, Fairbanks. Written for the Alaska Department of Transportation and Public Facilities, Division of Planning and Programming, Research Section, Fairbanks, Alaska. 54pp. (K)

Author abstract: Culverts are a very simple hydraulic structure. However, because the engineer must design for peak flows passing through the culvert while fish are trying to move upstream serious problems arise. Almost all culvert installations in interior and northern Alaska were casually examined, with approximately 100 examined in detail where hydraulic problems existed that may retard fish passage. Data from the field program are included in an appendix to this report. The two major hydraulic problems in regard to fish passage were high velocities and perching; inlet drops caused by deposited sediment, aufeis, alignment of culvert with stream, and non-uniform culvert slopes are some of the other fish passage deterrents that were observed. Also, all known baffled structures were evaluated. Numerous recommendations were made that should improve the hydraulic conditions that exist at a culvert relative to fish passage. Also, it is recommended that further studies be carried out to evaluate the swimming performance of the native fish. Present design criteria are based on very limited studies. Lastly, it is recommended that the concept of the velocity in the occupied zone (area in culvert where fish swim) be considered as the culvert design velocity for fish passage in place of the presently used average cross-sectional velocity.

191) LaPerriere, J.D. 1980. Variation in invertebrate drift in subarctic Alaskan streams. Institute of Water Resources, University of Alaska, Fairbanks. 27pp. (C, E, I)

Electronic abstract: Data from thirteen streams in interior, subarctic Alaska are analyzed to find predictive equations that explain the amount of invertebrate fish-food drifting in the water column. The alkalinity of the water and the stream's average velocity are found to be the factors that influence the amount of drift expressed as concentration or export rate. The alkalinity is shown to be related to the invertebrates' food supply. Average velocity is speculated to be an indication of the shear force at the sediment-water interface where benthic invertebrates forage for their food. These shear forces are seen to operate on benthic invertebrates in an analogous way to that in which they operate in sediment transport. The algae of boreal streams in this region are shown to be somewhat reliant on alkalinity, but a highly significant relationship is shown between total phosphorus and algae when both muskeg (brownwater) and boreal (clearwater) streams are considered together. Brownwater streams of this region tend to have a higher total phosphorus concentration than clearwater streams, but to have a depressed pH that is characteristic of standing waters in muskeg.

192) LaPerriere, J.D. 1983. Alkalinity, discharge, average velocity, and invertebrate drift concentration in subarctic Alaskan streams. Journal of Freshwater Ecology. 2: 141-151. (C, G, I)

Electronic abstract: This study measured the associations of alkalinity, current and invertebrate drift among 13 streams in subarctic Alaska. A significant positive correlation was found between alkalinity and drift concentration expressed as numbers per unit volume. Significant inverse relations were found between stream discharge and drift concentration expressed as either numbers or weight. This "dilution" was to be expected since stream wetted perimeter, the source of invertebrates to drift, increases as approximately the square root of the discharge. Multiple regression analysis also showed a positive relation between stream average velocity and drift concentrations. Invertebrate drift was seen, therefore, to be somewhat analogous to sediment transport in streams.

193) LaPerriere, J.D. 1994. Benthic ecology of a spring-fed river of interior Alaska. Freshwater Biology. 32: 349-357. (C, E, I, J)

Electronic abstract: A massive aquifer between the Gerstle, Tanana and Delta rivers in interior Alaska receives water from them and from smaller streams that flow from the Granite Mountains in the Alaska Range. Groundwater from the aquifer intersects the surface in a mid-sized (20 m^3/s ± 10%) spring-fed stream, Clearwater Creek. Mean annual air temperature is about -2.6°C. However, even in winter when air temperature often reaches -40°C, the stream does not form a complete ice cover. Water temperature ranges from 0 to 7.8°C. Specific conductance and the concentrations of major ions vary little throughout the year, and summed ionic salinity exceeds 250 mg/l. Benthic algal standing crop (as chlorophyll *a*) was at least an order of magnitude higher than that in a nearby surface-water stream, the upper Chena River. Standing crop peaked in spring and autumn (about 20 mg/m^2) and averaged about half this value, although biomass of an early spring bloom of *Hydrurus foetidus* was underestimated. Algal standing crop was inversely related to the concentrations of inorganic nitrogen and orthophosphate-phosphorus in the water column. The ratio of total nitrogen to total phosphorus (as mass concentrations) was always about 30. Measurements of primary production made in Clearwater Creek were among the highest reported for streams in subarctic Alaska. Macroinvertebrate diversity in Clearwater Creek was low. Numbers of "morpho-species" in monthly Surber samples (0.09 m^2) averaged nine, and ranged from three to fourteen. However, benthos and drift densities were similar to those reported from other Alaskan streams. In early spring and autumn, drifting macroinvertebrates were primarily Ephemeroptera, Plecoptera and Trichoptera, but in summer, Diptera dominated the drift. The low diversity of macroinvertebrates is hypothesized to be a consequence of the small annual range in water temperature and the relatively constant discharge of Clearwater Creek.

194) LaPerriere, J.D., E.E. Van Nieuwenhuyse, and P.R. Anderson. 1989. Benthic algal biomass and productivity in high subarctic streams, Alaska. High Latitude Limnology. Reprinted in Hydrobiologia. 172: 63-75. (C, E, I)

Electronic abstract: Year-round measurements of the standing crop of epilithic algae (as chlorophyll *a* concentration) in two streams - one second and one fourth order (map scale 1:63 360) - in interior Alaska (64 degree -65 degree N) were only about one tenth that reported from streams of temperate North America. Cell densities in these streams, however, were similar to those in comparable temperate streams. Year-round domination of the benthic flora by very tiny diatoms (*Achnanthes* spp.) may explain the apparent disparity between low chlorophyll a content and nearly average cell densities. Chlorophyll *a* standing crop in a more alkaline groundwater-fed stream, however, was higher and within the range of similarly sized temperate streams. Maximum chlorophyll *a* standing crop varied positively with alkalinity in 5 clear-water streams where standing crop was measured on natural or artificial substrates. Seasonal mean concentrations of sestonic chlorophyll *a* (used as estimates of benthic algal chlorophyll *a* standing crop) varied directly and significantly with alkalinity among ten clear-water streams; and, with total phosphorus among 8 of 10 clear-water and 5 brown-water streams studied. During the summer, when there is little darkness, gross primary productivity (as estimated by the diurnal dissolved-oxygen method) was similar to that of northern temperate streams. Gross primary productivity was also seen to vary directly with alkalinity in 5 clear-water streams of this region.

195) Lilly, M.R., J. Mendez, R. McCaffrey, D.M. Nyman, and S. Swenson. 2001. Ground-water and surface-water interactions in Whitestone, North and Providence Creeks: Final Report. Written by GW Scientific and Alaska Boreal Forest Council, Fairbanks, Alaska and Restoration Science and Engineering, Anchorage, Alaska. Written for the Alaska Department of Environmental Conservation, Juneau, Alaska. 21pp. plus Appendix and a CD with project website content and data. (G, I, J)

Author abstract: Upwelling areas in Alaskan rivers and streams are identified to be a crucial link in anadromous fish spawning and rearing. Future development in watersheds where spawning is common relies on a better understanding of the dynamics of these areas. A study to characterize three clear-water tributary streams of the Tanana River was implemented in the fall of 2001, near the confluence of the Tanana and Delta Rivers. The streams monitored were Whitestone, North, and Providence Creek. Using measurements of specific conductance, dissolved oxygen, temperature, flow and visual observations, we mapped the streams for upwelling occurrences. One of the three streams, Whitestone Creek, was also continuously monitored to gain a better understanding of temporal variations in the groundwater and stream interactions throughout the year.

Results of the study indicate spatial and temporal variations in the occurrence of upwellings. Data indicates the lower section of Whitestone Creek experienced upwelling in the late-fall but became a loosing reach (recharged the groundwater) as local ground-water levels declined through the winter period. In early spring, the stream again became influenced by upwelling, or the discharge of groundwater. Visible ground water upwelling in the form of bubbling vents and springs were observed at different locations all the way from the headwaters to the mouth of Whitestone Creek, indicating a very heterogeneous spatial distribution. This visible upwelling evidence was also present in North and Providence Creek, with a high density of vents seen at the headwaters but also further downstream. Non-visible upwelling occurrence was also evidenced in these streams by an increase in discharge along reaches with no tributary contribution. Conclusions from the study indicate that a combination of warmer upwelling water, high flow velocities and stream depth could all contribute in different degrees to keeping reaches ice-free in these streams during winter. Winter aerial photography showing ice-free stream reaches, in combination with ground-based hydrology measurements and observations, may become a very useful tool for locating areas of groundwater upwelling and thus habitat favorable for winter spawning.

196) Loftus, W.F. 1976. Food habits of two species of juvenile salmon, *Oncorhynchus tshawytscha* (Walbaum) and *Oncorhynchus keta* (Walbaum), from the Salcha and Jim River drainages, Alaska. M.S. Thesis, Central Michigan University, Mt. Pleasant. 77pp. (C)

Author abstract: Between 16 May and 8 June 1973, 454 chinook salmon smolts and 121 chum salmon smolts were trapped in the Salcha River, Alaska. Smaller samples of Chinook fry were taken from two Salcha tributaries, Flat and Ninety-Eight Creeks, on 18 August 1973, and from the Jim River tributary, Prospect Creek on 25 September 1972. Stomach contents were examined, and food items classed to the lowest possible taxon. The results of the numerical, frequency of occurrence, and volumetric analyses were combined to yield an importance value for each taxon. The importance value is applied for the first time in a salmon food habits study, and its widespread use will enable results to be easily compared.

Immature aquatic insects of the orders Diptera, Plecoptera, and Ephemeroptera predominated in the diet of both salmon species. All other food items were relatively insignificant. Chironomidae was the most important family of food organisms. Chinook smolts, being larger fish, preyed more heavily upon Plecopterans than did chum smolts. Both species appear to feed primarily upon benthos and invertebrate drift. Competition for food between the two species is indicated by the data.

197) Lotspeich, F.B., and A.E. Helmers. 1974. Environmental guidelines for development roads in the subarctic. Ecological Research Series, EPA-660/3-74-009. US Environmental Protection Agency, Office of Research and Development, National Environmental Research Center, Corvallis, Oregon, and Arctic Environmental Research Laboratory, College, Alaska. Project 21ARX, Program Element 1BA021. 63pp. (K)

Author abstract: This set of guidelines is based on Federal and State regulations that set standards to protect the total environment. Although major highway construction is under stringent regulation, pioneer type access roads such as are needed by loggers, miners, land developers, etc. have been neglected. These smaller roads frequently pose serious erosion hazards because planning, design and construction of them is not thorough, as it is for major roads; this results in erosion, fire and insect traps, and generally unattractive roadways.

Suggestions and recommendations contained in these guidelines are for the use of operators with limited engineering and planning staffs. Although all examples of poor practice are from the vicinity of Fairbanks, all suggested treatments are taken from the literature from the conterminous United States, with some modifications for subarctic conditions. Most of these recommendations are simple in concept, and if properly applied, do prevent erosion and result in superior access roads which are esthetically pleasing.

198) Lubinski, B.R. 1995. Winter habitat of Arctic grayling in an interior Alaska stream. M.S. Thesis, University of Alaska, Fairbanks. 143pp. (A, G)

Author abstract: Placer mining and the lack of information on winter ecology of Arctic grayling *Thymallus arcticus*, has raised concern for this popular sportfish. A study was designed to validate aerial radio telemetry data and to locate and describe overwinter areas (OWA) of Arctic grayling in Beaver Creek, Alaska. Reliance on aerial data alone resulted in overestimation of survival and misidentification of 14 of 26 designated OWAs. Twenty-one Arctic grayling were tracked downstream 12-58 km to 12 OWAs spanning a 31-km section of Beaver Creek. Radio-tagged and untagged Arctic grayling occupied areas with ice thickness of 0.4-1.4 m overlying 0.06-0.52 m of water, flowing at 0.03-0.56 m/s. During winter, discharge, cross-sectional area, velocities, and water width in four OWAs decreased until late March; then, cross-sectional area increased due to an increase in discharge that pushed the ice upward. Adult Arctic grayling overwintered downstream of habitat disturbances, and occupied much shallower winter habitats than expected.

199) MacLean, R. 1997. The effect of permafrost on the biogeochemistry of two subarctic streams. M.S. Thesis, University of Alaska, Fairbanks. 69pp. (I)

Author abstract: Discontinuous permafrost has a profound effect on the hydrology of subarctic streams. Permafrost distribution is very sensitive to wildfire, changes in climate, and changes in land use. An understanding of the interactions between permafrost dominated soils and stream chemistry is important in predicting the effects of changing permafrost distribution on stream ecosystems and nutrient budgets in watersheds. Chemical measurements of groundwater, soil water and stream water were made in two watersheds in Interior Alaska. One watershed had extensive permafrost and the other had limited permafrost. Soil water collected within the rooting zone (0.3 – 0.5 m) in both watersheds was high in dissolved organic carbon (DOC), dissolved organic nitrogen (DON) and dissolved inorganic nitrogen (DIN) but low in dissolved minerals (dominantly Ca, Mg and Na) and conductivity. The presence of permafrost appeared to result in higher fluxes of DOC into stream water from upland soils.

200) Maclean, S.H. 2003. Influence of hydrological processes on the spatial and temporal variation in spawning habitat quality for two chum salmon stocks in interior Alaska. M.S. Thesis, University of Alaska, Fairbanks. 93pp. (B, G, I, J)

Author abstract: I investigated the hydrological mechanisms that influence spatial and temporal variability in incubation habitat quality for summer- and fall-run chum salmon. The intragravel habitat was characterized by measuring water velocity, temperature, and dissolved oxygen (DO). Habitat quality was characterized by determining the survival of eggs in gravel filled baskets. Summer-run egg survival was greatest in a zone of upwelling produced by hydraulic gradients between the main Chena River and a slough. Water took approximately one month to make this trip and microbial activity likely reduced the concentration of DO considerably. As a consequence of these processes, there was considerable spatial and temporal variability in upwelling velocity, DO, and temperature. Most variability in egg-to-fry survival was explained by DO, and, to a lesser extent, by water velocity. Fall-run fish used an area of groundwater upwelling on the south side of the Tanana River. Here physical habitat characteristics were spatially and temporally uniform compared to the summer-run site, a consequence of the larger spatial scale of processes generating the upwelling. Egg-to-fry survival was low despite high DO and favorable temperature. This was probably the consequence of glacial silt invading egg baskets and reducing intragravel flow related to falling groundwater tables.

201) Maurer, M.A. 1987. Compilation of stream macroinvertebrate data for the Birch Creek, Beaver Creek, Fortymile River, and Minto Flats drainages. Alaska Division of Geological and Geophysical Surveys, Alaska Public-Data File 87-30. 56pp. (C, I)

Author abstract (Author introduction): This report summarizes an investigation made by the State of Alaska, Department of Natural Resources, Division of Geological and Geophysical surveys (DGGS) in cooperation with the U.S. Bureau of Land Management (BLM) from August to November 1987. The objective of the investigation is to: (1) inventory the benthic invertebrate community in the Fortymile River drainage, (2) compile available benthic invertebrate data on the Fortymile River, Birch Creek, Beaver Creek, and Minto Flats drainages, and (3) determine whether cumulative placer mining impacts on the benthic invertebrate community in these four drainages have been documented.

202) McCaffrey, R. 2001. Aerial survey of ground-water upwelling in the Tanana River floodplain near Big Delta, Alaska. Written by the Alaska Boreal Forest Council, Fairbanks, Alaska. Written for the Alaska Department of Environmental Conservation, Juneau, Alaska. Work supported by Grant NP-01-16. 6pp. plus Appendices and 4 data CDs with georeferenced photo images and overlays. (G, J)

Compiler abstract: Upwellings in Alaskan rivers and streams are believed to be important spawning and rearing habitat for anadromous fish. The objective of this project was to map evidence of ground-water upwelling in the Tanana River floodplain near Big Delta, Alaska between its confluence with the Delta River and its confluence with Little Delta Creek. The typically warmer water from upwellings was hypothesized to result in retarded ice cover formation in the Fall, and in advanced ice breakup in the Spring. Therefore, evidence of upwellings was mapped by taking aerial photographs during Spring and Fall of 1999, Spring 2000, and Spring 2001, when the typically warmer water from upwellings would result in areas of open water in the otherwise frozen Tanana River. Georeferenced images and evidence of upwellings are provided on compact computer disks (i.e. CDs).

203) McFadden, T., and M. Stallion. 1976. Debris of the Chena River. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Fairbanks, Alaska. Available from the National Technical Information Service, Springfield VA 22161 as ADA-029 357. 18pp. (D)

Electronic abstract: Debris over a 44-mile stretch of the Chena River was studied. The study area extended from the first bridge on the Chena Hot Springs Road to the Chena River Flood Control damsite. The purpose of the study was to assess the potential danger to the Chena River Flood Control Dam outlet structure. Debris was cataloged, log jams were measured, and sources of debris were studied. The average size of logs was determined, as well as the number of logs present on the river. It was concluded that a serious debris problem existed and would remain serious for the foreseeable future. Recommendations for debris handling were made.

204) Miller, M.C., and J.R. Stout. 1989. Variability of macroinvertebrate community composition in an Arctic and Subarctic stream. High Latitude Limnology. 172: 111-127. (C)

Electronic abstract: The macroinvertebrate community composition was compared in two Alaskan streams (USA) for numeric and species constancy during the ice-free period from 1981 to 1983. Imnavait Creek is a first order Arctic stream (60 degree 39' N, 149 degree 21' W) draining upland tundra in the foothills of the Brooks Range. Caribou-Poker Creek is a 4th order Subarctic stream (65 degree 08' N, 147 degree 28' W) draining the taiga forest north of Fairbanks, Alaska. The aquatic insect larvae and other macroinvertebrates were sampled with drift nets and Hess bottom samplers for four periods, each 1 week long in the ice free season of three years. We found 112 species in the Arctic stream and 138 species in the subarctic stream in a chironomid-dominated community. In any sample period the communities contained 51-60 species in the Arctic and 49-92 species in the subarctic. Between the four sample periods on average 39% and 50% of the species were present in two sequential samples in the Arctic and Subarctic stream, respectively. New immigrants, never before found in the system, averaged 37% and 31% of the community, respectively. These systems are exposed to several intermediate disturbances: prolonged and variable freeze-up, extreme variation in discharge, wide diel and seasonal changes in temperature, and erosion by frazil and anchor ice. The dipterans that compose the most numerous and variable taxa must have variable diapause, ability to grow in cold waters, and good dispersal powers, even migrating across drainages in the Arctic. Much of the seasonal dominance pattern appears therefore to be stochastic.

205) Neill, C.R., J.S. Buska, E.F. Chacho, C.M. Collins, and L.W. Gatto. 1984. Overview of Tanana River monitoring and research studies near Fairbanks, Alaska. US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 84-37. 360pp. (A, F, G, I)

Author abstract: The Tanana Rive changes character in the vicinity of Fairbanks, from the braided pattern upstream of North Pole to the anastomosing or irregular meander patter upstream of the Chena River confluence. This transition in planform is accompanied by a marked decrease in gradient and a change in dominant bed material from gravel to sand. Within the past 50 years the river has been affected by a variety of human activities, including flood control works, access causeways and gravel extractions. The river's cross-section shows large variation in width and depth from one location to another, but total cross-sectional area and mean velocity are relatively constant at a discharge of about 60,000 cfs, close to the mean annual flood. Annual flow hydrographs are quite similar from one year to another. Sediment transport in the river average about 360,000 tons per year of bed load, approximately equally divided between sand and gravel sizes and about 28,000,000 tons per year of suspended load, of which about 35% is sand and the rest silt and clay. Natural channel processes are dominated by within-bank shifts in channel and bar patterns and cross-sectional shapes, erosion of the main floodplain and island banks being fairly localized and generally proceeding at modest rates. No relationships have been discerned between rates of bank erosion and soil, permafrost or vegetation factors. Response to human intrusions is generally difficult to distinguish from natural processes beyond the immediate vicinity of the intrusions and more than a short time after cessation of activity. Details are discussed regarding observation of inferred response to groin construction and gravel extraction. Generally structural intrusions and gravel extractions activities that have not constituted a major disturbance to the river system have achieved their desired result with no apparent adverse effects of any significance. Blockage of the north channel at Goose Island by causeways, reoccupation of gravel extraction areas from permanent bars and islands, and secondary channel closures are believed to have considerable effects on flow and erosional pattern for some distance downstream. The Phase III in-river levee and groin construction constituted a strong local disturbance of the river system where local river slope was steepened and large quantities of bed material were put into transport from pilot channel enlargement as the river adjusted to the new alignment. As of the end of 1982, the full and final effects of the disturbance were not clear. Recommendations are given regarding impacts from human activities, alleviation of impacts, levee protection, further interpretive analysis and future monitoring of river behavior.

206) Olsen, J.B., W.J. Spearman, G.K. Sage, S.J. Miller, B.G. Flannery, and J.K. Wenburg. 2004. Variation in the population structure of Yukon River chum and coho salmon: Evaluating the potential impact of localized habitat degradation. Transactions of the American Fisheries Society. 133: 476-483. (K)

Author abstract: We used microsatellite and mitochondrial DNA–restriction fragment length polymorphism (mtDNA–RFLP) analyses to test the hypothesis that chum salmon *Oncorhynchus keta* and coho salmon *O. kisutch* in the Yukon River, Alaska, exhibit population structure at differing spatial scales. If the hypothesis is true, then the risk of losing genetic diversity because of habitat degradation from a gold mine near a Yukon River tributary could differ between the two species. For each species, collections were made from two tributaries in both the Innoko and Tanana rivers, which are tributaries to the lower and middle Yukon River. The results revealed a large difference in the degree and spatial distribution of population structure between the two species. For chum salmon, the microsatellite loci (*F*-statistic [F_{ST}] = 0.021) and mtDNA (F_{ST} = -0.008) revealed a low degree of interpopulation genetic diversity on a relatively large geographic scale. This large-scale population structure should minimize, although not eliminate, the risk of genetic diversity loss due to localized habitat degradation. For coho salmon, the microsatellites (F_{ST} = 0.091) and mtDNA (F_{ST} = 0.586) revealed a high degree of interpopulation genetic diversity on a relatively small geographic scale. This small-scale population structure suggests that coho salmon are at a relatively high risk of losing genetic diversity due to localized

habitat degradation. Our study underscores the importance of a multispecies approach for evaluating the potential impact of land-use activities on the genetic diversity of Pacific salmon.

207) Oswood, M.W. 1989. Community structure of benthic invertebrates in interior Alaskan (USA) streams and rivers. Hydrobiologia. 72: 97-110. (C)

Electronic abstract: Taxonomic composition of benthic invertebrates in interior Alaskan streams and rivers is summarized from published and unpublished data. Diptera dominate the Alaskan stream fauna and constitute a larger proportion of the benthos in Alaskan streams than in streams of temperate North America. Plecoptera and Ephemeroptera are the next most abundant in Alaskan streams with Trichoptera generally very scarce. Several orders that occur regularly in streams of temperate North America are absent (or in very low abundance) in interior Alaskan streams: Hemiptera, Odonata, Megaloptera, Coleoptera. Netspinning caddisflies, burrowing mayflies, and several families of stoneflies (Pteronarcyidae, Peltoperlidae and Perlidae) are conspicuous by their absence or extreme scarcity. Taxonomic composition varies significantly among hydrologic regions (major watersheds) and among stream types (springs, headwater streams, small rivers, and large rivers). Only two taxa (Chironomidae and Nemouridae) significantly increase in proportional contribution from south to north while many taxa decrease.

208) Ott, A.G., J.F. Winters, and A.H. Townsend. 1998. Juvenile fish use of selected habitats in the Tanana River near Fairbanks (Preliminary report). Alaska Department of Fish and Game, Habitat and Restoration Division, Juneau, Alaska, Technical Report No. 97-1. 133pp. (K)

Author abstract (Author Executive Summary): During the summer of 1996, we conducted the first year of a two year study of juvenile fish abundance in various habitats of the Tanana River. Limited sampling in 1994 provided guidance on techniques and locations. Fish were collected using seines, minnow traps, and electrofishing. Tanana River habitat types sampled included rocky bluffs, gravel bars, silt bars, root wads, cutbanks, backwaters, Clearwater tributaries, connected wetlands, and tannin-colored sloughs. Predominate fish species found were longnose sucker (*Catostomus catostomus*) and lake chub (*Couesius plumbeus*). These species were captured in most of the habitat types sampled. Young-of-the-year longnose suckers were most abundant in tannin-colored sloughs and the interconnected wetland complex. Backwater habitats within the active floodplain of the Tanana River were used preferentially by longnose suckers and lake chub. Coho salmon (*Oncorhynchus kisutch*) juveniles were abundant in late May/early June 1996 and catches were highest in the main channel of the river. Chinook salmon (*Oncorhynchus tshawytscha*) outmigrants were not found and a few chum salmon (*Oncorhynchus keta*) fry were caught in 1996. Arctic grayling (*Thymallus arcticus*), round white fish (*Prosopium cylindraceum*), least cisco (*Coregonus sardinella*), burbot (*Lota lota*), and northern pike (*Esox lucius*) were occasionally caught in the Tanana River or in the lower parts of tributaries and sloughs.

209) Ott, R.A. 1998. The impact of winter logging roads on vegetation, ground cover, permafrost, and water movement on the Tanana River floodplain in interior Alaska. Cooperative Agreement AK-DF-A97-RN0006, 10-97-052 report written by the Tanana Chiefs Conference, Inc., Forestry Program, Fairbanks, Alaska. Written for the Alaska Department of Natural Resources, Division of Forestry, Fairbanks, Alaska. 31pp. (K)

Author abstract: Winter logging roads are used in interior Alaska to cross floodplain wetlands underlain by permafrost in order to access productive forest stands. Although construction of winter roads is restricted to times when the active layer is frozen and/or when the presence of a snow layer helps protect the ground surface, winter roads still may impact floodplain areas. Potential effects of winter roads in these areas include: changes of water movement, increased active layer depth, development of thermokarst topography, removal of soil, and delayed re-vegetation of roadbeds.

During September 1997, I quantified active layer depths, and vegetation and ground cover patterns, on 2 winter roads and adjacent undisturbed areas in 8 plant communities (4 forest, 4 shrub) underlain by permafrost. The study was conducted on the Tanana River floodplain near the village of Nenana in central Alaska. Within each plant community 4 to 5 sample lines, oriented perpendicular to the roadbed and centered over it, were spaced at 30 ft. intervals. Data that were collected at 2 ft. intervals along each sample line were: active layer depth, erect vegetation occurrence by life-form for 3 height strata (>6 ft., 3 to 6 ft., and <3 feet), occurrence of mat-forming (ground layer) vegetation by life-form, ground cover occurrence, and ground surface height.

In general, roadbeds were dominated by graminoids. Short shrubs generally were the second most frequent erect life-form on roadbeds. Exposed soil was present in small amounts (1.2 to 14.6% occurrence) on the roadbeds, but was greater than in non-roadbed areas in 5 of the communities. Continued use of the winter roads keeps them in early seral stages of plant succession. It is expected that perennial graminoids will dominate winter roadbeds as long as they continue to be frequently used.

Surface permafrost has receded in the roadbeds of 6 sampled plant communities. During construction, standing vegetation and some or all of the organic mat was removed in the roadbeds. The ground was not shaded by tall vegetation initially after road construction. Although roadbeds are now covered with graminoids, shading effects are probably less than those produced by the several layers of vegetation that were present before road construction. The removal of the organic mat resulted in the reduction or elimination of the insulating properties of that layer. Increased active layer thickness of winter roadbeds was greatest in the 2 black spruce communities. Both spruce communities were located on the Cosna Road; the loss of the entire organic mat on that roadbed probably accounts for these sites being the most influenced of the 6 communities where roadbed permafrost has receded. In contrast, the other 4 plant communities where permafrost has receded in the roadbeds are located along Soldier Slough Road, which retained an insulating layer of organic material on the ground.

The 2 communities—shrub birch-leatherleaf-Labrador tea community and the leatherleaf community—where mean active layer depths indicated that permafrost actually aggraded in the roadbeds also were located on the Cosna Road. Taliks (thawed zones) were common under a thin layer of permafrost off the roadbeds in these 2 communities. These taliks are probably a result of

the winter of 1995-96. Cold temperatures with little snowfall during that winter probably resulted in the development of a thin permafrost layer that is now in the process of thawing. For reasons that are unknown at this time, the thin permafrost layer under the roadbeds of the shrub birch-leatherleaf-Labrador tea community and the leatherleaf community is not thawing as fast as in the non-roadbed areas.

Saturated substrates were only recorded in the roadbeds of the 2 communities that had tussocks—tamarack woodland community and cottongrass tussock community—and open water was present only in the roadbed of the cottongrass tussock community. Lowering of the ground surface through removal of tussocks in the roadbeds may have brought the water table closer to the surface. Water flow was not observed to be channeled along winter roadbeds. Erosion due to thawing of ice-rich soil was not observed.

210) Ott, R.A., and W.E. Putman. 1999. Monitoring riparian buffers along glacial rivers in interior Alaska: Procedures for data collection and processing. Cooperative Agreement AK-DF-A97-RN0006, 10-97-052 report written by the Tanana Chiefs Conference, Inc., Forestry Program, Fairbanks, Alaska. Written for the Alaska Department of Natural Resources, Division of Forestry, Fairbanks, Alaska. 14pp. (K)

Compiler abstract: Tanana Chiefs Conference Forestry Program (TCC Forestry) installed two monitoring sites in mature white spruce riparian buffers along the Tanana River and Tok River. The study was designed to increase understanding of (1) the persistence of riparian buffers in the absence of erosion, with an emphasis on the tree component; and (2) large woody debris (LWD) recruitment rates into rivers. TCC Forestry provided the Alaska Division of Forestry with an ArcView project (buffer_monitoring.apr) containing all data collected during monitoring site installations (summer 1997) as well as tree mortality data collected the following year (fall 1998). This document is a supplement to the ArcView project. It contains study site locations, data collection methods, procedures used to process and display the spatial data, and descriptions of variable names contained in the ArcView project.

211) Ott, R.A., M.A. Lee, W.E. Putman, O.K. Mason, G.T. Worum, and D.N. Burns. 2001. Bank erosion and large woody debris recruitment along the Tanana River, interior Alaska. Project NP-01-R9 report written by the Alaska Department of Natural Resources, Division of Forestry and the Tanana Chiefs Conference, Inc., Forestry Program, Fairbanks, Alaska. Written for the Alaska Department of Environmental Conservation, Division of Air and Water Quality, Juneau, Alaska. 34pp. (D, F, G)

Author abstract: The management intent of the Alaska Forest Resources and Practices Act (FRPA) for riparian areas is to protect fish habitat and water quality from significant adverse effects of timber harvest. Among other things, FRPA requires maintaining short- and long-term supplies of LWD, stream bank stability, and channel morphology. In interior Alaska, concerns have focused on forest harvest impacts on river bank erosion and large woody debris (LWD) recruitment along the 824 km-long Tanana River.

This project was initiated to quantify baseline conditions of the amount and spatial distribution of bank erosion, and the associated LWD recruitment along the entire length of the

Tanana River, which currently has been little impacted by contemporary forest harvest. River bank erosion and LWD recruitment were quantified for the 1978-80 to 1998-99 time period using change analysis within a Geographic Information System, and existing forest inventory data. Data were summarized by 10 km reaches.

For the entire river, 5,104 ha of river bank eroded, with 3,888 ha contributing LWD. The distribution of land area eroded was highly variable, and ranged from 0.3 ha to 309 ha/10 km of river. Based on erosion patterns, five distinct regions of the river were identified. The amount of land area eroded along the Tanana River was related to slope patterns and the distribution of silt-laden tributaries of glacial origin. Among vegetation size classes, eroded land area was distributed fairly evenly among stands of sapling-sized trees and dwarf forests (28.3%); stands of pole-sized trees (27.8%); and shrublands, wetlands, and other non-forested land cover (22.9%). Among vegetation types, erosion occurred most frequently in tall shrublands (21.0%), followed by stands of balsam poplar saplings (15.7%). A total of 4,266 individual erosion patches were identified along the entire Tanana River. Erosion patches varied in size from 0.01 to 58.84 ha, but the majority (78.0%) were 0.01 to 1.00 ha in size. Almost all (94.5%) of the erosion patches were ≤ 5.0 ha in size. The greatest cumulative amount of erosion (16.1%) occurred within patches that were 0.01 to 1.00 ha in size. Land area contained within erosion patches ≤ 5 ha was 47.2% of the total. Maximum erosion distance within an erosion patch varied from <2 m to 401 m, but was most commonly (26.6%) 10 to 19 m.

The volume of LWD recruited into the Tanana River totaled 448,070 m^3. The distribution of LWD was highly variable and ranged from 8.2 m^3 to 50,867 m^3/10 km of river. Spatial patterns of LWD recruitment were similar to land erosion patterns. Among vegetation size classes, the largest LWD volumes (47.6%) originated from sawlog-sized stands of trees. Among vegetation types, LWD volume was greatest (24.7%) from stands of white spruce sawlogs. Erosion patches 0.01 to 1.00 ha in size contributed the most LWD (10.6%). The majority of LWD (53.6%) was recruited from erosion patches ≤ 9 ha in size.

Information obtained from this project will allow resource managers to better understand natural processes of river bank erosion and LWD recruitment, and to highlight future research needs that can be used to assess the implications of management actions.

212) Perry, R.W., M.J. Bradford, and J.A. Grout. 2003. Effects of disturbance on contribution of energy sources to growth of juvenile Chinook salmon (*Oncorhynchus tshawytsha*) in boreal streams. Canadian Journal of Fisheries and Aquatic Sciences. 60: 390-400. (C, E)

Author abstract: We used stable isotopes of carbon in a growth-dependent tissue-turnover model to quantify the relative contribution of autochthonous and terrestrial energy sources to juvenile Chinook salmon (*Oncorhynchus tshawytscha*) in five small borel streams tributary to the upper Yukon River. We used a tissue-turnover model because fish did not grow enough to come into isotopic equilibrium with their diet. In two streams, autochthonous energy sources contributed 23 and 41% to the growth of juvenile salmon. In the other three, fish growth was largely due to terrestrial (i.e., allochthonous) energy sources. This low contribution of autochthonous energy appeared to be related to stream specific disturbances: a recent forest fire impacted two of the streams and the third was affected by a large midsummer spate during the study. These disturbances reduced the relative abundance of herbivorous macroinvertebrates, the contribution of autochthonous material to other invertebrates, and ultimately, the energy flow

between stream algae and fish. Our findings suggest that disturbances to streams can be an important mechanism affecting transfer of primary energy sources to higher trophic levels.

213) Peterson, L.A. 1973. An investigation of selected physical and chemical characteristics of two subarctic streams. M.S. Thesis, University of Alaska, Fairbanks. 185pp. (G, I)

Electronic abstract: The objectives were to delineate baseline physical and chemical characteristics of the Chatanika River and Goldstream Creek, ascertain the source of nutrients in the streams from breakup to freezeup, delineate any significant local variation within each stream and compare the physical and chemical characteristics between the streams. The concentrations of the selected physical and chemical parameters were generally low in both streams, remaining within expected levels of unpolluted fresh water streams in the Chatanika River. Five parameters exceeded expected levels of unpolluted fresh water streams at two or more sample sites on Goldstream Creek. The concentrations of nutrients in both streams were generally quite low from breakup to freezeup; there were no important single point sources of nutrients in the Chatanika River or Goldstream Creek. The Chatanika River did not exhibit any significant local variation in water quality in the study area. Two tributaries of Goldstream Creek and one area within Goldstream Creek exhibited significant local variation in water quality, which was caused by groundwater inflow of different quality at the three locations. the major differences in water quality between the Chatanika River and Goldstream Creek are due to topography and soil types, which cause surface and groundwater movement through Goldstream valley to be slower than through the Chatanika River valley, resulting in different quality surface and groundwaters entering these streams. The quality of the water in the Chatanika River is such that it would be an acceptable source for domestic and most industrial waters, and would be able to assimilate some waste without undue degradation of the water quality. Goldstream Creek should not be considered as a source for water or for waste assimilation due to low flow and poor water quality during winter.

214) Popovics, L.M. 1999. The effect of soil and stream water quality on primary and secondary productivity of Rock Creek, Denali National Park and Preserve, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 98pp. (A, C, E, G, I)

Author abstract: Aquatic productivity may be affected by physical and chemical properties of soil water and streamwater. This study related primary and secondary productivity to parameters in relation to four soil mapping units within Rock Creek watershed. Physical and chemical properties of soil were measured on these four sites. Stream characteristics were determined using measurements on hydrology, stream water chemistry, organic matter retention, limiting nutrients, primary production and secondary production.

Geochemicals dominated the streamwater chemistry with concentrations typically greater than in soil water. Periphyton biomass and invertebrate densities were low in Rock Creek compared to other subarctic streams. Nutrient diffusing substrate studies indicated primary productivity increased in response to phosphorus- and some nitrogen-and-phosphorus treatments. This response is consistent with undetected streamwater levels of phosphorus. Physical factors affecting retention, stream discharge, and channel morphology were significant in limiting the primary and secondary productivity of Rock Creek.

215) Ray, S.R. 1988. Physical and chemical characteristics of headwater streams at Caribou-Poker Creeks Research Watershed, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 172pp. (G, I)

Author abstract: The major-element hydrogeochemistry of four streams in the Caribou-Poker Creeks Research Watershed was studied during low-flow conditions. The flow of the streams was measured and samples analyzed for major ions at two-week intervals from November, 1985 through April, 1987. Samples were analyzed for Ca, Mg, Na, K, Al, Fe, Mn, Si, Cl, NO_3, SO_4, and HCO_3.

The streams are dilute calcium-bicarbonate waters with a range of 37 to 108 mg/l for TDS and 6.54 to 7.58 for pH. The variability in calcium concentration in the different streams depends on the amount and distribution of permafrost in the basin.

The ratio of baseflow to total runoff for each stream was constant, suggesting geomorphic control.

The effect of permafrost on the stream chemistry and baseflow was the major finding of this study.

216) Rickard, W.E., and C.W. Slaughter. 1973. Thaw and erosion on vehicular trails in permafrost landscapes. Journal of Soil and Water Conservation. 28: 263-266. (K)

Author abstract: Two types of off-road access trails constructed on permafrost terrain in central Alaska were monitored to determine the environmental consequences of off-road vehicular travel for both recreational and business pursuits on such terrain. Tractor-cleared trails showed severe permafrost thaw and soil movement the first season after use. A hand-cleared controlled-access trail was markedly more stable, showing lower levels of soil movement even after three seasons of frequent travel.

217) Schallock, E.W., and F.B. Lotspeich. 1974. Winter dissolved oxygen in some Alaskan rivers. Environmental Protection Agency, Arctic Environmental Research Lab, University of Alaska, Fairbanks, Ecological Research Series Report EPA-660/3-74-008. 33pp. (G, I)

Electronic abstract: Water samples collected during the years 1969 through 1972, from 36 selected Alaskan rivers were analyzed for dissolved oxygen, pH, conductivity and alkalinity. Dissolved oxygen (d.o.) ranged from 0.0 to 15.3 ml/l (106 percent saturation); pH from 6.2 to 8.4; conductivity varied from 105 to 3000 (umho/cm); and alkalinity from 28 to 410 (mg/l). Severe d.o. depletion during winter was found in many river systems large and small, and located in a range of latitudes (70 deg n to 61 deg n). Sufficient data were collected on the Chena, Chatanika, and Salcha rivers to reveal annual d.o. trends: near saturation during spring 'breakup' and fall 'freezeup' when water temperatures are near 0 deg c; somewhat lower d.o. concentrations during warm water summer periods; and yearly minimum concentrations during the winter (January-March) interval. Data indicate that d.o. depression begins in October and continues into February. d.o. from stations near the mouth of a river were generally depressed more than at upper stations. The latter trend was observed in the Yukon River which contained 10.5 mg/l (73 percent saturation) at the Canadian border but only 1.9 mg/l (13 percent) near the mouth. pH

gradually decreased in some rivers although alkalinity and conductivity increased. The depressed winter d.o. concentrations and low winter discharge in many Alaskan rivers are more severe and widespread than present literature indicates. Winter conditions may already limit aquatic organisms in some systems.

218) Slaughter, C.W. 1971. Caribou-Poker Creeks Research Watershed, interior Alaska, background and current status. US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 157. 11pp. (G, I, J)

Electronic abstract: The Caribou-Poker Creeks Research Watershed was established in 1969 as a site for cooperative, inter-agency investigation of hydrologic and related aspects of a subarctic environment. The relatively undisturbed 40-square-mile drainage basin includes both permafrost-dominated and nonpermafrost watersheds, and has a variety of vegetation communities. Research is directed to hydrologic behavior of north-facing (permafrost) and south-facing (non-permafrost) basins in this upland setting. Air temperature and precipitation are monitored at three elevations (mouth, 1600 ft and 2100 ft); water temperature is measured at two locations, and streamflow is measured at periodic intervals. Related work is underway dealing with soil moisture relations, nutrient cycling in a black spruce environment, and surface water chemistry.

219) Smidt, S. 1997. Spatial variation in the community structure of stream macroinvertebrates within a subarctic Alaskan watershed. M.S. Thesis, University of Alaska, Fairbanks. 53pp. (C)

Author abstract: We investigated spatial variability in the community structure of stream macroinvertebrates at six reaches within Caribou-Poker Creeks Research Watershed differing in river continuum position (stream orders 1-4) and influence of permafrost. Leaf litter input, measured between July and October 1995, was similar among most reaches. However, observed differences in the phenology of input may be very important. We sampled benthic organic material and macroinvertebrates six times during the ice-free season between June 1995 and June 1996. Mean invertebrate abundance (range: 1160 – 14494 indiv./m^2) and biomass (range: 0.21 – 0.84 g ash-free dry weight/m^2) were significantly different among sites, the lowest values occurring in the stream draining a high permafrost basin. Taxonomic and functional feeding group differences among sites appeared to be related to the amount of the drainage basin underlain by permafrost and position along a truncated river continuum. This research highlights the importance of permafrost for stream communities.

220) Smidt, S., and M. Oswood. 2002. Landscape patterns and stream reaches in the Alaskan taiga forest: Potential roles of permafrost in differentiating macroinvertebrate communities. Hydrobiologia. 468: 95-105. (C)

Electronic abstract We investigated spatial variability in the community structure of stream macroinvertebrates at six reaches within Caribou-Poker Creeks Research Watershed in the Alaskan taiga forest. Stream reaches differed most notably in river continuum position (stream orders 1-4) and influence of permafrost. Permafrost may underly much of an entire watershed or may be only locally present in valley bottoms. Permafrost distribution influences hydrology, water temperature, and riparian vegetation. We sampled benthic macroinvertebrates six times during the ice-free season between June 1995 and June 1996. Mean invertebrate abundance (range: 1160-14494 individuals \ m^{-2}) was significantly different among sites, the lower values occurring in stream reaches affected by the local presence of permafrost and the highest value in a headwater stream unaffected by permafrost. Taxonomic composition of the macroinvertebrate community also differed among reaches, with the quantity of watershed-level permafrost and stream size providing the strongest influences. This research highlights the importance of permafrost at two spatial scales (watershed and reach) for macroinvertebrate communities of headwater streams at high latitudes.

221) Wellen, P.M., and D.L. Kane. 1985. Appendix to a hydraulic evaluation of fish passage through roadway culverts in Alaska: Data report. Final Report No. FHWA-AK-RD-85-24A written by the Institute of Water Resources/Engineering Experiment Station, University of Alaska, Fairbanks. Written for the Alaska Department of Transportation and Public Facilities, Division of Planning, Research Section, Fairbanks, Alaska. 240pp. (K)

Author abstract: Culverts are a very simple hydraulic structure. However, because the engineer must design for peak flows passing through the culvert while fish are trying to move upstream serious problems arise. Almost all culvert installations in interior and northern Alaska were casually examined, with approximately 100 examined in detail where hydraulic problems existed that may retard fish passage. Data from the field program are included in an appendix to this report. The two major hydraulic problems in regard to fish passage were high velocities and perching; inlet drops caused by deposited sediment, aufeis, alignment of culvert with stream, and non-uniform culvert slopes are some of the other fish passage deterrents that were observed. Also, all known baffled structures were evaluated. Numerous recommendations were made that should improve the hydraulic conditions that exist at a culvert relative to fish passage. Also, it is recommended that further studies be carried out to evaluate the swimming performance of the native fish. Present design criteria are based on very limited studies. Lastly, it is recommended that the concept of the velocity in the occupied zone (area in culvert where fish swim) be considered as the culvert design velocity for fish passage in place of the presently used average cross-sectional velocity.

222) Worum, G.T., D.N. Burns, W.E. Putman, R.A. Ott, and M.A. Lee. 2001. Images of bank erosion and large woody debris recruitment along the Tanana River, interior Alaska: Results of a change analysis. Volume I: Upper Tanana River, Volume II: Middle Tanana River, Volume III: Lower Tanana River. Project NP-00-N9 report written by the Alaska Department of Natural Resources, Division of Forestry and the Tanana Chiefs Conference, Inc., Forestry Program, Fairbanks, Alaska. Written for the Alaska Department of Environmental Conservation, Division of Air and Water Quality, Juneau, Alaska. (A, D, F)

Compiler abstract: In interior Alaska, concerns have been raised regarding the impact of forest management activities on fish habitat and water quality along the 824 km-long Tanana River. It has been suggested that the harvest of riparian timber along the Tanana River can increase riverbank erosion rates with the result that productive spawning or rearing areas could be degraded through sedimentation processes or changes in channel morphology. It has also been suggested that timber harvest near along the river will decrease the supply of LWD that is recruited into the river through natural erosion processes.

This project was conducted to quantify baseline conditions (1978-80 through 1998-1999) of the amount of bank erosion, and the associated LWD recruitment along the entire length of the Tanana River, which currently has been little impacted by contemporary forest harvest. Bank erosion and LWD recruitment were quantified by conducting a change analysis within a Geographic Information System (GIS).

This very over-sized three volume report contains the images used to conduct the change analysis, plus images showing the results of the change analysis, for the entire Tanana River. Each page contains three orthorectified images for one 10 km section of the river (except for the first reach at the source of the river, which was 4 km in length). The three images on each page are: 1) a late 1970s or early 1980s digital color infrared aerial photograph with the vegetation types delineated along the 10 km length of the river, 2) a late 1990s satellite image with the vegetation types delineated along the same section of river, and 3) the satellite image with colored polygons showing where bank erosion had occurred during the time period of study. In addition, each page contains a tabular summary of the results of the change analysis for the 10 km reach shown in the three images. The interpretation of the results of this project, and a more detailed description of the methods used, can be found in Ott et al. (2001).

223) Wuttig, K.G. 1997. Successional changes in the hydrology, water quality, primary production, and growth of juvenile Arctic grayling of blocked Tanana River sloughs, Alaska. M.S. Thesis, University of Alaska, Fairbanks. 105pp. (C, E, G, I, J)

Author abstract: A comparative stream study was conducted to assess the influence of development and blockage on the hydrology, water quality, primary production, and Arctic grayling of Badger Slough, Alaska. Data collected showed that Badger Slough exhibited stable, clear flows throughout the summer, and higher total and total dissolved phosphorus, orthophosphate, alkalinity, pH, conductivity, and average temperatures, and lower winter dissolved oxygen concentrations than both Piledriver and 23-Mile Sloughs. Mean algal biomass (3.3 mg m^{-3}) and primary production (6.9 g O_2 m^{-2} d^{-1}) are greater than that recorded for any other interior Alaska streams and percent fines in riffle substrates have increased. However, growth of age-0 grayling remains high. Badger Slough has eutrophied due to increased nutrients and stable flows, and the quality of rearing habitat for age-0 fish remains good. However, an annual flushing flow of 8.0 m^3 s^{-1} is recommended for controlling accumulations of fines and maintenance of grayling habitat.

Alaska—General

(State-Wide References and References in Which the Location of the Study Area Was Not Identified)

224) Arians, A. (Compiler). 2003. Summary of monitoring studies of the effectiveness of practices under the Alaska Forest Resources and Practices Act: 1990-2002. Grant NA17OZ1113 report written by the Alaska Department of Natural Resources, Division of Forestry, Anchorage, Alaska. Written for the Alaska Coastal Management Program, Office of the Governor. 29pp. (A, B, C, D, E, F, G, H, I, J)

Compiler abstract: This document provides summaries of effectiveness monitoring studies conducted with respect to activities performed under the current Alaska Forest Resources and Practices Act (FRPA). The document is divided into two broad categories—fish habitat and water quality. Within each of those two categories, project summaries are organized by FRPA Regions I, II, and III. A total of 28 projects are described; sixteen projects address fish habitat issues, and 12 projects address water quality issues. Eighteen of the projects were conducted within FRPA Region I (coastal Sitka spruce/hemlock forest), three projects were conducted within FRPA Region II (interior spruce/hardwood forest, south of the Alaska Range), and seven projects were conducted within FRPA Region III (interior spruce hardwood forest, north and west of the Alaska Range). Topics addressed by the summarized projects include all ten of the fish habitat and water quality variables protected by FRPA—channel morphology, clean spawning gravels, food sources, large woody debris, nutrient cycling, stream bank stability, stream flow, sunlight, water quality, and water temperature.

225) Ashton, W.S., and R.F. Carlson. 1984. Determination of seasonal, frequency and durational aspects of streamflow with regard to fish passage through roadway drainage structures. Final Report No. AK-RD-85-06 written by the Institute of Water Resources, University of Alaska, Fairbanks. Written for the Alaska Department of Transportation and Public Facilities, Division of Planning and Programming, Research Section, Fairbanks, Alaska. 51pp. (G)

Author abstract: Optimal design of culverts for fish passage for each stream crossing requires the magnitude, duration, frequency and seasonal relationship of the flow and the timing of fish movement. Although previous studies have measured fish swimming abilities and culvert water velocity profiles, there are limited studies in northern regions of the hydrologic relationship among magnitude, duration, frequency and season of discharge for the design of culverts for fish passage. We analyzed streamflow records from 33 gaging stations in southcentral, western, interior, and arctic Alaska (from watersheds with a drainage area less than 100 mi^2 each) to determine the highest consecutive mean discharge with one-, three-, seven- and fifteen-day durations, and the lowest consecutive mean discharge with three-, seven-, fourteen- and thirty-day durations. Streamflow during three seasons were analyzed: spring, April 1 to June 30; summer, July 1 to August 31; and fall, September 1 to November 30. The lognormal distribution, using the Blom plotting position formula, was used to estimate flows at recurrence intervals of 1.25, 2, 5, 10 and 20 years. Multiple linear regression equations were developed to predict flows from ungaged watersheds. Significant basin and climatic characteristics for high flows were drainage area, mean annual precipitation and percent of the drainage basin with forest cover.

Significant characteristics at low flows were drainage area, mean minimum January temperature, mean annual precipitation and percent of drainage basin covered by forests. This report provides the culvert designer with equations to predict flows, other than the instantaneous peak flows, for use in designing culverts for fish passage. Two example problems are given to show the application of these equations.

226) **Balding, G.O. 1976. Water availability, quality, and use in Alaska. USDI Geological Survey Anchorage, Alaska, Open-File Report 76-513. 236pp. (G, I)**

Electronic abstract: The Alaska Water Assessment, sponsored by the Water Resources Council, is a specific problem analysis for Alaska of the National Assessment of Water and Related Land Resources. The Alaska region has been divided into six hydrologic subregions and eighteen subareas. For each subarea, estimated mean annual runoff per square mile, suspended-sediment concentrations that can be expected during 'normal' summer runoff, flood magnitudes and frequencies, and ground-water yields are illustrated on maps. Tables show water quality of both ground water and surface water from selected wells and streams. Water use according to the type of use is discussed, and estimates are given for the amounts used. Water-use categories include domestic, irrigation, livestock, seafood processing, oil and gas development, petrochemical processing, pulp mills, hydroelectric, coal processing, steam electric, mineral processing, sand and gravel mining, and fish-hatchery operations.

227) **Bauer, S.B., and S.C. Ralph. 1999. Aquatic habitat indicators and their application to water quality objectives within the Clean Water Act. US Environmental Protection Agency, Region 10, Seattle, Washington, EPA-910-R-99-014. (A, B, F, G, J)**

Electronic abstract: The objective of this paper is to evaluate the application of aquatic habitat variables to water quality objectives under authority of the Clean Water Act (CWA). The project is limited to freshwater, lotic aquatic habitats in the Pacific Northwest and Alaska with an emphasis on salmonid habitat. Habitat variables were placed into one of the following categories- flow regime, habitat space, channel structure, substrate quality, streambank condition, riparian condition, temperature regime, and habitat access. Candidate habitat variables were evaluated for their relevance to the biotic community, responsiveness to human impacts, applications to target landscapes, and measurement reliability. The most critical obstacles for use of habitat variables at the regional level (state specific water quality criteria for Region 10 EPA) are the quantification of biological effect and the unreliability of the unreliability of the measurement system.

228) **Behlke, C.E., D.L. Kane, R.F. McLean, and M.D. Travis. 1991. Fundamentals of culvert design for passage of weak-swimming fish. Final Report No. FHWA-AK-RD-90-10 written by the Water Research Center, Institute of Northern Engineering, University of Alaska; the Alaska Department of Fish and Game, Habitat Division; and the Alaska Department of Transportation and Public Facilities, Statewide Research, Fairbanks, Alaska. Written for the Alaska Department of Transportation and Public Facilities, Statewide Research, Fairbanks, Alaska. 177pp. (K)**

Author abstract: Properly designed culverts do not produce water velocities that exceed fish swimming abilities. Fish have two different musculature systems for swimming. A white muscle system that generates power for short, vigorous swimming. A red muscle system that furnished power for long, sustained swimming. The culvert design must account for both swimming modes. Therefore, the engineer must know the hydraulic conditions where the fish swims. These conditions change throughout the culvert. The engineer determines acceptable hydraulic conditions by matching known fish swimming power and energy capabilities.

Subcritical flow is necessary to pass week-swimming, upstream-migrating fish. Therefore, this requirement precludes the use of inlet control. The engineer may use artificial roughness to create areas of slower water velocities within culverts. Examples of these are depressed inverts, weir baffles, and deep culvert corrugations.

This manual presents design procedures to pass upstream-migrating, weak-swimming fish. The manual also displays criteria for retrofitting existing culverts. This paper does not present cost-effective design criteria for strong-swimming fish.

229) Benson S.L., D.L. Hess, D.F. Meyer, K.A. Peck, and W.C. Swanner. 1997. Water resources data for Alaska, water year 1997. USDI Geological Survey, Water Resources Division, Juneau, Alaska, USGS/WRD/AK-97/1. (G, I)

Electronic abstract: This volume contains records for water discharge at 81 gauging stations; stage or contents only at 8 gauging stations; water quality at 21 gauging stations; and water levels for 60 observation wells. Also included are data for 51 crest-stage partial-record stations and 1 lake. Additional water data were collected at various sites not involved in the systematic data- collection program and is published as miscellaneous measurements and analyses.

230) Bigelow, B.B., R.D. Lamke, P.J. Still, J.L. Van Mannen, and J.E. Vaill. 1985. Water resources data for Alaska, water year 1984. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-84-1 (WRD/HD-85/264). 347pp. (G, I)

Electronic abstract: Water resources data for the 1984 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells. This report contains discharge records for 112 gaging stations; water quality for 43 stations; and water levels for 31 observation wells. Also included are 64 crest-stage, and 59 water quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

231) Bigelow, B.B., R.D. Lamke, P.J Still, J.L. Van Mannen, and J.E. Vaill. 1986. Water resources data for Alaska, water year 1985. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-85-1 (WRD/HD-86/252). 328pp. (G, I)

Electronic abstract: Water resources data for the 1985 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells. This report contains discharge records for 108 gauging stations; water quality for 40 stations; and water levels for 31 observation wells. Also included are 66 crest-stage, 15 low-flow, and 19 water-quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

232) Bigelow, B.B., R.D. Lamke, P.J. Still, J.L. Van Mannen, and R.L. Burrows. 1989. Water resources data for Alaska, water year 1988. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-88-1 (WRD/HD-89/231). 196pp. (G, I)

Electronic abstract: Water resources data for the 1988 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage of lakes; and water levels and water quality of groundwater wells. This volume contains records for water discharge at 85 gaging stations; water quality at 24 gaging stations, and water levels for 26 observation wells. Also included are data for 66 crest-stage partial-record stations and 13 lakes. Additional water data were collected at various sites, not involved in the systematic data collection program, and is published as miscellaneous measurements and analyses. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

233) Blevins, V., and R.F. Carlson. 1988. Retrofit design of drainage structures for improved fish passage: Literature review. Report No. AK-RD-89-02 written by the Water Research Center, Institute of Northern Engineering, University of Alaska, Fairbanks. Written for the Alaska Department of Transportation and Public Facilities, Research Section, Fairbanks, Alaska. 38pp. (K)

Author abstract: This report reviews existing literature on issues relevant to retrofitting culverts to mitigate fish passage barriers. The analysis of this information will set the stage for future laboratory experimentation on various retrofitting techniques. The topics in this report include a review of fish swimming capabilities, hydrologic factors involved in choosing a design flow, fish passage problems resulting from conventional culvert design, and potential retrofit solutions to these problems.

234) Brabets, T.P. 1996. Evaluation of the streamflow-gaging network of Alaska in providing regional streamflow information. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Resources Investigations Report 96-4001. 73pp. (G)

Electronic abstract: In 1906, the U.S. Geological Survey (USGS) began operating a network of streamflow-gaging stations in Alaska. The primary purpose of the streamflow-gaging network has been to provide peak flow, average flow, and low-flow characteristics to a variety of users. In 1993, the USGS began a study to evaluate the current network of 78 stations. The objectives of this study were to determine the adequacy of the existing network in predicting selected regional flow characteristics and to determine if providing additional streamflow-gaging stations could improve the network's ability to predict these characteristics. Alaska was divided into six distinct hydrologic regions: Arctic, Northwest, Southcentral, Southeast, Southwest, and Yukon. For each region, historical and current streamflow data were compiled. In Arctic, Northwest, and Southwest Alaska, insufficient data were available to develop regional regression equations. In these areas, proposed locations of streamflow-gaging stations were selected by using clustering techniques to define similar areas within a region and by spatial visual analysis using the precipitation, physiographic, and hydrologic unit maps of Alaska. Sufficient data existed in Southcentral and Southeast Alaska to use generalized least squares (GLS) procedures to develop regional regression equations to estimate the 50-year peak flow, annual average flow, and a low-flow statistic. GLS procedures were also used for Yukon Alaska but the results should be used with caution because the data do not have an adequate spatial distribution. Network analysis procedures were used for the Southcentral, Southeast, and Yukon regions. Network analysis indicates the reduction in the sampling error of the regional regression equation that can be obtained given different scenarios. For Alaska, a 10-year planning period was used. One scenario showed the results of continuing the current network with no additional gaging stations and another scenario showed the results of adding gaging stations to the network. With the exception of the annual average discharge equation for Southeast Alaska, by adding gaging stations in all three regions, the sampling error was reduced to a greater extent than by not adding gaging stations. The proposed streamflow-gaging network for Alaska consists of 308 gaging stations, of which 32 are designated as index stations. If the proposed network can not be implemented in it's entirely, then a lesser cost alternative would be to establish the index stations and to implement the network for a particular region.

235) **Childers, J.M. 1975. Channel erosion surveys along southern segment of the TAPS route, Alaska, 1972 and 1973. USDI Geological Survey, Anchorage, Alaska, Open-File Report. 57pp. (A, F)**

Author abstract: This report presents descriptions of preconstruction conditions at selected stream-channel sites along the southern segment of the Trans-Alaska Pipeline System from Flood Creek to Valdez. The information presented can be used in studies of severe channel erosion, streambed scour, bank erosion, or rechannelization. The report also presents a plan for detecting and measuring significant erosion and the important factors causing erosion, such as flood discharge, icing development, and construction activities.

236) **Childers, J.M., J.W. Nauman, D.R. Kernodle, and P.F. Doyle. 1977. Water resources along the Taps Route, Alaska, 1970-74. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Open-File Report 78-137. 136pp. (G, I)**

Electronic abstract: The U.S. Geological Survey installed 10 streamgaging and water-quality stations along the trans-Alaska pipeline route (TAPS) starting in 1970. These stations, mostly north of Fairbanks, add to the historical network of gaging stations and provide records of hydrologic conditions along the TAPS route. Selected data from 23 gaging stations along the TAPS route for the period 1970-74 (prior to construction of the pipeline) are compiled in graphic form. The data include annual hydrographs of daily mean or instantaneous values of a standard set of parameters which are indicative of physical, chemical and biological conditions of the streams. The hydrographs facilitate comparisons of data, both in time and between stream sites. Thus, they are a tool for evaluating streamflow characteristics along the TAPS route during the preconstruction period.

237) Dingman, S.L. 1973. The water balance in arctic and subarctic regions--annotated bibliography and preliminary assessment. US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 187. 131pp. (G)

Electronic abstract: Definitions and boundaries of the arctic and subarctic are reviewed; a map showing these boundaries and annotations of a number of publications dealing with this problem are also presented. A bibliography includes several hundred reports that directly discuss elements of the water balance in arctic and subarctic regions. These annotations are grouped by geographic area: the northern hemisphere, Europe, the U.S.S.R., Alaska, Canada, and Greenland and Iceland. For each area, annotations are presented according to water-balance elements: precipitation, evapotranspiration, runoff, streamflow, groundwater contributions to runoff, and changes in glacial storage. A subsequent section gives annotations of articles on the water balance of the Arctic Ocean. This is followed by a brief assessment of the state of knowledge on the water-balance elements in each geographic region. This bibliography is intended to be complete for the period 1950-1971 (some earlier articles are included), especially for articles published in English. A large number of items from the Russian and European literature are included, but the bibliography is probably less complete for these. A total of 688 annotations are included; many articles are annotated in more than one section, as they include information on more than one water-balance element or more than one geographic area.

238) Dion, C.A. 2002. Growth, foraging behavior and distribution of age-0 Arctic grayling in an Alaskan stream. M.S. Thesis, University of Alaska, Fairbanks. 81pp. (C, J)

Author abstract: I evaluated the ability of three models to relate habitat characteristics to habitat quality for age-0 Arctic grayling *Thymallus arcticus* in an Alaskan stream. A temperature-based growth model made accurate predictions, showing it can reliably assess thermal habitat quality. Deviations between predicted and observed growth were useful because they identified the timing of possible critical periods, when competition for food or space may cause density-dependent mortality and emigration. A foraging model consistently overestimated the mean prey size of fish, showing that such models need further work before they can accurately assess food availability from invertebrate drift. A habitat selection model accurately predicted small fish would occupy the stream margins and the ontogenetic shift into faster, deeper water, but its detailed predictions for larger fish were not very precise. These models were useful tools for assessing habitat quality and gave insight into possible interactions between habitat characteristics and population dynamics.

239) Doyle, P.F., and J.M. Childers. 1975. Channel erosion surveys along TAPS route, Alaska, 1975. USDI Geological Survey, Anchorage, Alaska, Open-File Report. 95pp. (A, F)

Author abstract: Channel surveys at 27 sites along TAPS route during 1975 documented significant channel changes and identified possible causative factors. Some of the important findings of the year's surveillance include: 8 feet (2.4 metres) of flood scour measured at the Salcha River crossing site, 180 feet (55 metres) of lateral bank erosion measured over 3 years on the Middle Fork Koyukuk River near Coldfoot, and rapid shifting of anabranches on braided stream crossings during high water.

Aerial photogrammetric surveys were used for the first time during 1975. Preliminary results show this method is especially suited for surveillance of large braided river channels.

240) Doyle, P.F., and J.M. Childers. 1976. Channel erosion surveys along TAPS route, Alaska, 1976. USDI Geological Survey, Anchorage, Alaska, Open-File Report. 90pp. (A, F)

Author abstract: Channel surveys were made along TAPS route during 1976 at the same 27 sites that were surveyed in 1975. One additional site was put under surveillance in 1976. Except for construction changes wrought by installation of the pipeline, most of the sites surveyed showed very little change since the 1975 surveys. Some of the significant events of 1976 at the monitored crossing sites include: glacier-dammed lake break-out floods on the Tazlina and Tsina Rivers, severe icings on the Gulkana River which resulted in a spring flood 3-4 feet (1 meter) over banktop, and virtual completion of all the buried crossings and all but one overhead crossing before the 1976 channel erosion resurveys were made.

Aerial photogrammetric surveys were used again in 1976 on the same seven sites as in 1975. Comparison of the photogrammetric surveys with each other and with on-the-ground surveys indicate that the method is generally applicable for channel erosion studies. However, it requires engineering judgment and personal knowledge of the site to avoid reaching inaccurate conclusions about channel change in some instances.

241) Edmundson, J.A. 1997. Growth patterns of juvenile sockeye salmon in different thermal environments of Alaskan lakes. M.S. Thesis, University of Alaska, Fairbanks. 79pp. (J)

Author abstract: Rearing conditions imposed on juvenile salmonids in lakes are important determinants of freshwater growth patterns. In Alaska, sockeye salmon (*Oncorhynchus nerka*) nursery lakes exhibit a wide range in thermal characteristics. Compared to clear lakes, stained lakes are warmer and have longer growing seasons, whereas glacial lakes are colder and have shorter growing seasons. In stained lakes, a shallow thermocline restricts most of the heat to the surface layers. Deep mixing in glacial lakes, concomitant with meltwater intrusion, keep much of the water column near 4 ^{o}C. Mean depth accounts for 77% of the among-lake variation in the seasonal average water temperature (*TS*). Length of growing season is dependent on latitude and altitude; however, water temperature is not. Taken together, the factors *TS,* zooplankton biomass, and sockeye fry density accounted for 70% of the variation in age-1 sockeye smolt size. This limnological information can be included in stock-recruit models of sockeye salmon to improve assessments for management.

242) Elliot, S.T., and D.J. Hubartt. 1984. A study of land use activities and their relationship to the sport fish resources in Alaska. Annual performance report for: Establishment of guidelines for protection of the sport fish resources during land use activities. Federal Aid in Fish Restoration and Anadromous Fish Studies, Volume 25, Study No. D-I, Job No. D-I-A&B. Alaska Department of Fish and Game, Sport Fish Division, Juneau, Alaska. 17pp. (K)

Author abstract: The winter survival of rearing salmonids is considered by managers to be the most important aspect of the influence of timber harvest on salmonid production. The Alaska Working Group on Cooperative Fishery-Forestry Research, of which this project is a member, initiated a study to compare winter survival and movement of rearing fish in clear-cut and forested sections of streams and clear-cut and buffer zone sections of streams. The study also examined the value of ponds and sloughs as "refuge habitat" during the winter months and will attempt to determine the rate of smoltification of juveniles from these areas.

Movement of juveniles occurred mostly between August and November with most of the movement being local, e.g., immediately upstream or downstream. However, juvenile coho (*Oncorhynchus kisutch*) living in the estuarine zone move upstream and disperse throughout the watershed. Rates of survival were highest (73% - 100%) for fish living in old growth forested stream sections and for fish wintering in sloughs and ponds. The survival rate of fish wintering in clear-cuts was the poorest (29% - 70%) and intermediate in buffer zones (40% - 86%).

The issue concerning the fate of coho fry in logged streams (Elliott, 1983) cannot be addressed until smolt work is completed in June 1984. Those results will be included in future reports.

* This report is numbered for the sake of consistency, however, this project received no federal dollars this year.

The results of this study are preliminary, pending further analysis.

243) Emmett, W.W. 1972. The hydraulic geometry of some Alaskan streams south of the Yukon River. USDI Geological Survey, Water Resources Division, Alaska District, Open-File Report. 102pp. (A, G)

Author abstract: Channel geometry surveys were conducted to determine bankfull stage, discharge, and other hydraulic parameters at 22 locations along the proposed route of the trans-Alaska pipeline corridor south of the Yukon river. Combined with the records from gaging stations located at some of the sites, the data are sufficient to describe some of the channel and flow characteristics typical of each of two major hydrologic areas, the Yukon river Region and the South-Central region. Although each region follows general hydrologic trends, least squares relations indicate each exhibits its own particular deviations.

Average values of the hydraulic and geometric properties of rivers were used to illustrate their application to practical engineering problems, namely the computation of depth of channel scour and of bedload discharge. For design purposes, caution is recommended when making computations based on average values. In the absence of other data, however, the average data become useful predictive tools.

244) Everest, F.H., and R.D. Harr. 1982. Silvicultural treatments. In: Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America. W.R. Meehan, Editor. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-134. Pages 1-18. (I, J)

Electronic abstract: Distribution of anadromous salmonids and coniferous forest coincides along much of the Pacific Slope; consequently, the habitat of anadromous fish is subject to a wide variety of silvicultural treatments required to establish and nurture young forests. The silvicultural activities include: cutting prescriptions to improve natural regeneration; preparing sites for planting; removing slash to reduce fire hazard; seeding and planting; reducing competition to enhance growth of young trees. Anadromous salmonids have exacting habitat requirements and most production in forested watersheds occurs in small (first-order to third order) streams. Some silvicultural treatments, such as broadcast burning and machine scarification and piling, can degrade water quality and fish habitat in small streams, but seldom do so because of the low spatial and temporal intensity of the activities. The highest risk of habitat damage from silvicultural activities occurs in areas with erosive soils and high annual precipitation, or high summer solar radiation and low streamflow. Maximum risk from solar heating occurs in western and northeast Oregon, western and central Washington, northwest California, and central Idaho. High-risk areas for decreased water temperatures are located in northern and central Idaho, northeastern Oregon, southeastern Washington, northern British Columbia, and Alaska. Areas of central Idaho; northwest California; western Oregon, Washington, and British Columbia; and southeast Alaska are vulnerable to surface erosion and mass wasting.

245) Everest, F.H., and W.R. Meehan. 1981. Forest management and anadromous fish habitat productivity. In: Transactions of the Forty-Sixth North American Wildlife and Natural Resources Conference. K. Sabol, Editor. Wildlife Management Institute, Washington, D.C. Pages 521-530. (A, D, F, I)

Electronic abstract: The anadromous fishery resources of western North America are produced largely within forested watersheds. Forest and rangeland management activities that can influence the quality of anadromous fish habitat include timber harvest, road construction, and livestock grazing. Organic debris from forested watersheds of the Pacific Northwest and Alaska enters streams through direct litterfall, landslides, debris torrents, timber felling, and streambank erosion, plus blowdown of trees and branches. Large woody debris can create habitat for rearing salmonids, but may cause sedimentation in spawning areas. Large, naturally occurring debris can promote streambank stability and reduce streambed scour. Large accumulations of fine organic debris can adversely affect habitat by reducing dissolved oxygen and producing toxic leachates. Total removal of debris can result in a completely open channel, promoting streambed sour, streambank instability, and loss of fish habitat productivity. Debris torrents, a common mass erosion event in the Pacific Northwest, have a negative impact on habitat and production of anadromous salmonids in small streams immediately downstream from the torrent egress. Studies within a 1-mile reach of Knowles Creek, however, indicate that the total effect of debris torrents in that sediment-poor watershed tends to be positive. Preliminary results of a livestock grazing study do not show profound effects on fish populations among various grazing systems or between one to three years of season-long grazing and ungrazed controls.

246) Helfield, J.M. 2002. Interactions of salmon, bear and riparian vegetation in Alaska. Dissertation abstracts International Part B: Science and Engineering 62: 5493. (C, D, E, I)

Electronic abstract. Anadromous Pacific salmon (*Oncorhynchus spp*.) spend most of their lives feeding and growing at sea before returning to freshwater to spawn and die in their natal streams. Returning salmon provide a seasonal food source for numerous mammal and bird species, and nutrients from decaying salmon carcasses are incorporated into freshwater biota at various trophic levels. Consequently, annual spawning migrations provide a mechanism for transporting marine-derived nutrients from the fertile northern Pacific Ocean to freshwater and terrestrial ecosystems. Riparian trees and shrubs near spawning streams derive approximately 22-26% of their foliar nitrogen (N) from spawning salmon, and growth rates of Sitka spruce (*Picea sitchensis*) and white spruce (*P. glauca*) are significantly increased as a consequence of this nutrient subsidy. Marine-derived nitrogen (MDN) is less important to riparian ecosystems where symbiotic N-fixation by alder (*Alnus crispa*) is prevalent, although salmon carcasses may be an important source of other marine nutrients affecting productivity in these forests. Since riparian forests affect the quality of instream habitat through shading, sediment and nutrient filtration and production of large woody debris, this fertilization process serves not only to enhance riparian production, but may also act as a positive feedback mechanism by which salmon-borne nutrients improve spawning and rearing habitat for subsequent salmon generations. Brown bear (*Ursus arctos*) are an important vector for transferring marine nutrients to riparian forests, through dissemination of partially- eaten salmon carcasses and salmon-enriched wastes. To the extent that this process affects productivity and species composition in riparian forests, interactions of salmon and bear may be characterized as keystone interactions controlling the long-term structure and dynamics of riparian communities. It should be recognized that marine nutrients may also be transferred to riparian systems via other terrestrial piscivores and abiotic processes, and that the relative importance of these different pathways varies spatially and temporally within and among salmon- bearing watersheds. Accordingly, it may be more meaningful to consider the interactions and processes that structure riparian communities rather than their specific component parts. These findings illustrate the complexity of interactions surrounding riparian ecosystems, the importance of linkages across ecosystem boundaries, and the interdependence of salmon populations, terrestrial wildlife and riparian vegetation.

247) Jordan, M.C., and R.F. Carlson. 1987. Design of depressed invert culverts. Final Report No. FHWA-AK-RD-87-23 written by the Water Research Center, Institute of Northern Engineering, University of Alaska, Fairbanks. Written for the Alaska Department of Transportation and Public Facilities, Research Section, Fairbanks, Alaska. 64pp. (K)

Author abstract: The hydraulic characteristics of a depressed invert culvert were studied. Also, a design procedure for depressed invert culverts is outlined. The hydraulic characteristics were studied by reviewing pertinent literature and by the use of a hydraulic model. The design procedure is similar to that already used by state hydrologists.

Formulas for determining the geometric properties of a depressed invert culvert are presented. The hydraulic model was used to determine the discharge coefficients for a depressed invert culvert flowing under inlet control and set flush to a vertical headwall. A literature review was performed which examined velocity profiles, flow over permeable beds, and flow resistance in culverts and over rough beds.

The design procedure is applicable to depressed invert culverts flowing under nonsubmerged conditions and set flush to a vertical headwall. The design procedure can be used as an outline for the development of a comprehensive design manual for depressed invert culverts.

248) Kemnitz, R.T., K.M. Novcaski, R.L. Rickman, W.C. Swanner, and K.R. Linn. 1993. Water resources data: Alaska water year 1992. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-92-1. 444pp. (G, I)

Author abstract: Water resources data for the 1992 water year for Alaska consists of records of stage, discharge, and water quality of streams; stages of lakes; and water levels and water quality of ground-water wells. This volume contains records for water discharge at 104 gaging stations; water quality at 24 gaging stations; water levels for 73 observation wells; and water quality analyses for 7 wells. Also included are data for 67 crest-stage partial-record stations and 14 lakes. Additional water data were collected at various sites not involved in the systematic data-collection program and are published as miscellaneous measurements and analyses. These data represent that part of the National Water Data system operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

249) Lamke, R.D., J.L. Van Maanen, B.B. Bigelow, P.J. Still, and R.T. Kemnitz. 1990. Water resources data for Alaska, water year 1989. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-89-1. (G, I)

Electronic abstract: Water resources data for the 1989 water year for Alaska consist of records of stage, discharge, and water quality of streams, stage of lakes, and water levels and water quality of ground water wells. This volume contains records for water discharge of 85 gaging stations, water quality at 26 gaging stations, and water levels for 27 observation wells. Also included are data for 73 crest-stage partial record stations and 19 lakes. Additional water data were collected at various sites not involved in the systematic data-collection program and are published as miscellaneous measurements and analyses. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

250) Lamke, R.D., P.J. Still, B.B. Bigelow, H.R. Seitz, and J.E. Vaill. 1983. Water resources data for Alaska, water year 1982. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-82-1. 363pp. (G, I)

Electronic abstract: Water resources data for the 1982 water year for Alaska consists of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells and springs. This report contains discharge records for 108 gaging stations; stage only record for 1 gaging station; water quality for 49 stations; and water levels for 28 observation wells. Also included are 43 low-flow, 67 crest-stage , and 48 water-quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality.

251) Lamke, R.D., R.T. Kemnitz, M.R. Carr, D.S. Thomas, and K.M. Novcaski. 1992. Water resources data for Alaska, water year 1991. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-91-1. (G, I)

Electronic abstract: Water resources data for the 1991 water year for Alaska consists of records of stage, discharge, and water quality of streams; stages, of lakes; and water levels and water quality of groundwater wells. This volume contains records for water discharge at 82 gaging stations; water quality at 24 gaging stations; water levels for 75 observation wells; and water quality analyses for 93 wells. Also included are data for 65 crest-stage partial-record stations and 13 lakes. Additional water data were collected at various sites not involved in the systematic data collection program and are published as miscellaneous measurements and analyses. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

252) Lloyd, D.S. 1987. Turbidity as a water quality standard for salmonid habitats in Alaska. North American Journal of Fisheries. 7: 34-45. (I)

Electronic abstract: Evidence both of trophic level changes induced by reduction in light penetration and of more direct effects of sediment and turbidity on aquatic life indicates that turbidity constitutes a valid and useful water quality standard that can be used to protect aquatic habitats from sediment pollution. A review of studies conducted in Alaska and elsewhere indicated that water quality standards allowing increases of 25 or 5 nephelometric turbidity units above ambient turbidity in clear coldwater habitats provide moderate and relatively high protection, respectively, for salmonid fish resources in Alaska. Even stricter limits may be warranted to protect extremely clear waters, but such stringent limits apparently are not necessary to protect naturally turbid systems.

253) Lloyd, D.S., J.P. Koenings, and J.D. LaPerriere. 1987. Effects of turbidity in fresh waters of Alaska. North American Journal of Fisheries Management. 7: 18-33. (C, I)

Electronic abstract: Euphotic volume in lakes correlated strongly with production of juvenile sockeye salmon (*Oncorhynchus nerka*). The authors observed reduced abundance of zooplankton, macroinvertebrates, and Arctic grayling (*Thymallus arcticus*) in naturally and artificially turbid aquatic systems. Turbidity measurements correlated less consistently with measures of suspended sediment concentration (total nonfilterable residue), but provided an adequate estimator for use as a water quality standard to protect aquatic habitats.

254) Loeffler, R.M., and J.M. Childers. 1977. Channel erosion surveys along the TAPS route, Alaska, 1977. USDI Geological Survey, Anchorage, Alaska, Open-File Report 78-611. 90pp. (A, F)

Author abstract: Channel surveys were made along the TAPS route during 1977 at the same 28 sites that were studied in 1976. In addition, a new site at pipeline mile 22 near Deadhorse (alignment No. 134) along the Sagavanirktok River was put under surveillance. Except for changes wrought by the completion of construction, most of the sites showed very little change. Significant events include: virtual completion of all construction activities along the pipeline, the pipeline start-up, and the breakup flood along the Sagavanirktok River which breached many river-training structures. In general, 1977 saw heavy flooding on the streams draining the north and south slopes of the Brooks Range and moderate flooding on streams further south.

Aerial photogrammetric surveys were used again in 1977 on the same seven sites as in 1976. Results document the applicability of the method for channel erosion studies, especially those on large braided rivers. However, it requires engineering judgment and personal knowledge of the particular site to avoid being occasionally led to inaccurate conclusions.

255) MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. Sponsored by the Environmental Protection Agency, Seattle, Washington, Region X EPA/910/9-91/001. 180pp. (A, G, I)

Electronic abstract: The publication provides guidance for designing water quality monitoring projects and selecting monitoring parameters. Although the focus is on forest management and streams in the Pacific Northwest and Alaska, a broader perspective is taken and much of the information is more widely applicable. Part I reviews the regulatory mechanisms for nonpoint source pollution and defines seven types of monitoring. A step-by-step process for developing monitoring projects is presented. Because monitoring is a sample procedure, study design and statistical analysis are explicitly addressed. Part II is a technical review of the parameters, and these are grouped into seven categories: physical and chemical constituents, flow, sediment, channel characteristics, riparian, and aquatic organisms.

256) Milner, A.M., and G.E. Petts. 1994. Glacial rivers: Physical habitat and ecology. Freshwater Biology. 32: 295-307. (C, G, I, J)

Electronic abstract: This review examines the physical habitat and ecology of glacial rivers. Typical glacial rivers have summer temperatures below 10 degree C, a single seasonal peak in discharge, which in the Northern Hemisphere typically occurs in July, a diel fluctuation in flow which usually peaks in late afternoon, and turbidity levels in summer that exceed 30 NTU. Where maximum temperatures are less than or equal to 2 degree C benthic invertebrate communities are dominated by Diamesa (Chironomidae). Downstream, temperatures increase, channels become more stable and valley floors become older. Orthocladiinae (Chironomidae), Simuliidae, Baetidae, Nemouridae and Chloroperlidae become characteristic members of the invertebrate community.

257) Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska—requirements for protection and restoration. US Department of Commerce, National Oceanic and Atmospheric Administration, Coastal Ocean Office, Decision Analsysis Series No.7. (K)

Electronic abstract: The document presents a science overview of the major forest management issues involved in the recovery of anadromous salmonids affected by timber harvest in the Pacific Northwest and Alaska. The synthesis reviews salmonid habitat requirements and potential effects of logging, describes the technical foundation of forest practices and restoration, analyzes current federal and non-federal forest practices, and recommends required elements of comprehensive watershed management for recovery of anadromous salmonids. abstract obtained from http://www.cop.noaa.gov/pubs/das/das7.html. Accessed October 27, 2004.

258) Murphy, M.L., and A.M. Milner. 1997. Alaska timber harvest and fish habitat. Freshwaters of Alaska. Ecological Syntheses, Springer, New York. Ecological Studies 119: 229-263. (K)

Electronic abstract: Fishing and timber harvest are major industries in Alaska. If not carefully planned and conducted, timber harvest and associated road construction may adversely affect anadromous fish habitat, which has sometimes brought these industries into conflict. This chapter reviews forestry-fisheries interactions in Alaska, from the early research on the effects of timber harvest to the consensus and compromise of today. The review is organized around two main parts of salmon freshwater life history: spawning and rearing. Spawning is primarily affected by physical habitat variables; rearing is affected by both physical and trophic variables, requiring a broader understanding of the stream ecosystem.

259) O'Brien, W.J., and J.J. Showalter. 1993. Effects of current velocity and suspended debris on the drift feeding of Arctic grayling. Transactions of the American Fisheries Society. 122: 609-615. (C, G, I)

Electronic abstract: The authors videotaped Arctic grayling *Thymallus arcticus* feeding on large *Daphnia middendorffiana* drifting at different water velocities in an experimental stream with and without stream debris. The angle and distance at which fish first located each prey was determined from the videotapes. Both measures were affected by stream velocity and added debris. Location distance was unchanged at the lower velocities (11.6 and 32.3 cm/s) but declined at higher velocities. However, prey encounter rate increased up to water velocities of 45.8 cm/s, and thus water velocity compensated for reduced search area. Added debris always shortened location distance and decreased location angle. These findings have implications for position choice in streams and search strategies.

260) Oswood, M.W., A.M. Milner, and J.G. Irons III. 1991. Climate change and Alaskan rivers and streams. In: Global Climate Change and Freshwater Ecosystems. P. Firth and S.G. Fischer, Editors. Springer-Verlag, New York. Pages 192-210. (K)

Author abstract (Author Conclusion): Global climate warming in response to increased atmospheric carbon dioxide and other greenhouse gasses is likely to have major impacts on subarctic and arctic streams. Sediment and flow regimes are likely to changes as a result of changing mass balance of glaciers. Thermal regimes of streams also likely to change, resulting in biogeographic changes in freshwater organisms. Release of carbon (as carbon dioxide or as dissolved organic carbon in hydrologic transport) may be a major effect of warming carbon rich soils, potentially exacerbating climate warming. Quality food for stream invertebrates is likely to changes as a result of complex interactions of many climatic and biotic variables. Some of these changes may be synergistic (increasing the impact) or antagonistic (ameliorating the impact); however, given the current state of the climate models, prediction is uncertain at best.

261) Parks, B., and R.J. Madison. 1985. Estimation of the flow and water-quality characteristics of Alaskan streams. USDI Geological Survey, Water-Resources Investigations Report 84-4247. 64pp. (G, I)

Electronic abstract: Although hydrologic data are either sparse or nonexistent for large areas of Alaska, the drainage area, area of lakes, glacier and forest cover, and average precipitation in a hydrologic basin of interest can be measured or estimated from existing maps. Application of multiple linear regression techniques indicates that statistically significant correlations exist between properties of basins determined from maps and measured streamflow characteristics. This suggests that corresponding characteristics of ungaged basins can be estimated. Streamflow frequency characteristics can be estimated from regional equations developed for southeast, south-central and Yukon regions. Statewide or modified regional equations must be used, however, for the southwest, northwest, and Arctic Slope regions where there is a paucity of data. Equations developed from basin characteristics are given to estimate suspended-sediment values for glacial streams and, with less reliability, for nonglacial streams. Equations developed from available specific conductance data are given to estimate concentrations of major dissolved inorganic constituents. Suggestions are made for expanding the existing data base and thus improving the ability to estimate hydrologic characteristics for Alaskan streams.

262) Prowse, T.D. 1994. Environmental significance of ice to streamflow in cold regions. Freshwater Biology. 32: 241-259. (G)

Electronic abstract: The five major hydrologic regimes of cold regions are typically classified as proglacial, wetland, spring-fed, arctic nival and subarctic nival. The hydrologic response of streams in cold regions is influenced significantly by the source and pathways of moisture from the landscape to the stream channel. Snow and ice masses, such as snow cover, permafrost and icings, play principal and unique roles as major moisture sources, and in affecting runoff pathways. Once flow has been routed from the landscape into a channel system, the effects of floating ice begin to control the flow system. Notably, many of the most significant hydrologic events in cold regions, such as floods and low flows, are more the result of in-channel ice effects than of landscape runoff processes.

263) Robison, E.G. 1998. Reach scale sampling metrics and longitudinal pattern adjustment of small streams. P.h.D. Dissertation, Oregon State University, Corvallis. 254pp. (A)

Electronic abstract: Several types of channel morphology measurement parameters used to characterize fish habitat of small streams are refined, developed and evaluated in terms of their accuracy, precision, and sensitivity to disturbance. Data for 74 stream reaches in Oregon and Alaska are used in analysis. Over half the reaches are from a pre-pilot study funded by EPA's Environmental Monitoring and Assessment Program (EMAP). A new methodology for determining residual pools is developed (termed the Longitudinal Streambed Simulation Method). This new method and an older method are compared with a more rigorous time consuming method for determining residual pools. Results indicate a generally close correspondence. For instance, the absolute percent departure of longitudinal residual pool area was typically within 10% and always less than 25% for streams with wetted widths greater than 3.5 meters. Precision is evaluated for three data sets containing replicated stream reach measurements. Directly measured parameters like standard deviation depth are demonstrated as precise and repeatable. in contrast, visual scoring systems and visual determinations of riffles versus pools have low precision. Adequate reach length for determining various channel characteristics is evaluated by using classic sample size statistics, time series, and short versus long reach comparisons.

264) Scannell, P.K.W. 1992. Influence of temperature on freshwater fishes: A literature review with emphasis on species in Alaska. Alaska Department of Fish and Game, Division of Habitat, Juneau, Alaska, Technical Report No. 91-1. 47pp. (J)

Author abstract: Small (1-5°C) changes in water temperature may have consequential effects on fish, depending upon the time of year the changes occur, the magnitude and duration of the changes, and the fish species and life stages of the fish affected. Changes in water temperature affect survival at all life stages, rates of egg development and growth, timing of smolting, and mortality rates during overwintering. Increases or decreases in water temperature may influence reproduction by changing the timing of the spawning run; influencing fish to seek other spawning areas, increasing egg mortality and the occurrence of deformed alevins, changing the time for egg development; or causing fish to avoid certain streams or stream reaches. Changes in temperature have been shown to affect the number of eggs that are successfully fertilized when fish are delayed in migrating to spawning areas.

In Alaska, elevations in temperature may be particularly harmful to fishes that are adapted to coldwater conditions and rarely experience significant summer warming. Many of the studies that relate changes in temperature to effects on fish examine higher ranges than are usually experienced by fish in Alaska. Therefore, acceptable upper and lower temperature ranges from published literature are often not applicable to fish naturally occurring at higher latitudes. This report examines much of the published literature on coldwater species of fish that inhabit freshwater. Summaries are given of the effects of changes on temperature on different life stages. The final section of this report presents recommendations for optimal temperatures for various fish life stages.

265) Slaughter, C.W., and J.W. Aldrich. 1989. Annotated bibliography on soil erosion and erosion control in subarctic and high-latitude regions of North America. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-253. 234pp. (K)

Author abstract: This annotated bibliography emphasizes the physical processes of upland soil erosion, prediction of soil erosion and sediment yield, and erosion control. The bibliography is divided into two sections: (1) references specific to Alaska, the Arctic and subarctic, and similar high-latitude settings; and (2) references relevant to understanding erosion, sediment production, and erosion control. Most of the cited works were published prior to 1981. Annotations generally consist of the author's abstract or summary.

266) Still, P.J., and J.M. Crosby. 1989. Alaska Index: Streamflow, lake levels, and water quality records to September 30, 1988. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Open-File Report 89-269. 189pp. (G, I)

Electronic abstract: Streamflow, lake levels, and water quality data are compiled for stations in the southeast, south-central, southwest, Yukon basin, northwest, and Arctic Slope subregions of Alaska. The report includes a map of each hydrologic subregion and tables listing types of data collected and periods of records.

267) USDI Geological Survey. 1971. Index of surface-water records to September 30, 1970--Part 15. Alaska. USDI Geological Survey Circular 665, Washington, D.C. 21pp. (G)

Electronic abstract: The streamflow stations in Alaska (approximately 600) for which records have been or are to be published in reports of the geological survey for periods through September 30, 1970 are listed. In addition to the continuous-record gaging stations, this index includes crest-stage partial-record stations. A continuous-record station is a gaging station on a stream or reservoir for which the discharge, stage, or contents is published on a daily, weekly, or monthly basis for a continuous period of time. A crest-stage partial-record station is a streamflow station for which only the annual maximum discharge is published over a period of years for use in floodflow analyses.

268) USDI Geological Survey. 1976. Water resources data for Alaska, water year 1975. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-75-1. 410pp. (G, I)

Electronic abstract: Water resources data for the 1975 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells and springs. This report contains discharge records for 107 gaging stations; stage only records for 2 gaging stations; water quality for 31 stations; and water levels for 19 observation wells. Also included are 85 crest-stage partial-record stations. Additional water data were collected at various sites, not part of the systematic data collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

269) USDI Geological Survey. 1977. Water resources data for Alaska, water year 1976. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-76-1. 401pp. (G, I)

Electronic abstract: Water resources data for the 1976 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells and springs. This report contains discharge records for 102 gaging stations, stage only records for 2 gaging stations, water quality for 71 stations, and water levels for 24 observation wells. Also included are 91 crest-stage partial-record stations and 28 water-quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data-collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

270) USDI Geological Survey. 1978. Water resources data for Alaska, water year 1977. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-77-1. 439pp. (G, I)

Electronic abstract: Water resources data for the 1977 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells and springs. This report contains discharge records for 112 gaging stations, stage only records for 4 gaging stations, water quality for 60 stations, and water levels for 25 observation wells. Also included are 18 low-flow, 91 crest-stage, and 19 water-quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data-collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

271) USDI Geological Survey. 1979. Water resources data for Alaska, water year 1978. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-78-1. 425pp. (G, I)

Electronic abstract: Water resources data for the 1978 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells and springs. This report contains discharge records for 117 gaging stations, stage only records for 2 gaging stations, water quality for 64 stations, and water levels for 28 observation wells. Also included are 79 low-flow, 87 crest-stage, and 24 water-quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data-collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

272) USDI Geological Survey. 1980. Water resources data for Alaska, water year 1979. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-79-1. 365pp. (G, I)

Electronic abstract: Water resources data for the 1979 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells and springs. This report contains discharge records for 111 gaging stations, stage only records for 2 gaging stations, water quality for 58 stations, and water levels for 30 observation wells. Also included are 62 low-flow, 89 crest-stage, and 24 water-quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data-collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

273) USDI Geological Survey. 1981. Water resources data for Alaska, water year 1980. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-80-1. 373pp. (G, I)

Electronic abstract: Water resources data for the 1980 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells and springs. This report contains discharge records for 114 gaging stations, stage only record for 1 gaging station, water quality for 55 stations, and water levels for 33 observation wells. Also included are 56 low-flow, 8 crest-stage, and 2 water-quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data-collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

274) USDI Geological Survey. 1982. Water resources data, Alaska water year 1981. USDI Geological Survey, Water Resources Division, Anchorage, Alaska, Water-Data Report AK-81-1. (G, I)

Electronic abstract: Water-resources data for the 1981 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality in wells and springs. This report contains discharge records for 121 gaging stations; stage only record for 1 gaging station; water quality for 63 stations; and water levels for 30 observation wells. Also included are 50 low-flow, 71 crest-stage, and 20 water-quality partial-record stations. Additional water data were collected at various sites, not part of the systematic data-collection program, and are published as miscellaneous measurements of discharge, lake stage, or water quality. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

275) Vaill, J.E., P.J. Still, R.D. Lamke, B.B. Bigelow, and J.L. Van Maanen. 1988. Water resources data for Alaska, water year 1987. USDI Geological Survey, Water-Data Report AK-87-1 (WRD/HD-89/209). 284pp. (G, I)

Electronic abstract: Water resources data for the 1987 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality of groundwater wells. This volume contains records for water discharge at 83 gaging stations; water quality at 27 gaging stations; and water levels for 29 observation wells. Also included are data for 16 low-flow, 86 crest-stage, and 14 water-quality partial-record stations and 20 lakes. Additional water data were collected at various sites, not involved in the systematic data collection program, and are published as miscellaneous measurements and analyses. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

276) VanMaanen, J.L., R.D. Lamke, P.J. Still, J.E. Vaill, and B.B. Bigelow. 1988. Water resources data for Alaska, water year 1986. USDI Geological Survey, Water-Data Report AK-86-1 (WRD/HD-88/214). 330pp. (G, I)

Electronic abstract: Water resources data for the 1986 water year for Alaska consist of records of stage, discharge, and water quality of streams; stage and water quality of lakes; and water levels and water quality of groundwater wells. This volume contains records for water discharge at 103 gaging stations; water quality at 42 gaging stations; and water levels for 30 observation wells. Also included are data for 18 low-flow, 68 crest-stage, and 18 water-quality partial-record stations and 40 lakes. Additional water data were collected at various sites, not involved in the systematic data collection program, and are published as miscellaneous measurements and analyses. These data represent that part of the National Water Data System operated by the U.S. Geological Survey and cooperating State and Federal agencies in Alaska.

NON-ALASKA REFERENCES

Canada

277) Beaudry, P.G. 1989. Hydrology of the Skeena River floodplains I: Implications to herbicide use. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Pages 165-171. (I)

Author abstract: This study was initiated to provide information to silviculturists and concerned members of the public about the environmental characteristics of the Skeena River floodplains that affect the fate of forestry herbicides. This paper describes 1) the annual groundwater regime and its driving forces, 2) the stratigraphy of the deposits, 3) the physical characteristics of the soil, and 4) the climatic regime of both air and soil. Based on these data and the chemical and physical properties of certain herbicides, inferences are made about their probable fate in coastal alluvial environments. The period late July to early September is identified as the safest for the application of herbicides as the water table is low and consequently the chances of flooding are low. The surface deposits of fine silts and the rapid incorporation of organic matter into the soil should ensure low mobility of most herbicides.

278) Beaudry, P.G., and A. Gottesfeld. 2001. Effects of forest-harvest rates on stream-channel changes in the central interior of British Columbia. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 151-173. (A)

Author abstract: The study investigates the relationship between the level of forest harvesting within 12 medium-sized watersheds and the change in stream-channel width over time. Stream-channel widths and sediment sources were measured from a chronosequence of rectified aerial photographs, dating back to the early 1960s. During the period between the mid 1960s and 1984 most of the study reaches evolved towards narrower channels. During the period between 1984 and the mid 1990s most of the watersheds experienced an increase in average channel width. No statistical relationship could be established between the level of forest harvest and the increase in channel width. Decadal variations in climate appeared to best explain the variability in the observed increases in stream-channel width during the late period.

279) Berube, P. and F. Levesque. 1998. Effects of forestry clear-cutting on numbers and sizes of brook trout, *Salvelinus fontinalis* (Mitchill), in lakes of the Mastigouche Wildlife Reserve, Quebec. Canada Fisheries Management & Ecology. 5: 123-137. (K)

Electronic abstract: Brook trout, *Salvelinus fontinalis* (Mitchill), angling data, collected between 1971 and 1991, were analysed before, during, and after logging operations for 20 lakes located within 200 m of a clear-cutting area and 16 reference lakes undisturbed by logging. The mean weight of catches by anglers remained unchanged over the three periods, while catches per unit of effort (CPUE) and biomass per unit of effort (BPUE) decreased, respectively, by 18% and 22% after clear-cutting. These changes reflected a significant modification in population dynamics probably caused by logging operations. Results indicated that the negative impacts on aquatic fauna were felt more strongly on water bodies located in watersheds where deforestation was more severe; CPUE was inversely correlated with a cumulative cutting index (CI) developed from physiographic parameters. An increasing interannual trend of the spring-flood discharge in the order of 8% was noted. It was hypothesized that this increase might damage spawning and nursery habitats, hence affecting recruitment and offering a possible part of the explanation for the variations in fishing success. The cause-to-effect links and the mechanisms associated with changes affecting fish populations following deforestation remain to be clarified.

280) Bird, S.A. 2001. Streamside logging and riparian hazard assessment in step-pool streams. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 134-142. (A, D, F)

Author abstract: A riparian assessment is usually completed as part of the Interior Watershed Assessment Procedure (IWAP). The riparian assessment focuses on the role of riparian vegetation and woody debris in maintaining channel stability and channel structure, and on how this role has been affected by logging. This paper evaluates the effectiveness of riparian assessment procedures in identifying channel disturbance in step-pool streams.

The procedure relies on the identification of indirect channel impacts from riparian logging. Indirect impacts include the loss of bank cohesion following decay of the riparian tree-root network, and the lack of large riparian trees available to the channel from overbank sources. The effects of indirect impacts may not be fully apparent in the channelfor several decades and not observed until the riparian area has partially recovered, and this may confound the assessment. Overview assessment procedures designed to identify channel impacts from streamside logging should focus on direct channel impacts. These tend to occur from operating machinery in or across the stream channel, operating machinery on top of banks, salvaging logs out of the active channel, and delivering logging debris to the channel from surrounding hillslopes or valley bottoms.

281) Bovis, M.J., and M. Jakob. 1999. The role of debris supply conditions in predicting debris flow activity. Earth Surface Processes and Landforms. 24: 1039-1054. (K)

Author abstract: Debris flow frequency and magnitude were determined for 33 basins in southwest British Columbia. Basins were first classified as either weathering-limited or transport-limited using a discriminant function based on debris-contributing area, an area-weighted terrain stability number, and drainage density. Multiple regression was used to predict magnitude, peak discharge, frequency and activity (frequency times magnitude) within each group of basins. Model performance was improved by stratifying the total sample of debris flow basins into weathering-and transport-limited groups. Explained variance increased by an average of 15 per cent in the transport-limited sample, indicating that sediment supply conditions in the more active basins are fundamental in predicting debris flow activity. An independent test of the regression models with 11 basins yielded generally good results for debris flow magnitude and peak discharge. Prediction of debris flow frequency proved problematical in weathering-limited basins. The methods developed here provide estimates of debris flow attributes in basins for which few data on past events are available.

282) Brardinoni, F., M.A. Hassan, and H.O. Slaymaker. 2002. Complex mass wasting response of drainage basins to forest management in coastal British Columbia. Geomorphology. 49: 109-124. (K)

Author abstract: The impacts of logging activities on mass wasting were examined in five watersheds in the coastal mountains of British Columbia. Historical aerial photos were used to document mass wasting events, and their occurrence was related to logging activities in the study basins. Logged and forested areas were compared in terms of mass wasting magnitude and frequency, with reference to site characteristics. The recovery time of the landscape after logging was assessed. Bedrock type and basin physiography had no identifiable effect on mass wasting frequency and magnitude. Mass wasting failure was primarily controlled by slope gradient. Basin vulnerability increased, following clearcutting relative to forested areas, in that mass wasting was initiated on gentler slopes. The volume of sediment produced from logged slopes is of the same order as that from forested areas, which are steeper by as much as 10°. In both logged and forested areas, the size distribution of mass wasting events follows an exponential distribution. However, the variability in mass wasting size in forested areas is much higher than that obtained for logged areas. The recovery time after forest harvesting is over 20 years, which confirms published estimates based on vegetation reestablishment. Continuous disturbance of the basin, however, may extend the recovery time for the whole basin well beyond 20 years.

283) Buttle, J.M., I.F. Creed, and R.D. Moore. 2003. Advances in Canadian forest hydrology, 1999 – 2003. In: Quadrennial Report to the International Union of Geodesy and Geophysics and International Association of Hydrological Sciences. J.W. Pomeroy, Compiler. Canadian National Committee for the International Association of Hydrological Sciences (CNC-IAHS). Pages 5-19. (E, G, I)

Author abstract: Understanding the hydrological processes and properties of Canada's varied forest types is critical to sustaining their ecological, economic, social and cultural roles. This review examines recent progress in studying the hydrology of Canada's forest landscapes. Work in some areas, such as snow interception, accumulation and melt under forest cover, has led to modelling tools that can be readily applied for operational purposes. Our understanding in other areas, such as the link between runoff-generating processes in different forest landscapes and hydrochemical fluxes to receiving waters, is much more tentative. The 1999—2003 period saw considerable research activity examining the hydrological and biogeochemical response to natural and anthropogenic disturbance of forest landscapes, spurred by major funding initiatives at the provincial and federal levels. This work has provided valuable insight; however, application of the findings beyond the experimental site is often restricted by such issues as a limited consideration of the background variability of hydrological systems, incomplete appreciation of hydrological aspects at the experiment planning stage, and experimental design problems that often bedevil studies of basin response to disturbance. Overcoming these constraints will require, among other things, continued support for long-term hydroecological monitoring programs, the embedding of process measurement and modelling studies within these programs, and greater responsiveness to the vagaries of policy directions related to Canada's forest resources. Progress in these and related areas will contribute greatly to the development of hydrological indicators of sustainable forest management in Canada.

284) Carignan, R., P. D'Arcy, and S. Lamontagne. 2000. Comparative impacts of fire and forest harvesting on water quality in Boreal Shield lakes. Canadian Journal of Fisheries and Aquatic Sciences. 57: 105-117. (H, I)

Electronic abstract: Water quality was monitored in Boreal Shield lakes for 3 years following their simultaneous impact by clearcut logging or wildfire. Seventeen similar undisturbed lakes served as references. Dissolved organic carbon (DOC) and the light attenuation coefficient (e_{PAR}) were up to threefold higher in cut lakes than in reference and burnt lakes. Compared with median values for reference lakes, cut and burnt lakes had higher concentrations of total phosphorus (TP) (two- to three-fold), total organic nitrogen (TON) (twofold), and K^+, Cl^-, and Ca^{2+} (up to sixfold). NO_3^- and SO_4^{2-} concentrations were up to 60- and 6-fold higher, respectively, in burnt lakes than in reference and cut lakes. In most cases, impacts were directly proportional to the area harvested or burnt divided by the lake's volume or area. These simple models correctly predicted the changes observed in three lakes harvested during the study. Some of the ob served effects occur on different time scales. Mobile ions released by fire (K^+, Cl^-, SO_4^{2-}, NO_3^-) or harvesting (K^+, Cl^-, some DOC) are rapidly flushed out of the watershed (50% decrease in 3 years). Other constituents or properties (TP, TON, DOC, e_{PAR}, Ca^{2+}, Mg^{2+}) show little change or are still increasing after 3 years and will take a longer time to reach normal levels.

285) Carver, M. 2001. Using indicators to assess hydrologic risk. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 26-43. (K)

Author abstract: In British Columbia, forest managers employ indicators for evaluating hydrologic constraints. Although the Watershed Assessment Procedures provide the most visible example of this, broader administrative levels such as Land and Resource Management Plans and Timber Supply Reviews also make use of hydrologic indicators to support decisions. Unfortunately, the way indicators are used often does not take full advantage of current knowledge, nor does it always support transparent decision-making with scientific information clearly separated from social values. This paper reviews British Columbia's use of hydrologic indicators and provides practical options for improving the quality of hydrologic information provided to decision-makers.

In assessing forest-management options, decision-makers require clear expression of possible hydrologic outcomes. How these outcomes are best presented for consideration in decision-making is influenced by the spatial scale under consideration, data availability at this scale, data quality, analytic capabilities, and the current level of scientific knowledge. The literature demonstrates the prevalence of indicator and process models. The present version of the Watershed Assessment Procedure has moved away from a reliance on indicators to a greater focus on professional opinion based on limited field work. This shift may be suitable at the scale of specific watersheds, but it does not address broader management planning scales. The use of

Equivalent Clearcut Area as a single indicator of hydrologic impact continues to be evident in British Columbia at all management levels despite knowledge that Equivalent Clearcut Area can be only weakly linked to hydrologic impact.

A host of challenges is preventing the effective use of indicators in hydrologic assessment in British Columbia. The uncertainty and complexity associated with hydrologic linkage mechanisms present real challenges to the applied scientist when attempting to articulate potential hydrologic outcomes to decision-makers. Data availability/quality and computational power continue to be significant modeling issues. Evaluation of results and of the procedure itself have been lacking in British Columbia and yet form a cornerstone of effective adaptive management.

It is suggested that a preferred approach for supporting broad management decisions is a risk-assessment framework that provides a clear separation between scientific interpretation and value-based choices. A systematic evaluation of indicators linked to applied research would be required, along with standardized measures of hydrologic impact. It is concluded that until reliable process models can be developed and detailed data are available on a broad basis, indicators will continue to be an essential basis for making forest-management decisions.

286) Cheng, J.D. 1989. Streamflow changes after clear-cut logging of a pine beetle-infested watershed in southern British Columbia, Canada. Water Resources Research. 25: 449-456. (G)

Electronic abstract: The paired watershed technique was used to assess the streamflow changes of Camp Creek in interior British Columbia after clear-cut logging occurred over 30% of its 8400 ac. watershed. Existing hydrometric data for Camp Creek (beetle infested) and those of an adjacent control, Great Creek (not beetle infested), were analyzed for both the 1971-1976 prelogging and 1978-1983 postlogging periods. Postlogging Camp Creek streamflow changes are characterized by increases in annual and monthly water yields and annual peak flows, as well as earlier annual peak flow and half flow volume occurrence dates. The direction and magnitude of these postlogging streamflow increases are clear and consistent. The results are in good agreement with the findings of most previous studies conducted on watersheds that generally have been smaller than 2.5 km^2. This study provides strong evidence that changes in streamflow from large forested watersheds can be significant if a sizeable portion of its drainage is clear-cut.

287) Chew, L.C., and P.E. Ashmore. 2001. Channel adjustment and a test of rational regime theory in a proglacial braided stream. Geomorphology. 37: 43-63. (A)

Author abstract: The upstream reach of the Sunwapta River, Alberta, provides a useful quasi-experimental field case of channel adjustment in a proglacial stream. Historically, the formation of a proglacial lake deprived the river of its coarse sediment supply for several decades and lead to a dramatic decrease in braiding intensity close to the lake while braiding intensity increased further downstream. This response to the reduction of gravel input is consistent with previous experimental results. Subsequent construction activity and channelization close to the lake have contributed to the continuation of these temporal and spatial trends in channel pattern. The current state of adjustment of the river morphology can be explained, in the context of these historical changes, using rational regime equations. The study reach has no tributaries and bed material size decreases twofold along the reach while width and braiding intensity increase, yet channel slope decreases by only 10%. The absence of any significant change in discharge downstream along the reach allows testing of regime equations under conditions in which discharge is held constant. The current downstream trends in slope and fluctuations in width are predicted reliably from rational regime equations, but not by the existing empirical hydraulic geometry relations. The rational equations incorporate the effect of grain size and slope on channel width and the effect of width and grain size on channel slope. The regime equations are successful even though they were devised for single channel gravel streams. The small (10%) decrease in slope along the reach, despite a halving of median grain size, is attributed to the counteracting (positive) effect on slope of the downstream increase in braiding intensity and width. The downstream increase in braiding intensity must be largely the result of decreasing grain size. This confirms the influence of grain size on channel pattern thresholds and demonstrates, using spatial transitions in channel pattern, that channel pattern predictions based on stream power alone are inadequate.

288) Church, M., and J.M. Ryder. 2001. Watershed processes in the southern interior of British Columbia: Background to land management. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 1-16. (A, D, F, G, I)

Author abstract: The factors that govern morphology and processes along stream channels are the amount and timing of water delivery to the channel, the amount and calibre of sediment delivered, the gradient over which the channel flows, and conditions of bank vegetation and wood supply to the channel. A fundamental distinction must be recognized between low-order, headward drainage basins and larger, higher-order ones. Headward basins are the source of channeled streamflow and much of the sediment that moves through the drainage system. Trunk streams combine drainage from many headward channels. Headward channels are coupled to slopes that deliver sediment inputs directly; trunk streams are buffered from adjacent slopes by a valley flat. Headward channels are subject to episodic major disturbance, usually in the form of landsliding. Trunk channels experience the attenuated effect of disturbances at many places in the headwaters. Sediment delivery and onward transfer occur frequently in such channels. Exceptions occur. Headward channels sometimes are flat, and may drain extensive wetlands. Conversely, many valley streams are incised into and at least partially confined by high banks composed of Pleistocene sediments. Diagnosis of land surface conditions and actions to ensure soil and landscape stability should be focused upon hillside stability in headward drainage basins. Along valleys, the focus of attention must be the stream channel and riparian zone. Consequently, hydrological watershed assessment is an appropriate management tool in relatively small, upland drainage basins, but in larger drainage systems major management tool for uncoupled channels should be stream channel stability assessment.

289) Clague, J.J., R.J.W. Turner, and A.V. Reyes. 2003. Record of recent river channel instability, Cheakamus Valley, British Columbia. Geomorphology. 53: 317-332. (A, F)

Author abstract: Rivers flowing from glacier-clad Quaternary volcanoes in southwestern British Columbia have high sediment loads and anabranching and braided planforms. Their floodplains aggrade in response to recurrent large landslides on the volcanoes and to advance of glaciers during periods of climate cooling. In this paper, we document channel instability and aggradation during the last 200 years in lower Cheakamus River valley. Cheakamus River derives much of its flow and nearly all of its sediment from the Mount Garibaldi massif, which includes a number of volcanic centres dominated by Mount Garibaldi volcano. Stratigraphic analysis and radiocarbon and dendrochronological dating of recent floodplain sediments at North Vancouver Outdoor School in Cheakamus Valley show that Cheakamus River aggraded its floodplain about 1–2 m and buried a valley-floor forest in the early or mid 1800s. The aggradation was probably caused by a large (ca. $15–25\times10^6$ m^3) landslide from the flank of Mount Garibaldi, 15 km north of our study site, in 1855 or 1856. Examination of historical aerial photographs dating back to 1947 indicates that channel instability triggered by this event persisted until the river was dyked in the late 1950s. Our observations are consistent with data from many other mountain areas that suggest rivers with large, but highly variable sediment loads may rapidly aggrade their floodplains following a large spike in sediment supply. Channel instability may persist for decades to centuries after the triggering event.

290) Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland rivers. Canadian Journal of Fisheries and Aquatic Sciences. 59: 66-76. (A, D)

Author abstract: We examined changes in wood abundance and functions in Puget Lowland rivers from the last ~150 years of land use by comparing field data from an 11-km-long protected reach of the Nisqually River with field data from the Snohomish and Stillaguamish rivers and with archival data from several Puget Lowland rivers. Current wood abundance is one to two orders of magnitude less than before European settlement in the Snohomish and Stillaguamish basins. Most importantly, wood jams are now rare because of a lack of very large wood that can function as key pieces and low rates of wood recruitment. These changes in wood abundance and size appear to have fundamentally changed the morphology, dynamics, and habitat abundance and characteristics of lowland rivers across scales from channel unit to valley bottom. Based on our field studies, rivers had substantially more and deeper pools historically. Archival data and field studies indicate that wood jams were integral to creating and maintaining a dynamic, anastomosing river pattern with numerous floodplain channels and abundant edge habitat and routed floodwaters and sediment onto floodplains. Establishing the condition of the riverine landscape before European settlement sets a reference against which to evaluate contemporary conditions and develop restoration objectives.

291) Commandeur, P.R., B.T. Guy, and H. Hamilton. 1996. The effects of woody debris on sediment fluxes in small coastal stream channels. Pacific Forestry Centre, Canadian Forest Service, Victoria, British Columbia, Information Report BC-X-367. 27pp. (B, D, I)

Author abstract: Two first-order streams located on the south coast of British Columbia were studied to determine the role of woody debris in controlling the routing and storage of sediment within high gradient channels in logged areas. The removal of logging slash from one of the two channels resulted in a reduction in the trapping and storage of sediment compared to the control channel over a one-year period following logging. For the control, the steps created by the woody debris provided storage locations and reduced the transport of sediment, especially the larger sizes. About 37% of the sediment inputs were stored in the treated channel, whereas 66% of the sediment inputs were stored in the control channel. The remainder of the sediment inputs went through each channel. The sediment storage potential within the channels was limited, and in this study, the debris storage sites were filled in the first year following logging. Bedload (including some sediment transported in suspension but deposited within the weir/box) represented 30-35% of the total outputs for each channel. Over 90% of the bedload was finer than 2 mm for the control channel, whereas less than 40% consisted of particles finer than 2 mm for the treated channel. The role of woody debris in reducing stream sedimentation is briefly discussed.

292) Danylchuk, A.J., and W.M. Tonn. 2003. Natural disturbances on fish: Local and regional influences on winterkill of fathead minnows in boreal lakes. Transactions of the American Fisheries Society. 132: 289-298. (I)

Author abstract: We investigated the population dynamics of fathead minnow *Pimephales promelas* and the environmental factors of four small lakes in the boreal forest of Alberta, Canada, for 5 years to determine the influence of local and regional factors on the development of hypoxia and the occurrence of fish winterkill. Fathead minnow densities varied considerably among lakes and years, with dramatic (47–94%) year-to-year declines occurring when dissolved oxygen levels were extremely low in the intervening winter. Large declines (presumed winterkills) occurred after 25% of the "lake-winters," affecting three of four study lakes and 2 of 5 years. A fifth population in the same region, monitored for 15 years, displayed both a comparable frequency and temporal synchrony of large density decreases, suggesting that winterkill is a pervasive natural disturbance in small lakes of the Boreal Plains. In contrast to patterns displayed by larger fish species, smaller individuals in the fathead minnow populations were more strongly affected than larger individuals. Oxygen levels in a given lake and winter were related to (1) the collective interactions of productivity and depth of the lake, (2) the local and regional hydrogeology, and (3) the current and antecedent climate. As a result, the relative effects of these local and regional factors strongly influence the natural dynamics of fathead minnow populations in these lakes. Given that humans can alter many of the important factors, the natural incidence of winterkill could be augmented if human activities are poorly managed.

293) de Boer, D.H., M. Hassan, B. McVicar, and M. Stone. 2003. Recent (1999-2002) Canadian research on contemporary processes of river erosion and sedimentation, and river mechanics. In: Quadrennial Report to the International Union of Geodesy and Geophysics and International Association of Hydrological Sciences. J.W. Pomeroy, Compiler. Canadian National Committee for the International Association of Hydrological Sciences (CNC-IAHS). Pages 50-60. (A, F, I)

Author abstract: This review is part of the Canadian quadrennial report to the International Association of Hydrological Sciences (IAHS), and focuses on the science and management aspects of sediment dynamics in rivers and drainage basins published between 1999 and 2002. The themes of this review were selected to be of interest to the hydrological sciences in general,

and were chosen to represent a broad overview of the nature and directions of Canadian research in fluvial geomorphology, both in academia and in government and management. There is a large body of Canadian research that is aimed at elucidating the historical process record, for example through the use of lake sediments that reflect the erosional history of the contributing basin. This review, however, primarily concerns contemporary processes. The major themes of this review paper include sediment budgets and sediment yield; cohesive sediment transport; turbulent flow structure, sediment transport and bedforms; and bedload transport and channel morphology. These themes were selected because they have been the focus of substantial research in Canada.

Fluvial systems in Canada have a number of specific characteristics. First of all, Canada is a high latitude country, which means that, in most basins, the spring snowmelt is a dominant feature of the discharge and sediment transport regimes. Furthermore, in the northern part of the country, the presence of permafrost directly affects hydrological processes and is an important part of understanding fluvial processes and landforms. The northern location of Canada is also important from a historical perspective, since much of Canada was covered by ice during the Quaternary glaciations. As a result, the landscape in most of Canada is relatively young, and rivers are still actively adjusting to deglaciation, which only occurred during the late Pleistocene. The high latitude of the country also places it in that part of the world where CGMs generally indicate that the impact of global warming will be greatest in terms of temperature increase. Even though Canada is generally viewed as a relatively pristine country, its rivers are rarely unaffected by human activity. A multitude of dams has resulted in modifications of the annual discharge regime, and has led to changes in sediment storage and channel characteristics to a degree that is unknown, but likely substantial. Furthermore, in parts of Canada, human activity has led to a significant degradation of water and sediment quality—typically associated with urban, industrial and, sometimes, agricultural areas—and mobilization of large quantities of sediment within the drainage basin—typically caused by forestry and, sometimes, agriculture. Sediment quality and quantity in a stream directly affect the fish populations and, consequently, studies of the effect of human activity on fish habitat and behaviour form an important, practical part of fluvial geomorphology research in Canada.

Some of the characteristics of Canadian fluvial systems are reflected in the directions of research. Canadian research in fluvial geomorphology during the period of this review (1999-2002) continues in the same direction as earlier work summarized by Ashmore *et al.* (2000). There is a penchant for, and as a result, substantial progress has been made in, investigating the details of fluvial processes at relatively small scales. Examples of this emphasis are the investigations of floc structure, turbulence characteristics and bedload transport, which continue to form central themes in fluvial research in Canada. Translating the knowledge of small-scale, process-related research to an understanding of the behaviour of large-scale fluvial systems, however, continues to be a formidable challenge. Models play a prominent role in elucidating the link between small-scale processes and large-scale fluvial geomorphology, as they do in other fields such as climatology and oceanography. Canadian fluvial geomorphologists have recognized this role of models and, as a result, a number of papers describing models and modelling results have been published during the review period. It is to be expected that, in the future, the combination of detailed process measurements and models will gain importance in fluvial geomorphology in Canada, which will lead to an increased understanding of large-scale fluvial systems and strengthen the links between fundamental and applied research.

294) DeLong, S.C., S.A. Fall, and G.D. Sutherland. 2004. Estimating the impacts of harvest distribution on road-building and snag abundance. Canadian Journal of Forest Research. 34: 323-331. (K)

Author abstract: Various patterns of harvest in forests influence the length of road and number of stream crossings required. Snags are removed directly by harvesting, but they are also removed along road and opening edges to ensure worker safety. To assess the potential impacts of rate of harvest and pattern of harvest in an old-forest-dominated montane landscape, we developed a spatially explicit landscape dynamics model, which includes submodels for snag removal, harvesting activities, and access management. The model assesses the amount of new road construction and number of streams crossed by new roads, as well as changes in snag density and configuration across the landscape over a time horizon of several decades, in response to various harvesting patterns. We estimated that a dispersed 40-ha cutblock harvest pattern required about one-third more kilometres of new road over a 50-year period and removal of up to 70% more snags per hectare of harvest for safety purposes, compared with a harvest pattern based on natural-patch size distribution. Each 20% increase in stand-level retention resulted in a roughly equivalent increase in new road required. Up to eight times as many snags were removed per hectare of harvest for safety purposes at a stand-level retention of 70% than at a stand-level retention of 10%. The model appears to be an effective tool for determining the future impact of various harvest-pattern options on a number of important indicators of ecological impact.

295) Dhakal, A.S., and R.C. Sidle. 2003. Long-term modelling of landslides for different forest management practices. Earth Surface Processes and Landforms. 28: 853-868. (K)

Author abstract: Long-term effects of different forest management practices on landslide initiation and volume were analyzed using a physically based slope stability model. The watershed-based model calculates the effects of multiple harvesting entries on slope stability by accounting for the cumulative impacts of a prior vegetation removal on a more recent removal related to vegetation root strength and tree surcharge. Four sequential clearcuts and partial cuts with variable rotation lengths were simulated with or without leave areas and with or without understorey vegetation in a subwatershed of Carnation Creek, Vancouver Island, British Columbia. The combined infinite slope and distributed hydrologic models used to calculate safety factor revealed that most of the simulated landslides were clustered within a 5 to 17 year period after initial harvesting in cases where sufficient time (*c*. 50 years) lapsed prior to the next harvesting cycle. Partial cutting produced fewer landslides and reduced landslide volume by 1.4- to 1.6-fold compared to clearcutting. Approximately the same total landslide volume was produced when 100 per cent of the site was initially clearcut compared to harvesting 20 per cent of the area in successive 10 year intervals; a similar finding was obtained for partial cutting. Vegetation leave areas were effective in reducing landsliding by 2- to 3-fold. Retaining vigorous understorey vegetation also reduced landslide volume by 3.8- to 4.8-fold. The combined management strategies of partial cutting, increasing rotation length, provision of leave areas, and retention of viable understorey vegetation offer the best alternative for minimizing landslide occurrence in managed forests.

296) France, R. 1997. Land water linkages: Influences of riparian deforestation on lake thermocline depth and possible consequences for cold stenotherms. Canadian Journal of Fisheries and Aquatic Sciences. 54: 1299-1305. (J)

Author abstract: The purpose of the present study was to determine if riparian deforestation would expose lake surfaces to stronger winds and therefore bring about deepening of thermoclines and resulting habitat losses for cold stenotherms such as lake trout (*Salvelinus namaycush*). Removal of protective riparian trees through wind blowdown and two wildfires was found to triple the overwater windspeeds and produce thermocline deepening in two lakes at the Experimental Lakes Area. A survey of thermal stratification patterns in 63 northwestern Ontario lakes showed that lakes around which riparian trees had been removed a decade before through either clearcutting or by a wildfire were found to have thermocline depths over 2 m deeper per unit fetch length compared with lakes surrounded by mature forests. Riparian tree removal will therefore exacerbate hypolimnion habitat losses for cold stenotherms that have already been documented to be occurring as a result of lake acidification, eutrophication, and climate warming.

297) France, R.L. 1997. Macroinvertebrate colonization of woody debris in Canadian Shield lakes following riparian clearcutting. Conservation Biology. 11: 513-521. (C, D)

Electronic abstract: Deployment of litterfall traps revealed that clearcut logging of boreal riparian forests in northwestern Ontario, Canada resulted in a dramatic shift from once dominant conifers to regrowth composed largely of deciduous trees and reduced the allochthonous inputs of small woody debris to lake littoral zones by over 90%. Due to the rarity of macrophytes in these oligotrophic lakes, littoral macroinvertebrates were found to actively colonize woody debris placed within mesh litter bags. The recalcitrant nature of small woody debris in these lakes (average median persistence time of about 5 years estimated from mass loss data) indicates, however, that this important habitat resource will probably never completely disappear in relation to its projected rate of resupply during post-disturbance forest regeneration. Colonization rates of twigs and bark contained within the litter bags were not found to differ between coniferous and deciduous species. This indicates that macroinvertebrates in these boreal lakes are merely opportunistic colonizers of woody debris, probably for its use as either a biofilm substrate or a predation refuge. As a result, shifts in tree species composition following riparian clearcutting should not detrimentally affect the taxa richness or organism abundance of aquatic macroinvertebrates in these lakes.

298) Fuchs, S.A., S.G. Hinch, and E. Mellina. 2003. Effects of streamside logging on stream macroinvertebrate communities and habitat in the sub-boreal forests of British Columbia, Canada. Canadian Journal of Forest Research. 33: 1408-1415. (A, B, C, D)

Author abstract: Much of the future timber supply in the Northern Hemisphere will come from boreal and sub-boreal forests, yet there has been little investigation of how aquatic communities in these regions would be affected by logging. We conducted an empirical, comparative study to investigate the effects of streamside clear-cut logging on benthic macroinvertebrates, algal

standing stock, and in-stream physical and chemical habitats in the sub-boreal central interior region of British Columbia. We found that streams that flowed through old-growth forests (sites termed "not logged") did not differ from streams flowing through older logged forests (where the riparian zones were harvested 20–25 years before our sampling; sites termed "older logged") with respect to macroinvertebrate total density or biomass, feeding guild density or biomass, and chlorophyll *a* biomass. However, streams flowing through newly logged forests (where the riparian zones were harvested within 5 years of our sampling; sites termed "recently logged") had nearly twice the macroinvertebrate biomass as those in not logged or older logged sites and higher chlorophyll *a* biomass. There were no differences among the three stream categories in regard to structural aspects of the physical habitat (e.g., substrate composition, large organic debris density, dimensions of pools and riffles). Streamside logging in sub-boreal forests appears to enhance primary and secondary production, but this phenomenon may only be evident for the first two decades following logging.

299) Gluns, D.R. 2001. Snowline pattern during the melt season: Evaluation of the H60 concept. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 68-80. (G)

Author abstract: The H60 concept refers to the elevation of snowline when the upper 60% of a watershed is covered in snow. Timber harvesting in this "snow zone" is thought to have a greater influence on peak flows due to changes in snow accumulation and snowmelt when the forest canopy is removed. To account for this influence, the Interior Watershed Assessment Procedure provides a weighting mechanism for harvesting proposed in this zone. To test this principle, a 5-year study to look at snowlines and streamflow was undertaken. At the time of peak flow, on average, it was found that approximately 65% of a watershed was covered in snow. The H60 concept is valid for watersheds in the southern interior of British Columbia as a tool for evaluating forest-harvesting proposals.

300) Guthrie, R.H. 2002. The effects of logging on frequency and distribution of landslides in three watersheds on Vancouver Island, British Columbia. Geomorphology. 43: 273-292. (K)

Author abstract: Three hundred and sixty three landslides in three watersheds that totaled 382 km^2 were identified from air photographs, beginning at a date that preceded logging to the present. The three watersheds all lie on Vancouver Island; however, they have different precipitation regimes, topography, and amounts logged. Landslide areas in the watersheds varied in size from 200 m^2 to more than 1 ha. Nearly 80% of the landslides were debris slides; 15% were debris flows, and the remainder primarily rock falls. Following logging, the number of landslides increased substantially in all watersheds although the amount of increase was variable: approximately 11, 3, and 16 times in Macktush Creek, Artlish River, and Nahwitti River, respectively. Other analyses of changes in landslide density also produced highly variable results, with the number of landslides increasing between 2.4 and 24 times. Further, 2–12 times more landslides reached streams following logging activities. Densities for landslides impacting streams increased for the period of record from 1.5 to 10 times following logging activities. The densities were substantially greater where only landslides that reached streams since development began in a watershed were considered. Roads had the greatest spatial impact in the watersheds (compared to their total area), with frequencies determined to have increased by 27, 12, and 94 times for Macktush, Artlish, and Nahwitti, respectively. The results highlight the relative impact of roads and their role in slope stability.

301) Guyette, R.P., and W.G. Cole. 1999. Age characteristics of coarse woody debris (*Pinus strobus*) in a lake littoral zone. Canadian Journal of Fisheries and Aquatic Sciences. 56: 496-505. (D)

Author abstract: Littoral coarse woody debris (CWD) is a persistent class of aquatic habitat that accumulates over many centuries and provides habitat for diverse floral and faunal communities. We used dendrochronological methods to analyze residence times and age-related characteristics of eastern white pine (*Pinus strobus*) CWD in the littoral zone of Swan Lake in Algonquin Provincial Park, Ontario. The mean calendar date of all the annual rings in CWD samples was 1551. Annual rings dated from calendar year 1893 to 982. The mean time from carbon assimilation in a live tree to carbon loss from littoral woody debris was 443 years. Outside ring dates of the woody debris were significantly correlated with the bole's maximum and minimum diameter ratio, mass, specific gravity, length, and submergence. Negative exponential functions described the temporal structure of the CWD mass and abundance. Accelerated inputs of woody debris resulted from late nineteenth century logging and a disturbance circa 1500. No mature eastern white pine have fallen into the lake over the last 100 years.

302) Hartman, G.F., J.C. Scrivener, and M.J. Miles. 1996. Impacts of logging in Carnation Creek, a high-energy coastal stream in British Columbia, and their implication for restoring fish habitat. Canadian Journal of Fisheries and Aquatic Sciences. 53 (Suppl. 1): 237-251. (A, B, F)

Author abstract: The land form, surficial geology, and hydrometeorology of the west coast of British Columbia cause streams in the region to be highly variable in flow and vulnerable to land-use disturbance. Carnation Creek, a small drainage in this region, was studied intensively for > 20 yr to examine the impacts of forest harvesting. Landslides and debris torrents modified steep slope tributaries and the mainstem of the creek. Bank erosion also altered the stream channel on the alluvial flood plain. These effects were additive in the system and reduced the quality of spawning and rearing habitat for juvenile salmonids. In streams like Carnation Creek, it is necessary to restore some stability to the hill slopes and gullies before attempting fish habitat improvements in the main channel. Salmonid production was limited by combinations of processes and conditions that were different for each species and life-history stage. Knowledge of the processes that limit fish production must be applied in habitat improvement work or the projects risk failure. Programs intended to restore natural function to systems or to improve habitat for fish must be planned, evaluated, and reported methodically if they are to succeed and provide information of use to future programs.

303) Hartman, G.F., J.C. Scrivener, and T.E. McMahon. 1987. Saying that logging is either 'good' or 'bad' for fish doesn't tell you how to manage the system. The Forestry Chronicle. (June): 159-164. (D, J)

Author abstract: A 16-year multi-disciplinary watershed study at Carnation Creek, British Columbia, revealed that different activities in a forest harvest program had different impacts on the physical and biological components of the system. Changes in stream temperature, as a result of logging and a climatic warming trend, and changes in the distribution and volume of woody debris in the channel caused complex sequences of processes to influence salmonid production in both a positive and negative manner. The influence depended on the type of physical change, the fish species and its life history stage, and the elapsed time after the logging activity. Some direct implications of the research to the problems of managing in the face of complexity are discussed.

304) Hartman, G.F., L.B. Holtby, and J.C. Scrivener. 1984. Some effects of natural and logging-related winter stream temperature changes on the early life history of coho salmon (*Oncorhynchus kisutch*) in Carnation Creek, British Columbia. 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 141-149. (J)

Author abstract: Carnation Creek is a small rain-forest stream located on Barkley Sound, Vancouver Island, British Columbia. It is the site of a 15-year watershed study concerned with the impact of logging on anadromous and resident salmonids. This paper deals with some of the effects of natural and logging-induced stream temperature changes in winter on juvenile coho salmon. Extensive logging began in the winter of 1976-77 and continued until 1980-81, by which time 41% of the watershed had been clearcut. Stream temperatures in early winter from 1976-77 through 1980-81 were higher than they had been prior to logging. Temperature increases resulted from climatic amelioration, which began in 1976, and from the effects of logging. As a result of higher temperatures, coho salmon fry emerged earlier in the spring than they had prior to logging. Early emergent fish that did not move downstream during spring freshets began growing sooner. In 1981, the year of highest winter temperatures, fry emerged 47 days earlier than in the prelogging years and this, coupled with faster growth in late spring, led to the fish entering their first winter at a larger size. Consequently, survival through the winter was greater, leading to increased numbers and size of 1-year smolts and an increased proportion of 1-year versus 2-year smolts. Brief speculation is offered about processes that may have affected stream temperatures during winter.

305) Henderson, G.S., and D.A.A. Toews. 2001. Using sediment budgets to test the watershed assessment procedure in southeastern British Columbia. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 189-208. (G, I)

Author abstract: In 1997 and 1998, the British Columbia Ministry of Forests tested the appropriateness of using the sediment-source technique described in the province's 1999 Interior Watershed Assessment Procedure (IWAP) to assess the input and output of sediment in 11 sub-watersheds in the Nelson Forest Region in southeastern British Columbia. Sediment input was estimated using the Rapid Road Erosion Technique Survey (RREST), a survey technique that estimates quantities of sediment that erode from forestry roads and are transported into the stream system. Sediment output was calculated for the same sub-watersheds by measuring suspended sediment, turbidity, and streamflow, and these measurements were used to calculate sediment yield in nine of the 11 basins. Results show that, in these watersheds, forestry roads are a relatively small part of the annual sediment budget, and that natural sediment sources dominate the sediment regime. It is unlikely that rehabilitation of forestry roads would result in significant reductions in sediment yield when measured at the outlet of the basin.

306) Hogan, D. 2001. Stream channel assessment in the interior of British Columbia. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 112-133. (A)

Author abstract: The Channel Assessment Procedure referred to in the Watershed Assessment Procedure was developed to provide an objective, repeatable method to assess stream-channel disturbance. It is based on field indicators of disturbance that were developed with an understanding of the naturally high variability of stream channels. The indicators relate to channel aggradation and degradation that can be linked to the primary hydrologic and geomorphic processes operating in a watershed. The channelassessment of Norns Creek is described to provide an illustration of the utility of the channel assessment as a component analysis within a watershed assessment. The channel assessment provides a detailed description of the channel reaches, including morphology, hillslope/channel coupling, and sediment transport and deposition sites. With the accompanying geo-referenced inventory of disturbance indicators, the experienced geomorphologist can then link watershed processes and channel conditions. This information is relevant to fish habitats and can form the basis for determining appropriate watershed restoration prescriptions.

307) Hogan, D.L. 1989. Channel response to mass wasting in the Queen Charlotte Islands, British Columbia: Temporal and spatial changes in stream morphology. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Pages 125-142. (A)

Author abstract: A paired watershed study is being used to compare stream channels with various ages of mass wasting disturbance with similar channel types in undisturbed basins. In year 1 of a 4 year program (1988), approximately 27 km of stream channel were inventoried, including a wide range of stream sizes and debris torrent ages from 1 to 150 years. Morphological parameters of relevance to fish habitats were the focus of the field surveys. A case study is presented here.

A fundamental consequence of debris torrent inputs to stream channels is the establishment of sediment wedges associated with debris jams. Specific sedimentological, morphological and hydraulic changes occur upstream and downstream of the jams. The sediment wedges are of two basic types, vertical and lateral. The location, size and function of each type of jam controls morphology and their distribution along the water course influences the spatial adjustment of the channel. The integrity and longevity of the debris jams control the temporal response of the channel. Initial results indicate that severe morphological alterations persist during the first decade following debris torrenting, but the channel begins to develop more normal characteristics during second and third decades. The morphological nature of stream channels 30 years after disturbance begins to resemble undisturbed channels.

308) Hogan, D.L., and D.J. Wilford. 1989. A sediment transfer hazard classification system: Linking erosion to fish habitat. In: Proceedings of Watershed '89: A Conference on the Stewardship of Soil, Air, and Water Resources, 21-23 March 1989, Juneau, Alaska. E.B. Alexander, Editor. USDA Forest Service, Alaska Region, R10-MB-77. Pages 143-155. (I)

Author abstract: A problem in watershed management is linking upslope erosion associated with forestry practices to downstream sedimentation of fish habitats. To overcome this problem, a sediment transfer hazard classification system was developed and applied to a northwestern British Columbia watershed. The system is based on geomorphic factors that influence sediment production, transport, and deposition. Data to describe these factors are obtained from air photographs, topographic maps, fish habitat inventories and interpretive terrain maps. The final product of the system is a sediment transfer hazard map that indicates where in a watershed sediment production and movement is a potential problem. This is an important tool for watershed and integrated resource managers because not all unstable or erodible sites pose a sedimentation hazard to fish. Knowing the hazards, managers can decide in an informed way where to restrict forest harvesting or focus limited dollars on special road construction and harvesting techniques. This paper describes the Sediment Transfer Hazard Classification System.

309) Johnston, N.T., E.A. MacIsaac, P.J. Tschaplinski, and K.J. Hall. 2004. Effects of the abundance of spawning sockeye salmon (*Oncorhynchus nerka*) on nutrients and algal biomass in forested streams. Canadian Journal of Fisheries and Aquatic Sciences. 61: 384-403. (C, D, E)

Author abstract: We used natural variation in sockeye salmon (*Oncorhynchus nerka*) spawner biomass among sites and years in three undisturbed, forested watersheds in interior British Columbia to test the hypotheses that salmon were a major source of particulate organic matter inputs to the streams and that carcass biomass determined stream-water nutrient concentrations and epilithic algal production. Sockeye carcasses were retained at the spawning sites, primarily (75–80%) by large woody debris (LWD) or pools formed by LWD. The abundance and distribution of sockeye salmon determined stream-water nutrient concentrations and epilithic chlorophyll *a* concentrations during late summer and early fall when most primary production occurred in the oligotrophic streams. Periphyton accrual rates were elevated at sites with high salmon biomass. Peak chlorophyll *a* concentration increased with increasing carcass biomass per unit discharge above a threshold value to reach maxima 10-fold greater than ambient levels. Epilithic algae were dominated by a few common, large diatom taxa. Salmon carcasses were the dominant source of particulate organic carbon in low gradient stream reaches. Nutrient budget modeling indicated that most of the salmon-origin nutrients were exported from the spawning streams or removed to the terrestrial ecosystem; diffuse impacts may extend over a much larger area than simply the sites used for spawning.

310) Jordan, P. 2001. Regional incidence of landslides. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 237-247. (K)

Author abstract: A regional study was made of landslides in portions of the Arrow Forest District and the Kootenay Lake Forest District, which permits some preliminary conclusions to be made about the areal frequency of landslides, their causes, and their importance as sediment sources to streams. The study covered all or parts of 100 map sheets, totaling about one million hectares. Approximately 1700 landslides were inventoried by air-photo interpretation. A subset of about one-quarter of this study area, centered on the Slocan Valley, is discussed in this paper.

The data show that landslide frequencies are typically increased by roughly 10 times by forest development (depending on how one defines the land base for calculation of areal frequencies). The landslide frequency on private land is higher than on Crown land. About 95% of development-related landslides are due to roads or skid trails. On older roads, road-fill failures are apparently the most common cause. However, on newer roads, that most common cause is drainage concentration and diversion by roads. An important category of landslides occurs some distance below roads, below a culvert or a point of accidental drainage discharge. In many of these cases, the road itself is on gently sloping, low-hazard terrain, and the landslide occurs on steeper terrain below. This is known as the "gentle-over-steep" situation. The Forest Practices Code does little to reduce landslide hazard in this situation, because the need for professional engineering involvement in road design is triggered by the hazard at the road location, not below the road.

The terrain type most frequently involved in landslides, on an areal basis, is deep glaciofluvial or other stratified glacial deposits in valley bottoms. Otherwise, there are few generalizations that can be made about terrain factors contributing to landslide hazard, or about contributions of landslide sediment to streams. Landslides, like other geomorphic and hydrologic processes, tend to follow magnitude-frequency relations. Small landslides are most frequent, and often do not reach a stream. Large landslides are much less frequent, but often enter streams. In most watersheds, landslides are not a major component of the sediment budget, but in the rare cases where a large landslide occurs, it can dominate the sediment regime for 1 or several years.

311) Jordan, P. 2001. Sediment budgets in the Nelson Forest region. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 174-188. (I)

Author abstract: We have ongoing sediment-budget studies in two parts of the Kootenays: at Redfish-Laird creeks in the West Arm Demonstration Forest, and at Gold Creek, one of the community watersheds of the City of Cranbrook. In addition, a number of watersheds have had monitoring programs that provide some sediment-budget information for 1 or more years.

The Redfish-Laird study began in 1993. Results show that April-September sediment yields for each year in Redfish Creek, which is developed with roads and logging, ranged from 25% greater than to double the yields for Laird Creek, the control. Most of the difference is probably

attributable to erosion from roads, and to a lesser extent, to road-related landslides that occurred before the study began. Road-maintenance activities can contribute significantly to sediment production. Contributions of sediment from cutblocks were insignificant.

The study in Gold Creek, which began in 1998, has so far shown much lower development-related sediment inputs to the creeks than in Redfish Creek. This is apparently due to a fundamental difference between the two areas in runoff generation mechanism. At Gold Creek, most of the snowmelt runoff from upland areas appears to enter fractured bedrock, and reach the creek through groundwater flow. This results in a low connectivity between sources of eroded sediment and the creek. In contrast, the hydrograph of Redfish Creek is dominated by surface runoff, and the sediment deliverability from roads to the creek is higher.

In 1997, we monitored suspended sediment production on 11 creeks used for community and domestic water supply. Watersheds underlain by granitic rocks tended to have the lowest average sediment yield; otherwise, there was little apparent relation between sediment yield and bedrock geology or extent of development. In general, sediment yield from most creeks used for water supply was quite low compared to typical yields elsewhere in British Columbia.

A sampling strategy of daily manual sampling during the spring freshet, and less frequent sampling for the rest of the year, has been found effective both for measuring total sediment yield and for monitoring water quality. Recording turbidity meters provide additional useful information.

312) Kelly, D.J., M.L. Bothwell, and D.W. Schindler. 2003. Effects of solar ultraviolet radiation on stream benthic communities: An intersite comparison. Ecology. 84: 2724-2740. (C, H)

Author abstract: The effects of solar ultraviolet radiation (UVR), both mid-ultraviolet (UVB; 280–320 nm) and near-ultraviolet (UVA; 320–400 nm), on benthic algal and invertebrate communities were compared in three reaches of a British Columbia coastal stream that differed in the degree of shading by riparian canopy (a full canopy, a partial canopy, and no canopy). At each of the three sites benthic communities were exposed to three different radiation treatments: photosynthetically active radiation alone (PAR; 400–700 nm), PAR+UVA, and PAR+UVA+UVB. Relative to the site with no canopy, UVR was 88% and 66% lower, and PAR was 83% and 49% lower at sites with full and partial canopy, respectively. Late summer increases in UVR to the streambed caused by declines in water level and dissolved organic carbon (DOC) were also lower at sites with high canopy.

Sites with less canopy shading had greater algal accrual, decreased biomass of total invertebrates, mayflies, and stoneflies, and reduced invertebrate community diversity compared to the heavily shaded reach of the stream. UVR produced taxon-specific community responses that varied across sites and increased with increasing UVR as summer progressed. At the full canopy site UVR had no impact, and the final (day 91) biomass and diversity of invertebrates was highest, and algal biomass lowest. Higher UVA radiation under reduced canopies inhibited algal accrual but had little effect on algal community composition. The biomass of several invertebrate taxa (e.g., *Dicosmoecus* spp., Limnephilidae) and community diversity were reduced by both UVA and UVB. Less sensitive taxa (e.g., *Paraleptophlebia* spp., Paraleptophlebidae) were inhibited only by the highest UVB levels in late summer when water transparency to UVR was greatest. Inhibition of grazers by UVR appeared to indirectly increase algal accrual, particularly at the partial canopy site.

Our results indicate that riparian shading may moderate UVR effects on benthic communities, mainly through impacts on invertebrates with indirect effects on algae. By reducing UVR exposure of streambeds, riparian canopies may be important for ameliorating UVR effects on shallow lotic systems, especially during late-summer, low-flow periods when DOC concentrations are reduced.

313) Kreutzweiser, D.P., and S.S. Capell. 2001. Fine sediment deposition in streams after selective forest harvesting without riparian buffers. Canadian Journal of Forest Research. 31: 2134-2142. (I)

Author abstract: Fine sediment accumulation was measured in streams in low-order forest watersheds across a gradient of selective harvesting with no protective riparian buffers. Comparisons were made among sites in selection-cut (40% canopy removal), shelterwood-cut (50% canopy removal), diameter limit cut (about 85% canopy removal), and undisturbed tolerant hardwood catchments. These were further compared with a headwater stream catchment not harvested but affected by logging road activities. The greatest increases in fine inorganic sediment occurred at the road-improvement site with mean bedload estimates more than 4000 times higher than pre-manipulation values. Sediment bedload was still significantly elevated 2 years after the road-improvement activities. Significant increases (up to 1900 times the preharvest average) in inorganic sediment also occurred at the highly disturbed diameter-limit site as a result of heavy ground disturbance and channeled flowpaths from skidder activity in riparian areas. Similar increases were detected at the selection-cut site but were attributable to secondary road construction in the runoff area. In the shelterwood harvest area, where logging roads were not a factor, no measurable increases in sediment deposition were detected. There was little indication that harvesting activities at any site affected the organic fraction or the particle size distribution of fine sediments. The results of this study suggest that riparian buffer zones may not be necessary for selective harvesting in hardwood forests at up to 50% removal, at least in terms of reducing sediment inputs.

314) Larkin, G.A., P.A. Slaney, P. Warburton, and A.S. Wilson. 1998. Suspended sediment and fish habitat sedimentation in central interior watersheds of British Columbia. Province of British Columbia, Ministry of Environment, Lands and Parks, and Ministry of Forests, Watershed Restoration Management Report No. 7. 31pp. (B, I)

Author abstract: Many watersheds in the central interior of British Columbia are designated for rehabilitation under the Watershed Restoration Program, which includes measures to control surface erosion. A study of suspended sediment and fish habitat sedimentation in several watersheds of the central interior, precursory to restoration activity, is described in this report. Suspended sediment concentrations measured during the spring snowmelt period indicated that sediment delivery to the nine streams surveyed was highly variable. Concentration profiles in some streams were indicative of chronic sources of sediment, but profiles in other streams were indicative of episodic sources of sediment. Severity-of-ill-effect values determined from the suspended sediment data were sufficiently high to indicate lethal and paralethal effects on the resident and migratory fish populations present in streams during the study period. Particularly severe impacts were predicted for eggs and developing larvae. High flow conditions in the spring of 1997 created considerable interference with the calibration and evaluation of sediment traps as monitors for hillslope and/or stream bank restoration projects. Despite the problems, a positive relationship between sediment accumulation in the traps and suspended sediment loading was evident. The sediment traps are a robust technique and are recommended for selected use under moderate flow conditions, and where bedload movement is not dominant. The traps should become an integral part of monitoring the effectiveness of restoration projects involving erosion control, and will complement other evaluations of project success.

315) Macdonald, E., C.J. Burgess, G.J. Scrimgeour, S. Boutin, S. Reedy, and B. Kotak. 2004. Should riparian buffers be part of forest management based on emulation of natural disturbance? Forest Ecology and Management. 187: 185-196. (K)

Author abstract: Riparian communities (those near open water) have often been shown to display high structural and compositional diversity and they have been identified as potentially serving a keystone role in the landscape. Thus, they are the focus of specific management guidelines that attempt to protect terrestrial and aquatic ecosystems. We used a digital forest inventory database for a portion of the boreal mixed-wood forest in Alberta, Canada, to examine whether proximity to a lake affects forest composition, age, or configuration. Two analyses were employed: (1) forest composition (dominant canopy species, proportional composition of different species) and age (decade-of-origin) in bands of 50 m width and varying distance from small lakes were compared to forest in a similar spatial configuration but away from open water and (2) forest composition, dominant canopy species, age, and stand shape metrics were examined along transects emanating out from lakes in two regions, which varied in topography and dominant forest cover. We found no effect of distance from lake on forest age. The proportion of the landscape covered by forest of the predominant canopy species increased with distance from lake, but this was largely due to a corresponding decline in cover of non-forest vegetation rather than a change in forest canopy composition. At the spatial resolution of forest management planning, riparian forests in this region are of similar age and composition as those away from lakes. Since there is no natural analogue for riparian buffer strips around lakes, they may not be justified in the context of ecosystem management following the natural disturbance paradigm. Management of riparian forests should focus on meeting defined management and conservation objectives through, for example, protection of finer scale features of riparian zones and landscape-level planning for allocation of uncut forest.

316) Macdonald, J.S., E.A. MacIsaac, and H.E. Herunter. 2003. The effect of variable-retention riparian buffer zones on water temperatures in small headwater streams in sub-boreal ecosystems of British Columbia. Canadian Journal of Forest Research. 33: 1371-1382. (J)

Author abstract: Stream temperature impacts resulting from forest harvesting in riparian areas have been documented in a number of locations in North America. As part of the Stuart–Takla Fisheries–Forestry Interaction Project, we have investigated the influence of three variable-retention riparian harvesting prescriptions on temperatures in first-order streams in the interior sub-boreal forests of northern British Columbia. Prescriptions were designed to represent a range of possible harvesting options outlined by the Forest Practices Code of B.C., or associated best management practice guidelines. Five years after the completion of harvesting treatments, temperatures remained four to six degrees warmer, and diurnal temperature variation remained

higher than in the control streams regardless of treatment. Initially, the high-retention treatment acted to mitigate the temperature effects of the harvesting, but 3 successive years of windthrow was antecedent to reduced canopy density and equivalent temperature impacts. We speculate that late autumn reversals in the impacts of forest harvesting also occur. Temperature impacts in this study remained within the tolerance limits of local biota. However, even modest temperature changes could alter insect production, egg incubation, fish rearing, migration timing, and susceptibility to disease, and the effects of large changes to daily temperature range are not well understood.

317) Macdonald, J.S., P.G. Beaudry, E.A. MacIsaac, and H.E. Herunter. 2003. The effects of forest harvesting and best management practices on streamflow and suspended sediment concentrations during snowmelt in headwater streams in sub-boreal forests of British Columbia, Canada. Canadian Journal of Forest Research. 33: 1397-1407. (G, I)

Author abstract: This paper examines suspended sediment concentration and stream discharge during freshet in three small sub-boreal forest streams (<1.5 m in width) in the central interior of British Columbia for 1 year prior to (1996) and for 5 years following forest harvesting (1997–2001). Harvesting prescriptions in a 20-m strip beside one stream required complete removal of merchantable timber (>15 cm diameter at breast height (DBH) for pine and >20 cm for spruce), while all stems <30 cm DBH were retained beside a second stream. A third stream remained unharvested as a control. The two riparian treatments were prescribed to test the efficacy of current British Columbia legislation that allows for varying amounts of riparian retention as best management practices for the management of windthrow. Both treated watersheds were clear-cut harvested (approximately 55% removal) in January 1997, and in the following year, temporary access roads were deactivated, including two stream crossings in the low-retention watershed. An increase in peak snowmelt and total freshet discharge was first noted in the second spring following harvest in both treatments and remained above predicted in all subsequent years. Suspended sediment also increased during freshet following harvest but returned to levels at or below preharvest predictions within 3 years or less in the high-retention watershed.

318) Magnan, P., and I. St-Onge. 2000. Impact of logging and natural fires on fish communities of Canadian Shield lakes. Project Report 2000-36 written by the Sustainable Forest Management Network, University of Alberta, Edmonton. 22pp. (K)

Author abstract: The goal of this study was to determine if natural fires and logging have a significant impact on abundance, growth, and size structure of fish populations in 38 lakes of the Canadian Shield (Québec, Canada). The watersheds of 9 of these lakes underwent logging and 9 underwent natural fires while the 20 remaining lakes were used as references. No significant differences were found among the three lake groups in the catch per unit of effort of the most abundant species: white sucker (*Catostomus commersoni*), northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), lake whitefish (*Coregonus clupeaformis*), fallfish (*Semotilus corporalis*), brook charr (*Salvelinus fontinalis*), walleye (*Stizostedion vitreum*), and burbot (*Lota lota*). No significant difference was found in the back-calculated length of yellow perch and white sucker, for which age determinations were made, among control, burned, and logged lakes.

However, we found that the proportion of small yellow perch and white sucker were significantly lower in populations of impacted lakes (burned and logged lakes pooled). The influence of logging and fires remained significant when a series of biotic and abiotic variables on watershed and lake characteristics were accounted for in multiple regression analyses. The lower proportion of small fish in impacted lakes could be due either to an increase in post-emergence mortality and (or) a shift of individuals to the pelagic zone.

319) Marcogliese, D.J., M. Ball, and M.W. Lankester. 2001. Potential impacts of clearcutting on parasites of minnows in small boreal lakes. Folia Parasitologica. 48: 269-274. (K)

Author abstract: Clearcutting and deforestation lead to increase erosion, increased water temperature, altered water chemistry, and modified watershed hydrology in aquatic systems. Effects on biological organisms have been documented for phytoplankton, zooplankton, benthos, and fish. In this study, parasites of the northern redbelly dace, Phoxinus eos (Cope), were examined from an experimental area consisting of headwater lakes and their watersheds in the boreal forest of Ontario, Canada prior to and after clearcutting around the lakes. Catchments of two lakes were heavily, and one lake partially, clearcut in 1996, and that of a fourth lakes was untouched. In 1993, three years prior to clearcutting, five taxa of parasites, including the monogeneans *Dactylogyrus* sp, and *Gyrodactylus* sp., metacercaria of the digenean *Clinostomum complanatum* (Rudolphi, 1819), and the nematode *Rhabdochona canadensis* Moravec et Arai, 1971 and the myxozoan *Mysobolus* sp, were founding or on northern redbelly dace. In 1998, two years after clearcutting, eight taxa werer found on northern redbelly dace, including all of the above pluse the digeneans *Allocreadium* sp. and *Ornithodiplostomum ptychocheilus* (Faurs, 1917) and the copepod *Ergasilus lizae* Kr?yer, 1863. Mean infracommunity species richness and the maximum number of species per fish were higher in the control and partially cut lakes than in the heavily logged lakes. Uninfected fish were found in the heavily cut lakes, but not in the other lakes. Thus, disturbance may reduce parasite infracommunity complexity. Among individual parasite species, *R. canadensis* was absent from the two most heavily clearcut lakes and abundant in the two other lakes in 1998. Clearcutting may have affected the abundance of certain invertebrates in these lakes, in particular the mayflies that serve as intermediate hosts for *R. canadensis*. The parasites *Allocreadium* sp., *O. ptychocheilus*, and *E. lizae* have not been previously reported in or on northern redbelly dace.

320) McEachern, G. 2003. Where land and waters meet: Understanding and protecting riparian areas in Canada's Forests. J.D. Gysbers and P.Lee, Editors; M. Carver, Contributor. Global Forest Watch Canada, Edmonton, Alberta. 39pp. (C, D, E, F, G, H, ,I, J)

Author abstract (Author Executive Summary): Global Forest Watch Canada has prepared this report in order to provide an overview of the current North American literature on the role and functions of riparian areas in Canada's forests, the impacts of disturbance (both natural and human-caused), and the mitigation of forestry impacts on riparian areas. The report also provides guidance on forest management practices that would improve the protection of riparian areas.

This report represents the most comprehensive review currently available about the state of our knowledge on this topic. It found that:

- Riparian areas can be negatively impacted by forest management activities;
- Improving forest management would substantially advance the protection of riparian areas and help to protect the ecological values they contain.

Riparian areas, those places where water meets land, sometimes dramatically and sometimes with great subtlety, are rich components of our forest systems. As with other transitional zones, riparian areas contain elements of two major ecological systems—in this case, the aquatic and the terrestrial. The combination of these ecological systems results in areas rich in diversity and site-specific character that provide critical ecological functions in Canada's forest ecosystems.

Riparian areas have always been affected by natural disturbances, from the changes wrought by fire or wind to the impact of beavers felling shoreline trees. Increasingly, they are also being affected by industrial activities, particularly logging. Industrial impacts can range from the very direct (e.g., building a road or bridge or logging directly within riparian zones) to the indirect (e.g., cutting in upland forests can change water yield and nutrient export).

This review concludes that further research and literature reviews of the impact of forestry on riparian areas need to be conducted. It also points to the need for greater sensitivity and scrutiny of forestry operations in or near riparian areas, including greater public and industry education about the values of riparian areas, audits of current management practices and increased consideration of the values of riparian areas during logging operations.

We hope this report will be useful both for increasing understanding of riparian areas and for providing specific ideas regarding the management of riparian areas.

321) Mellina, E., R.D. Moore, S.G. Hinch, J.S. Macdonald, and G. Pearson. 2002. Stream temperature responses to clearcut logging in British Columbia: The moderating influences of groundwater and headwater lakes. Canadian Journal of Fisheries and Aquatic Sciences. 59: 1886-1900. (J)

Author abstract: Although the future timber supply in the northern hemisphere is expected to come from boreal and subboreal forests, little research has been conducted in these regions that examines the temperature responses of small, lake-headed streams to streamside timber harvesting. We examined the temperature patterns of two subboreal outlet streams in north-central British Columbia for 1 year before and 3 years after clearcut logging and found only modest changes (averaging 0.05–1.1°C) with respect to summer daily maximum and minimum temperatures, diurnal fluctuations, and stream cooling. A multistream comparative survey conducted in the same geographic region revealed that streams headed by small lakes or swamps tended to cool as they flowed downstream, and headwater streams warmed, regardless of whether or not timber harvesting took place. Stream cooling was attributed to a combination of warm outlet temperatures (promoted by the presence of the lakes) and cold groundwater inflows. A regression model revealed that summertime downstream warming or cooling in headwater and outlet streams could be predicted by upstream maximum summer temperatures and canopy cover. Lentic water bodies and groundwater inflows are important determinants of stream temperature patterns in subboreal forests and may subsequently moderate their responses to streamside harvesting.

322) Michel, B. 1971. Winter regime of rivers and lakes. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Cold Regions Science and Engineering Monograph III-B1a. 139pp. (K)

Author abstract: The monograph summarizes existing knowledge of river and lake ice surveys, heart balance on open water in winter, frazil, ice cover formation, ice breakup and ice control.

323) Millar, R.G. 2001. Riparian logging and channel stability. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 143-150. (A, F)

Author abstract: Recently developed theory is used to derive a simple planform stability diagram. The stability diagram is based on the threshold between meandering and braiding rivers, and includes a friction angle parameter that can be used as a surrogate to quantify the stabilizing influence of riparian vegetation. The planform stability diagram can be used as a relatively simple screening tool to determine the sensitivity of a particular river or stream to riparian logging. The necessary parameters are channel slope (S), bankfull or mean annual discharge (Q), and the median bank grain diameter (D_{50}). Given that direct riparian logging is now forbidden under the Forest Practices Code, the stability diagram is probably most useful in assessing the current channel condition, and in the case of a wide and unstable channel, to assess whether direct riparian logging represents a significant factor in the current channel condition.

324) Moore, K. 1991. Partial cutting and helicopter yarding on environmentally sensitive floodplains in old-growth hemlock/spruce forests. FRDA Report 166. Issued under Canada-BC Forest Resource Development Agreement. A joint publication of Forestry Canada and the British Columbia Ministry of Forests. Co-published by B.C. Ministry of Forests, and Canada/BC Economic & Regional Development Agreement. 43pp. (K)

Author abstract (Author Summary): At Naden Harbour on the Queen Charlotte Islands, B.C., partial cutting and yarding with a Sikorsky S 64-E Sky-Crane helicopter has been used to remove old-growth Sitka spruce, western hemlock, and western red cedar from environmentally sensitive floodplain sites. Between 1986 and 1989, 67 500 m^3 of timber was logged from 141 ha in 14 partially cut blocks.

A retrospective study of the development of these partial cutting operations was conducted. Four case studies are presented to describe the type of floodplain sites on which partial cutting has been used. Various forestry concerns about partial cutting are reviewed, including the silvicultural implications, the damage to residual trees, blowdown following cutting, and the protection of important fish habitats. The procedures used to select appropriate sites, mark individual trees, and conduct falling, yarding, and postlogging clean-up are described.

The partial cutting and helicopter yarding at Naden Harbour has been successful in meeting the objectives of (1) harvesting a previously inaccessible volume of timber and (2) protecting environmentally sensitive fish habitats. The methods and procedures developed here for partial cutting and helicopter yarding may be appropriate on a variety of other sites in coastal British

Columbia where objectives such as protecting wildlife habitats, retaining aesthetic values, or maintaining the stability of steep slopes require or favour partial cutting over conventional clearcutting and cable yarding.

Most of the silvicultural concerns for partial cutting in old-growth coastal forests have been overcome at Naden Harbour. Most blocks are expected to be windfirm and will become fully stocked uneven-aged stands that will support another harvest before the normal rotation period. Procedures for improving the condition of the residual stand are identified in this report. As well, recommendations are made to ensure that the silvicultural objectives for the residual partially cut stand are set before tree marking and cutting begin.

325) Moore, R., T. Gomi, and A. Dhakal. 2003. Headwater stream temperature response to forest harvesting in coastal British Columbia: Influences of riparian buffer width, channel morphology and weather. AGU 2003 Fall Meeting, 8-13 December, San Francisco. Eos Transactions 84(46): Suppl. abstract H32D-03. (A, H, J)

Electronic abstract: Forest harvesting can influence stream temperature regimes, and the potentially deleterious impacts of higher temperatures on salmonids and other species have generated significant debate. One common approach to protecting streams is to leave a riparian buffer to provide shade. However, little information has been collected on the effectiveness of different buffer widths. We report the results of a 6-year field experiment to evaluate the effects of different riparian buffer widths on stream and riparian ecosystems, including stream temperature response, in headwater streams in coastal British Columbia. The experiment included 13 streams, with at least three being assigned to each of four treatments, including no harvesting (80 yr-old second growth conifer riparian forest), clear-cut harvesting with 10 m and 30 m riparian buffers, and clear-cut harvesting with no buffer. Regression analysis was used to calibrate the pre-harvest data for each treatment stream with one of the control streams, to provide a basis for estimating post-harvest treatment effects. Autoregressive and heteroskedastic errors were included in the regression model, because stream temperature exhibited serial correlation and the error variance increased with stream temperature. Temperature response was substantial in the clearcut treatments with no buffers, with maximum temperatures increasing by up to 8 degrees C. The magnitude of temperature response amongst the no-buffer treatments varied with channel morphology, particularly in relation to bank shading and stream depth. The treatment effect for daily maximum water temperature increased with decreasing flow and increasing maximum air temperature on the current day, and also exhibited significant autocorrelation, indicating that the sequence of daily weather conditions can influence the magnitude of temperature response.

326) Morse, B., and F. Hicks. 2003. Advances in river ice hydrology. In: Quadrennial Report to the International Union of Geodesy and Geophysics and International Association of Hydrological Sciences. J.W. Pomeroy, Compiler. Canadian National Committee for the International Association of Hydrological Sciences (CNC-IAHS). Pages 32-41. (A, F, G, I)

Author abstract: We identify three significant recent advances in the hydrology of river ice: (1) by bringing together disparate information, excellent review articles (Shen 2003; Prowse 2001a&b; Beltaos 2000) have noticeably advanced our appreciation of river ice hydrology.

Recently, there have also been two special journal issues on river ice (CJCE 2003 and HP 2002) and five conferences (CRIPE 1999, 2001 and 2003 and IAHR 2000 and 2002); (2) There has been the recognition that in order to advance, collaborate efforts are required (Prowse, 2001b) and Shen (2003) has specifically called for a collaborative research project; and (3) perhaps the greatest advance is the fact that there has been the birth of the discipline of the *hydrology* of river ice: The case has been made that river ice is too important to ignore when studying water quantity (Water Survey of Canada has launched a program to address this issue), water quality (temperature, dissolved oxygen, nutrients and pollutants), sediment transport and geomorphology (particularly as it relates to breakup), stream ecology (plants, food cycle, etc.) and fish habitat, behaviour and survival. There have also been significant advances in modelling (1-D public domain ice jam models are now available; the first public-domain 2-D model capable of simulating flows with an ice cover is now available and a commercial version of a complete 2-D ice-process model is being completed). The main need for further work is to: (1) interface geomorpological and habitat models with these river ice hydrodynamic models; (2) develop a complete package (database management, remote sensing, forecasting, intervention methodologies, etc.) to better intervene in ice jam induce flash floods (e.g. Badger Nfld, February 2003). We would add that, given the importance of winter navigation on the St. Lawrence River to the Canadian economy (approximately $2 billion annually), a durable and dependable solution to prevent ice jams downstream of Montreal is still required.

327) Mossop, B., and M.J. Bradford. 2004. Importance of large woody debris for juvenile chinook salmon habitat in small boreal forest streams in the upper Yukon River basin, Canada. Canadian Journal of Forest Research. 34: 1955-1966. (A, D)

Author abstract: The importance of large woody debris (LWD) in forested stream ecosystems is well documented. However, little is known about LWD in northern boreal forest streams. We investigated the abundance, characteristics, and function of LWD in 13 small tributary streams of the upper Yukon River basin, Yukon Territory, Canada. LWD abundance was similar to values reported from temperate regions, whereas LWD size and total volume were well below values for the Pacific Northwest. LWD formed 28% of the pools, which provide important habitat for juvenile chinook salmon (*Oncorhynchus tshawytscha* Walbaum). The median diameter of pool-forming pieces was 17 cm, and ring counts on fallen riparian trees indicated that pool-forming pieces were likely 70–200 years old when downed. Juvenile chinook salmon density was correlated with LWD abundance in our study reaches. We conclude that despite differences in climate and forest type, LWD in Yukon streams and LWD in temperate regions appear to perform a similar function in creating fish habitat. Resource managers should consider the relatively slow tree growth and thus potentially long recovery times following human disturbances in these watersheds.

328) Negishi, J.N., and J.S. Richardson. 2003. Responses of organic matter and macroinvertebrates to placements of boulder clusters in a small stream of southwestern British Columbia, Canada. Canadian Journal of Fisheries and Aquatic Sciences. 60: 247-258. (C)

Author abstract: Diversity and productivity of stream food webs are related to habitat heterogeneity and efficiency of energy retention. We tested the hypothesis that experimental

boulder placements in a second-order stream would increase diversity and abundance of macroinvertebrates by restoring detrital retention and habitat heterogeneity. Two relatively natural, upstream, reference reaches and a downstream treatment reach with a relatively straight channel and less woody debris were studied for 3 months before and 1.2 years after the placement of six boulder clusters in the treatment reach. Mean velocity and its coefficient of variation increased in the treatment reach (140 and 115%, respectively), whereas the reference reaches remained relatively unchanged after the placements. Enhanced particulate organic matter storage (550%) was accompanied by increased total macroinvertebrate abundance (280%) in the treatment reach, converging with those of the reference reaches almost 1 year after the treatment. Detritivorous taxa numerically dominated the macroinvertebrate community, the total densities of which were best predicted by the fine fraction of organic matter biomass at microhabitat scale. However, the effect of boulder clusters on taxonomic richness was negligible. Our findings suggest that boulder clusters can be used at least as a short-term means to restore macroinvertebrate productivity in detritus-based stream systems.

329) Nicholls, K.H., R.J. Steedman, and E.C. Carney. 2003. Changes in phytoplankton communities following logging in the drainage basins of three boreal forest lakes in northwestern Ontario (Canada), 1991–2000. Canadian Journal of Fisheries and Aquatic Sciences. 60: 43-54. (C)

Author abstract: The phytoplankton communities of three small boreal forest lakes (L26, L39, and L42) on Ontario's Precambrian Shield (Canada) were investigated over 10 years for possible effects of forest harvesting (logging) within their drainage basins (5 years before logging vs. 5 years after logging). During the postlogging period, higher biovolumes of several taxa were recorded, consistent with previously reported changes in nutrients, chlorophyll, light penetration, and mixing depth. Among the most dramatic changes were increases of 100 and 266% in Cyanophyceae in L39 and L42, respectively, 167% in Dinophyceae in L26, 51 and 130% in Chlorophyceae in L26 and L42, respectively, 182% in Bacillariophyceae in L26, and 53 and 73% in total phytoplankton in L26 and L42, respectively. Other effects associated with logging in the watersheds of these lakes included an increase in the numbers of taxa (in accordance with the intermediate disturbance hypothesis) and a decrease in interannual variability in phytoplankton community structure (in accordance with the ecosystem diversity–stability hypothesis). The less extensive logging of the L26 drainage basin and the maintenance of an unlogged shoreline buffer strip did not preclude apparent effects on phytoplankton comparable with some of those found in the other two lakes, where drainage basin logging was more extensive.

330) Outhet, D.N. 1974. Bank erosion in the southern Mackenzie River Delta, Northwest Territories, Canada. M.S. Thesis, University of Alberta, Edmonton. 89pp. (F, G, J)

Author abstract: Analysis of 2-week time lapse photography in the field and from the air, along with other data collected in the field, indicates that in the southern Mackenzie River Delta, the shape of an eroding bank is positively correlated with the erosion process and the rate and character of erosion. Poor correlations between bank erosion and the following factors indicate the complexity of erosion processes: current velocity; channel orientation to the wind; ice content of the bank sediment; vegetation; roots; water temperature; and ice during break-up.

Prediction of bank erosion cannot be made by measuring these factors. There are five different easily-distinguished bank shapes in the study area each with its own maximum and minimum erosion rates and manner of erosion. This information allows the short-term prediction of eroding bank behavior on the basis of bank shapes and the production of a map showing the erosion rate category into which each bank fits. This map may be used in the planning of construction in the area to avoid rapidly eroding banks such as those that may erode up to 30 m/yr.

331) Patoine A., B. Pinel-Alloul, and E.E. Prepas. 2002. Effects of catchment perturbations by logging and wildfires on zooplankton species richness and composition in Boreal Shield lakes. Freshwater Biology. 47: 1996-2014. (C, I)

Electronic abstract (Summary):
1. Forest logging and wildfires are important perturbations of the boreal forest, but their effects on lake biota remain largely unknown. Here, we test whether zooplankton species richness and species assemblages differed among three groups of lakes in Eastern Canada characterised by different catchment conditions: logged in 1995 (*n*=9); burnt in 1995 (*n*=9); unperturbed (*n*=20). Lakes were sampled in June, July and September 1 year after catchment perturbations.
2. Cumulative species richness in reference lakes averaged 46 (33–60) of which 63% were rotifers. Mean cumulative species richness and mean diversity in logged and burnt lakes did not differ from those in reference lakes.
3. Lake species assemblages were described by the density of 62 species (41 rotifers and 21 crustaceans). Among-group differences in species assemblages were not significant. Eighteen per cent of the total variability in species assemblages could be explained by 13 environmental factors, among which dissolved oxygen concentration and cyanobacteria biovolume were the most important. About 5% of species assemblage variability was attributed to covariation between environmental factors and time of sampling, while 4.1% was attributed to temporal variation.
4. Variations in zooplankton species richness and assemblages in Boreal Shield lakes are important, both among lakes and among sampling dates. They seem to depend on environmental factors unrelated to catchment-based perturbations, at least on the short-term of 1 year.

332) Patoine, A., B. Pinel-Alloul, and E.E. Prepas. 2002. Influence of catchment deforestation by logging and natural forest fires on crustacean community size structure in lakes of the eastern Boreal Canadian forest. Journal of Plankton Research. 24: 601-616. (C, E)

Electronic abstract: Logging and wildfires are important perturbation factors of the Canadian Boreal forest, but their effects on aquatic communities remain largely unknown. Here, we assess the ecological effects of logging and wildfires on aquatic communities, based on changes in crustacean zooplankton size spectra among logged, burnt and unperturbed lakes of the Canadian Precambrian Boreal Shield. A laboratory version of the Optical Particle Counter (OPC-1L) was used to establish the crustacean size spectra of zooplankton samples collected in 38 lakes characterized by different catchment conditions: logged in 1995 (nine 'logged' lakes); burnt in 1995 (nine 'burnt' lakes); left unperturbed over the past 70 years (20 reference lakes). Size spectra are characterized by crustacean biovolume in 22 size classes, from 200–300 µm equivalent spherical diameter (ESD) to 2300–2400 µm ESD. Size spectra in logged and burnt

lakes were on average shifted towards larger size classes relative to reference lakes, although the reference and burnt groups of lakes were the only pair statistically different from one another (at $\alpha = 5\%$). As a result, biovolume of crustacean organisms >1100 µm ESD in burnt lakes was on average higher by 366 and 388%, respectively, 1 and 2 years following catchment perturbations relative to reference lakes. Among a set of 15 water quality variables and 14 fish species density variables, potassium concentration and white sucker density were the most important environmental correlates of crustacean size structure.

333) Patoine, A., B. Pinel-Alloul, E.E. Prepas, and R. Carignan. 2000. Do logging and forest fires influence zooplankton biomass in Canadian Boreal Shield lakes? Canadian Journal of Fisheries and Aquatic Sciences. 57: 155-164. (C)

Electronic abstract: Zooplankton biomass was assessed in 20 reference lakes, nine logged-watershed lakes, and nine burned-watershed lakes during three summers following watershed disturbances by logging or wildfires. Biomass of cladocerans, calanoids, cyclopoids, and rotifers was quantified in the 38 lakes for the first year following disturbances. Limnoplankton biomass in four size fractions was quantified during 3 years following disturbances. One year after disturbances, burned-watershed lakes supported 59% more biomass of the rotifer size fraction of limnoplankton (100-200 µm) than reference lakes, while logged-watershed lakes supported 43% less of calanoid biomass. Two years after disturbances, differences in limnoplankton biomass between burned-watershed lakes and reference lakes were more pronounced than during the first year, while logged-watershed lakes supported levels of limnoplankton biomass no different from those of reference lakes. Three years after disturbances, no significant variations could be detected among the three groups of lakes for any of the limnoplankton size fractions. The proportion of watershed area impacted by logging activities was on average less than half the proportion impacted by wildfires. Nonetheless, both types of disturbances seemed to have opposite effects on the zooplankton biomass during the first year, and the effects did not extend beyond 2 years.

334) Pinel-Alloul, B., and A. Patoine. 2000. Comparative impact of natural fires and forest logging on zooplankton communities of boreal lakes. Project Report 2000-23 written by the Sustainable Forest Management Network, University of Alberta, Edmonton. 39pp. (C, E, I)

Author abstract: The goal of the research project was to determine if natural fires and forest logging have a significant impact on zooplankton biomass, biodiversity, species assemblages, and size spectra in lakes of the Canadian Boreal Shield. Wildfires and logging disturbances occurred in 1995. The research project was carried out from 1996 to 1998 in 38 lakes of the boreal forest in Québec: Twenty (20) lakes, undisturbed since 70 years, served as references; nine (9) lakes had 9-72% of their watershed logged and another 9 lakes had 50-100% of their watershed burnt. Three methodological approaches were used to determine zooplankton attributes: a) taxonomic analysis for zooplankton biomass, species richness and assemblages, b) analysis of size-fractionated limnoplankton ash-free dry weight, and c) determination of crustacean biovolume size spectra using an Optical Particle Counter (OPC). Our study reveals that natural fire and logging disturbances have different impacts on zooplankton community of boreal lakes. Natural fires increase zooplankton and limnoplankton biomass because of higher

inputs of mineral nutrients (nitrates and phosphorus) from burnt watersheds. Burnt lakes supported on average 53-64% more biomass of cyclopoids and rotifers (or 59% more biomass of limnoplankton 100-200 µm size fraction) than reference lakes the first 2 years after fire. In contrast, logging does not increase zooplankton biomass because of higher inputs of dissolved organic carbon from watershed which inhibit light transmission and biological production. Cut lakes supported on average 43% fewer biomass of calanoids than reference lakes during the first year after logging. The biomass of cladocerans and copepodite stages did not vary significantly among reference, cut and burnt lakes. The impacts of natural fire and logging on zooplankton biomass were more pronounced 2 years after disturbances. Impacts of wildfire and logging on zooplankton biodiversity and species assemblages, measured the first year following disturbances, are minor. Crustacean biovolumes in large size classes (1200-1500 µm) were higher in perturbed lakes, especially in burnt lakes. Zooplankton biomass and size spectra, as well as limnoplankton biomass are promising tools to monitor the effects of watershed disturbances by natural fire and logging on zooplankton communities in boreal lakes. However among-lake and seasonal changes in watershed and limnological characteristics are more important sources of variability in zooplankton biomass than watershed disturbances, and should be considered when assessing the environmental impacts of watershed disturbances on zooplankton in boreal lakes.

335) Price, K., and D. McLennan. 2002. North Coast LRMP background report: Hydroriparian ecosystems of the North Coast. Written for the North Coast LRMP, British Columbia. 80pp. (C, D, F, H, I, J)

Author abstract (Author Summary—First paragraph): This report provides background information on riparian ecosystems for the North Coast LRMP [North Coast Land and Resource Management Plan]. The report

- describes North Coast riparian ecosystems,
- reviews riparian ecological functions,
- presents riparian management policies for BC and neighbouring jurisdictions,
- lists potential strategic planning issues for consideration.

Literature is taken from the North Coast where possible. Where research is cited from areas outside the North Coast, the report describes the potential relevance of studies to North Coast ecosystems.

336) Price, K., A. Suski, J. McGarvie, B. Beasley, and J.S. Richardson. 2003. Communities of aquatic insects of old-growth and clearcut coastal headwater streams of varying flow persistence. Canadian Journal of Forest Research. 33: 1416-1432. (C, G)

Author abstract: Headwater streams, varying in flow persistence from ephemeral to intermittent to perennial, provide the tightest coupling between water and land, yet they often receive the least protection during forest management. We described communities of aquatic insects in perennial, intermittent, and ephemeral channels surrounded by old-growth forest and 4- to 8-year-old clearcuts in Clayoquot Sound, British Columbia, to determine whether temporary streams have unique aquatic communities and to examine the short-term impacts of harvesting. We measured flow persistence, stream size, canopy cover, organic detritus, and algal biomass in 19 streams. We sampled aquatic invertebrates with a combination of emergence cages and

kicknet samples. Temporary and old-growth streams had more organic detritus and a higher abundance of shredders. Perennial and clearcut streams had a higher abundance of some algal grazers, but not higher algal biomass. Insect richness was similar in intermittent and perennial streams of each seral stage but lower in ephemeral streams. Intermittent streams contained four taxa not found in the other stream classes; perennial and ephemeral streams had none. Communities of aquatic insects differed between streams surrounded by clearcuts and old growth, and varied with continuity of flow.

337) Rice, S., and M. Church. 1996. Bed material texture in low order streams on the Queen Charlotte Islands, British Columbia. Earth Surface Processes and Landforms. 21: 1-18. (D, I)

Author abstract: Low order channels comprise a large proportion of the links of every drainage basin, and are often at the centre of land management concerns. They exhibit hydrological and geomorphological characteristics atypical of higher order links. This paper examines the nature and causes of variations in the bed material texture of two streams on the Queen Charlotte Islands, British Columbia. The extant, functional exponential model is found to be inadequate for explaining observed changes in grain size parameters with distance downstream. Recurrent disruption of sediment transport by large organic debris jams, and the sporadic contamination of the fluvial sediment population by colluvial inputs, preclude the development of longitudinal structure. Rather, grain size varies erratically over short distances. A stochastic model best describes the observed variations, and should be adopted as an alternative to the exponential model in low order links. Characteristic variances are controlled by the degree of hillslope-channel coupling, and the extent and characteristics of non-alluvial storage mechanisms.

338) Rice, S.P., M.T. Greenwood, and C.B. Joyce. 2001. Tributaries, sediment sources, and the longitudinal organisation of macroinvertebrate fauna along river systems. Canadian Journal of Fisheries and Aquatic Sciences. 58: 824-840. (C, I)

Author abstract: Tributary confluences are sites along a main channel where, because of the introduction of water and (or) sediment, the water volume, bed sediment character, and water quality of the mainstream can change abruptly. These shifts ensure that abiotic gradients seldom vary smoothly or continuously for distances of more than 10^0–10^2 km along any river system. The ways in which tributaries and related sediment recruitment points structure longitudinal changes in physical habitat are examined. Variables of importance to stream biota are affected and, in turn, it is suggested that the arrangement of tributaries and related features is an important control on the longitudinal organisation of macroinvertebrate benthos at moderate spatial scales. A new model is presented that stresses the importance of hydrological and sedimentological networks for organising lotic fauna. The link discontinuity concept emphasises the discontinuous nature of lotic ecosystem gradients, addresses the importance of tributaries in unregulated as well as regulated rivers, and extends, to its logical conclusion, the limited recognition of tributary influence in the river continuum concept. A case study from British Columbia, Canada, illustrates the general merit of the new model.

339) Richardson, J.S. 2000. Life beyond salmon streams: Communities of headwaters and their role in drainage networks. In: Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk, 15-19 February 1999, Kamloops, British Columbia, Volume Two. L.M. Darling, Editor. B.C. Ministry of Environment, Lands, and Parks, Victoria, B.C. and University College of the Cariboo, Kamloops, B.C. Pages 473-476. (C)

Author abstract: The headwaters of our watersheds are important for a number of intrinsic reasons, as well as for their impact on maintenance of downstream environments. The emphasis of research and management in stream ecosystems has typically been on salmonid fish, to the neglect of other stream and riparian organisms. Headwaters are sources of a large proportion of the energy used to fuel river food webs via organic matter that enters headwaters in the form of leaf litter from riparian vegetation. Headwaters themselves harbour a number of poorly known species, some of which occur nowhere else. There are many species associated with these environments, especially invertebrates, for which we lack even the most basic of information. Finally, the cumulative effects of small, incremental alterations to headwater channels may have impacts on downstream environments, but we have yet to design studies that adequately address this issue.

340) Rosenfeld, J., M. Porter, and E. Parkinson. 2000. Habitat factors affecting the abundance and distribution of juvenile cutthroat trout (*Oncorhynchus clarki*) and coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences. 57: 766-774. (A, D)

Author abstract: The distribution, abundance, and habitat associations of juvenile anadromous coastal cutthroat trout (*Oncorhynchus clarki*) and coho salmon (*Oncorhynchus kisutch*) were evaluated using survey data from 119 sites in coastal British Columbia. Both cutthroat and coho occurred at their highest densities in very small streams (<5 m channel width), and bankfull channel width was the single best predictor of cutthroat presence (p=0.0001) and density (R^2 =0.55). Within a channel, densities of coho and larger (yearling and older) cutthroat parr were highest in pools, while densities of young-of-the-year cutthroat were significantly lower in pools and highest in shallower habitats. Abundance of larger cutthroat parr and pool habitat were positively correlated with large woody debris (LWD) within a subset of intermediate-gradient gravel-cobble streams, where pools appear to be limiting to larger cutthroat parr abundance. More than 50% of pools were formed by scour associated with LWD in streams ranging from 1.2 to 11 m channel width, and pools formed by LWD scour were on average 10% deeper than pools formed by other mechanisms. Disproportionate use of small streams by cutthroat indicates that protection of small stream habitat is important for long-term conservation of sea-run populations.

341) Scherer, R. 2001. Effects of changes in forest cover on streamflow: A literature review. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 44-55. (G)

Author abstract: The Interior Watershed Assessment Procedure that is used in British Columbia relies heavily on the use of Equivalent Clearcut Area as a tool to estimate potential hydrologic impacts on forest development on peak flows. The purpose of this literature review was to summarize the results of numerous watershed experiments that have explored the relationship of changes in forest cover to changes in spring freshet peak flows, the timing of peak flows, water yield, and low flows. This review included only snowmelt-dominated watersheds that are situated within western Canada and the United States and that could be related to watersheds located within the central and southern interior of British Columbia. The review indicated highly variable changes in: peak flow (ranging from no change to 66% increase), peak-flow timing (ranging from no change to 18 days advancement), water yield (ranging from no change to 111% increase), and low flow (ranging from no change to 37% increase). Also, there was no consistent relationship between forest-cover removal and the above hydrologic variables.

342) Smith, D.G. 1976. Effect of vegetation on lateral migration of anastomosed channels of glaciers meltwater river. Geological Society of America Bulletin. 87: 857-860. (F)

Author abstract: A series of experiments were performed on bank materials of anastomosed channels in flood-plain silt deposits in the Alexandra Valley in Banff Park, Alberta, to determine the effect of vegetation roots on bank erodibility and lateral migration of channels. Underground roots from the dense growth of meadow grass and scrub willow provide the reinforcement of bank sediment and a riprap-like protection of channel banks from river erosion. Results from the experiments suggest that in cool environments with aggrading river conditions where overbank deposition of silt, clay, and fine sand dominate then valley fill, vegetation roots are able to rapidly accumulate and decay very slowly, thus affording protection to banks from erosion deeper party of the channels.

Experiments were performed with a specially designed erosion box, used as a means to stimulate natural erosion conditions and measure the influence of vegetation roots in reducing bank erosion. Results indicate that the bank sediments with 16 to 18 percent by volume of roots with a 5 –cm root-mat for bank protection, typical of the area, had 20,000 times more resistance to erosion than comparable bank sediment without vegetation. Assuming five severe erosion days per year, potential lateral channel migration would amount to 4.2 cm per year. Such resistance, due to vegetation, accounts for the remarkable stability of channels during the last 2,500 yr in the Alexandra Valley.

343) Steedman, R.J. 2000. Effects of experimental clearcut logging on water quality in three small boreal forest lake trout (*Salvelinus namaycush*) lakes. Canadian Journal of Fisheries and Aquatic Sciences. 57(S2): 92-96. (C, I)

Electronic abstract: Water quality was monitored in three 30-ha stratified headwater Precambrian Shield lakes for 5 years before and 3 years after moderate to extensive catchment deforestation. These lakes, which had water renewal times of about a decade, showed only minor changes in water quality by the third year after logging. Water quality response in a lake with moderate deforestation and intact shoreline forest was similar to that in two lakes with extensive upland and shoreline deforestation. By the second and third years after logging, May-September average volume-weighted concentrations of dissolved organic carbon, chlorophyll, total nitrogen, K^+, Cl^-, and Si had all increased, generally by about 10-40% over predisturbance levels, while

Ca^{2+} and Mg^{2+} had declined by 10-25%. Dry weather the first year after logging was associated with temporary declines of 10-20% in dissolved organic carbon and chlorophyll.

344) Steedman, R.J., and R.S. Kushneriuk. 2000. Effects of experimental clearcut logging on thermal stratification, dissolved oxygen, and lake trout (*Salvelinus namaycush*) habitat volume in three small boreal forest lakes. Canadian Journal of Fisheries and Aquatic Sciences. 57: 82-91. (I, J)

Author abstract: Clearcut logging around three 30- to 40-ha dimictic northwestern Ontario lakes was associated with increases of 5% or less in midlake wind speed and no measurable changes in spring and fall circulation efficiency or duration of stratification. Water clarity, indexed as the depth at which photosynthetically active radiation was 1% of surface intensity, declined by 25% after 3 years. Late-summer thermoclines were about 1 m shallower in two lakes after logging, but it was not possible to exclude weather as a factor. None of the lakes showed significant declines in lake trout (*Salvelinus namaycush*) habitat volume. A forested shoreline buffer strip around one of the lakes prevented increases in midlake wind speed but did not prevent declines in water clarity and thermocline depth.

345) Steedman, R.J., R.S. Kushneriuk, and R.L. France. 2001. Littoral water temperature response to experimental shoreline logging around small boreal forest lakes. Canadian Journal of Fisheries and Aquatic Sciences. 58: 1638-1647. (J)

Author abstract: Shoreline logging did not significantly increase average littoral water temperatures in two small boreal forest lakes in northwestern Ontario, Canada. However, over the early summer monitoring period clearcut shorelines were associated with increases of 1–2°C in maximum littoral water temperature, and increases of 0.3–0.6°C in average diurnal temperature range, compared with undisturbed shorelines or shorelines with 30-m shoreline buffer strips. Comparison of simultaneous water temperatures at littoral locations with and without shoreline forest showed that increased temperatures were caused by daytime heating.

346) St-Onge, I., and P. Magnan. 2000. Impact of logging and natural fires on fish communities of Laurentian Shield lakes. Canadian Journal of Fisheries and Aquatic Sciences. 57(S2): 165-174. (K)

Electronic abstract: The goal of this study was to determine if natural fires and logging have a significant impact on abundance, growth, and size structure of fish populations in 38 lakes of the Laurentian Shield (Québec, Canada). The watersheds of nine of these lakes underwent logging and nine underwent natural fires, while the 20 remaining lakes were used as references. No significant differences were found among the three lake groups in the catch per unit of effort of the most abundant species: white sucker (*Catostomus commersoni*), northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), lake whitefish (*Coregonus clupeaformis*), fallfish (*Semotilus corporalis*), brook trout (*Salvelinus fontinalis*), walleye (*Stizostedion vitreum*), and burbot (*Lota lota*). No significant difference was found among control, burned, and logged lakes in the back-calculated length of yellow perch, for which age determinations were made. However, we found that the proportions of small yellow perch and white sucker were significantly lower in populations of impacted lakes (burned and logged lakes pooled). The influence of logging and fires remained significant when a series of biotic and abiotic variables on watershed and lake characteristics were accounted for in multiple regression analyses. The lower proportion of small fish in impacted lakes could be due to an increase in postemergence mortality or to a shift of individuals to the pelagic zone.

347) Story, A., R.D. Moore, and J.S. Macdonald. 2003. Stream temperatures in two shaded reaches below cutblocks and logging roads: Downstream cooling linked to subsurface hydrology. Canadian Journal of Forest Research. 33: 1383-1396. (J)

Author abstract: This study examined water temperature patterns and their physical controls for two small, clearing-heated streams in shaded reaches downstream of all forestry activity. Field observations were made during July–August 2000 in the central interior of British Columbia, Canada. For both reaches, downstream cooling of up to 4°C had been observed during daytime over distances of ~200 m. Radiative and convective exchanges of energy at heavily shaded sites on both reaches represented a net input of heat during most afternoons and therefore could not explain the observed cooling. In one stream, the greatest downstream cooling occurred when streamflow at the upstream site dropped below about 5 $L{\cdot}s^{-1}$. At those times, temperatures at the downstream site were controlled mainly by local inflow of groundwater, because the warmer water from upstream was lost by infiltration in the upper 150 m of the reach. Warming often occurred in the upper subreach, where cool groundwater did not interact with the channel. At the second stream, creek temperature patterns were comparatively stable. Energy balance estimates from one afternoon suggested that groundwater inflow caused about 40% of the ~3°C gross cooling effect in the daily maximum temperature, whereas bed heat conduction and hyporheic exchange caused about 60%.

348) Tonn, W.M., P.W. Langlois, E.E. Prepas, A.J. Danylchuk, and S.M. Boss. 2004. Winterkill cascade: Indirect effects of a natural disturbance on littoral macroinvertebrates in boreal lakes. Journal of the North American Benthological Society. 23: 237-250. (C)

Author abstract: Natural disturbances can provide insights into mechanisms organizing communities by perturbing systems at larger scales and more realistic intensities than can often be achieved otherwise. We took advantage of 2 winterkills of fish, a common disturbance of small lakes on the Boreal Plains of northern Alberta (Canada), to assess the effects of sudden, large reductions in fish densities on littoral macroinvertebrate assemblages. Winterkill nearly eliminated the native fish assemblages (dominated by northern pike, *Esox lucius*, and yellow perch, *Perca flavescens*) in the 2 lakes, whereas 2 nearby lakes with similar fish assemblages were unaffected and served as references. Environmental characteristics of both winterkill and reference lakes changed little from year to year. Uni- and multivariate analyses of macroinvertebrates revealed some inherent among-lake differences; however, strong and parallel changes in the invertebrate assemblages occurred only in the 2 winterkill lakes, congruent with the winterkills of fish. Decreases in fish biomass were generally accompanied by increases in macroinvertebrate density, particularly among taxa (e.g., amphipods, leeches, chironomids) commonly eaten by the native fish. As a result, analyses of matrix concordance and variance partitioning showed variation in macroinvertebrate assemblages was related to both temporal changes in fish density and environmental differences among lakes but that the fish and

environmental matrices were not strongly concordant. Our serendipitous study of community-level disturbance revealed that winterkill-induced reductions of fish densities can have strong, cascading effects on littoral macroinvertebrates in these boreal lakes.

349) Tonn, W.M., C.A. Paszkowski, G.J. Scrimgeour, P.K.M. Aku, M. Lange, E.E. Prepas, and K. Westcott. 2003. Effects of forest harvesting and fire on fish assemblages in boreal plains lakes: A reference condition approach. Transactions of the American Fisheries Society. 132: 514-523. (K)

Author abstract: To assess the impacts of forest harvesting and fires on lentic fish assemblages in the Boreal Plains ecoregion (Alberta, Canada), we applied a reference condition approach to 37 lakes in burned, logged, or undisturbed catchments. Fish assemblages in the reference lakes were classified into two types: those dominated by large-bodied piscivores and those dominated by small-bodied fishes. A discriminant function analysis with only two environmental descriptors (lake maximum depth and average slope of the catchment) could correctly predict assemblage type in 84% of reference lakes. Depth likely reflects the influence that winter oxygen concentrations have on fish assemblage type, whereas catchment slope is correlated with a variety of landscape-level features. Although potential effects of forest harvesting and fire can increase the susceptibility of lakes to winter hypoxia (via nutrient enrichment) and alter connectivity to the regional drainage network (via altered hydrology), fish assemblages in 93% of the disturbed lakes did not deviate from the discriminant function predictions, suggesting little, if any, assemblage-level effects of the disturbances over the 1–2-year time period of our study. Indeed, the level of disturbance in a catchment could explain less than 3% of the variation in assemblage structure, although a slight increase in the catches of white sucker *Catostomus commersoni* and a greater proportion of small individuals in white sucker populations may have reflected a modest enrichment effect in burned lakes. Current levels of landscape disturbance on the Boreal Plains appear to have minimal effects on lake fish assemblages but, because of the susceptibility of these lakes to winterkill, higher levels of terrestrial disturbance could prove detrimental.

350) Tripp, D.B., and V.A. Poulin. 1992. The effects of logging and mass wasting on juvenile salmonid populations in streams on the Queen Charlotte Islands. Land Management Report Number 80 written by Tripp Biological Consultants, Ltd., Nanaimo, British Columbia, and V.A. Poulin & Associates, Ltd., Vancouver, British Columbia. Written for the Fish/Forestry Interaction Program, Research Branch, B.C. Ministry of Forests, Victoria. 38pp. (A, B, D, F)

Author abstract (Author Summary): The effects of logging and mass wasting on juvenile coho salmon (*Oncorhynchus kisutch*), steelhead trout (*O. mykiss*, formerly *Salmo gairdneri*), and Dolly Varden char (*Salvelinus malma*) were assessed in streams on the Queen Charlotte Islands. Fish densities and habitat characteristics of 27-33 stream reaches were measured during summer and fall. Reaches sampled included undisturbed old-growth forest streams (unlogged), logged streams not directly affected by recent mass wasting (logged), and logged streams directly affected by recent debris torrents and slides (mass wasted). Overwinter survivals and smolt yields in three mass wasted and three non-mass wasted streams (all logged) were also estimated

in a downstream spring fish trapping program, after determining the number of fish present in each stream theprevious fall.

Logged reaches had less undercut bank cover than unlogged reaches, but did not differ significantly from unlogged areas in any other habitat variable measured. Mass wasted stream reaches, in contrast, had even less undercut bank cover, less large organic debris (LOD), fewer pools and glides, and more riffles. They also had shallower pools during summer, a smaller wetted stream width relative to rooted channel width, and less overwinter cover in the form of deep pools with undercut banks and abundant LOD.

With one exception, there was no relationship between summer and fall fish densities and any of the habitat parameters measured in this study. The exception was the depth of gravel scour overwinter, which appeared to determine the early summer abundance of coho fry in mass and non-mass wasted streams (all logged). Logged reaches had significantly higher coho fry densities than unlogged or mass wasted reaches in summer and fall. Fish in mass wasted reaches exhibited faster growth rates and attained larger sizes, as long as fry were not trapped in isolated pools when reaches ‘‘dewatered’’. In mass wasted streams, a combination of poor egg-to-fry survivals due to excess gravel scour, and poor juvenile overwinter survivals due to overwinter habitat loss, nullified any gains in production attributable to logging. It also nullified the high growth rates and large size achieved by fish in their first year in mass wasted streams. Juvenile overwinter survivals for all species were 2.1-3.5 times higher in non-mass wasted streams than in mass wasted streams; smolt yields were 1.5-3.3 times higher.

The overall impacts of mass wasting on juvenile fish, and coho salmon in particular, are serious enough to jeopardize the continued existence of self-sustaining populations in directly affected reaches until stream conditions improve. Four out of 11 mass wasted reaches in 1982 and 2 out of 3 mass wasted reaches in 1984 had effectively no coho fry. Impacts on Dolly Varden and steelhead trout did not appear as serious, though they too showed declines in overwinter survivals and smolt yields. Impacts on other species such as chum and pink salmon were not investigated, though presumably these species would be negatively stressed by increased gravel scour. Fish populations in otherwise normal (logged) reaches downstream of major mass wasting events may also be adversely affected by mass wasting upstream, but the problem requires further study.

351) Verschuren, J.P., and M. Bristol. 1974. Runoff from small watersheds and river bank erosion near Watson Lake, Y.T. Indian and Northern Affairs Publication No. QS-1585-OOO-EE-A1 written by the Department of Civil Engineering, University of Alberta. Written for the Arctic Land Use Research Program, Northern Natural Resources and Environment Branch, Department of Indian and Northern Affairs. 35pp. plus Appendices. (G, F)

Author abstract: This report describes the current research being conducted by the Department of Civil Engineering of the University of Alberta as part of the Arctic Land-Use Research Program. The objective of the program has been to conduct research into environmental problems resulting from land-use operations associated with resource development. This study has been conducted in the south-east Yukon, an area of the boreal forest within the region of discontinuous permafrost.

Hydrographs are presented for the entire period of record for eight study watersheds in the Watson Lake area, together with daily rainfall and mean daily temperatures. The hydrographs are

analysed and compared with those of two study watersheds situated in the foothills area of Alberta.

A comparison is made between the study watersheds and those of southern mountain areas by means of basin response factors calculated as the ratio of total 'quick' runoff to total precipitation measured over a monthly time period. The response factors are used to indicate which of the Watson Lake watersheds will be most susceptible to land-use changes.

Results of the 1973 erosion study at two sites on the Liard River are presented together with a preliminary interpretation of the data acquired to date, including an explanation of the erosion mechanism for deep rivers and the role played by bank vegetation. An erosion index has been formulated based on channel and flood plain characteristics to give an objective, quantitative measure of bank erosion potential.

An approach to further gauging of small streams in the North and to river bank erosion studies in general, is suggested.

352) Whitaker, A., Y. Alila, and D.A.A. Toews. 2001. Modelling of peak flow change using the DHSVM model. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 94-111. (G)

Author abstract: The Distributed Hydrology Soil Vegetation Model (DHSVM) is a physically based model that uses a Digital Elevation Model (DEM) to stimulate the effect of topography on hydrologic processes. The influence of the forest canopy on the accumulation and melt of snowpack is simulated in an explicit and physically based approach. Model calibration was possible through the use of snow course surveys and snowline air-photo surveys in addition to stream discharge at Redfish Creek experimental watershed near Nelson, B.C., where extensive hourly data is available. The model appears to correctly simulate the influence of forest canopy on the snowpack, and simulated and observed hydrographs are well matched in both calibration and verification periods. Subsequently, 10 harvest scenarios, with varying levels of cutting in different elevation zones, were evaluated over the 5-year period of record (1992-1997). Redfish Creek basin (26km^2) is divided into four elevation zones based on the hypsometric curve. The three lower zones (770-1880 m) contain operable forest and make up 60% of the total basin area, while the high-elevation alpine zone (1880 - 2300 m) forms 40% of basin area. Results show that harvesting at progressively higher elevations (especially upper forest zone and alpine) causes progressively larger increases in peak flows. There is significant variability from year to year, indicating that the magnitude of peak-flow change depends on the unique weather conditions and seasonal melt pattern in a given year. Cutting in the lowest zone (H80-H100) has little or no effect on peak flow. In the middle forest zone (H60-H80), low-intensity cutting (7% of basin) has little effect, but consistent increases in peak flows are seen with high-intensity cutting (13% of basin). In the upper zone (above H60), low-intensity cutting increased peaks by 6.7-9.5%, while high-intensity cutting produced increases of 13.1-19.4%. A scenario with low-intensity cutting in all forest zones showed a significantly reduced impact on peak flows (except in 1997) even though a greater percentage of basin area (20%) was harvested. Peak-flow change is closely related to harvest elevation(s) and also to seasonal weather patterns in snow-dominated watersheds such as Redfish Creek.

353) Whitfield, P.H., and W.G. Whitley. 1986. Water quality-discharge relationships in the Yukon River basin, Canada. In: Proceedings of the Cold Regions Hydrology Symposium, University of Alaska, Fairbanks. D.L. Kane, Editor. American Water Resources Association Technical Publication Series TPS-86-1. American Water Resources Association, Bethesda, Maryland. Pages 149-156. (G, I)

Author abstract: Weekly and biweekly water quality samples were collected at ten sites throughout the Canadian portion of the Yukon River basin during 1982-1983. The relationships between the water quality variables and discharge are examined. Most of the relationships between the variables and discharge are either positive or negative and exhibit hysteresis, a few variables appear to be independent of discharge. A system of classification of the relationships, with potential causal mechanisms, is proposed.

354) Wilford, D.J. 1984. The sediment-storage function of large organic debris at the base of unstable slopes. 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 115-119. (I)

Author abstract: Large organic debris in old-growth forests provides important sediment-storage elements on hill slopes. As the old-growth trees fall or blow down across the slope, they form a series of cross-slope obstructions. Sediments and small organic debris from upslope mass movements are deposited behind these obstructions, forming a series of terraces which temporarily delay the delivery of sediments to stream channels. Documentation of this storage role of large organic debris is provided from an old-growth Sitka spruce-western hemlock forest site in the Queen Charlotte Islands of British Columbia.

355) Winkler, R.D. 2001. Forest influences on snow: Preliminary results on effects of regrowth. In: Watershed Assessment in the Southern Interior of British Columbia. Workshop proceedings, 9-10 March 2000, Penticton, British Columbia, Canada. D.A.A. Toews and S. Chatwin, Editors. British Columbia Ministry of Forests, Research Program, Victoria, Working Paper 57. Pages 56-67. (K)

Author abstract: In British Columbia, snow accumulation and snow melt dominate the hydrology of most interior watersheds. Both the amount of snow accumulation and the rate of melt vary with forest cover, and its removal and regrowth. For regulatory purposes, the complex relationships between forest cover, snowpack processes, and the risk of elevated spring flows are currently approximated by the single forest inventory variable, tree height. Field data from Mayson Lake and Upper Penticton Creek indicate that tree height alone explains little of the variability in snow accumulation or melt measured under various forest cover types relative to the open. Of the inventory variables measured, crown volume, length, and density explained the largest proportion of the variability in snow accumulation in the forest relative to the open, and the square root of basal area was the best predictor of melt. Work to develop a method of evaluating hydrologic recovery over a broader geographic area and range of forest cover types continues.

356) Woo, M.K., and P. Marsh. 2003. Snow, frozen soils and permafrost hydrology in Canada, 1999 – 2002. In: Quadrennial Report to the International Union of Geodesy and Geophysics and International Association of Hydrological Sciences. J.W. Pomeroy, Compiler. Canadian National Committee for the International Association of Hydrological Sciences (CNC-IAHS). Pages 27-31. (G)

Author abstract: This paper provides an overview of Canadian research on snow, frozen soils and permafrost hydrology for the period 1999-2002; the period between the 1999 IUGG meeting in Birmingham and the 2003 IUGG in Sapporo. During this period there were significant advances in both our understanding of the physical processes, and our ability to model these processes. This report assesses these advances.

357) Young, K.A., S.G. Hinch, and T.G. Northcote. 1999. Status of resident coastal cutthroat trout and their habitat twenty-five years after riparian logging. North American Journal of Fisheries Management. 19: 901-911. (A, D, J)

Author abstract: In 1973 two sections of a small headwater stream containing allopatric nonanadromous coastal cutthroat trout *Oncorhynchus clarki* were subjected to two types of streamside logging: (1) clear-cut to the streambank with all existing wood and logging debris left in the channel and on adjacent hill slopes (section B; 4.2% gradient), and (2) clear-cut to the streambank with all logging debris and existing instream wood removed from the channel and adjacent hill slopes (section A; 0.8% gradient; termed *scarified*). A third upstream reference section was undisturbed (section C; 4.8% gradient). The hill slopes of both treatment sections were burned in 1974. Instream habitat (large woody debris and pool percentage), water temperature, and fish populations were assessed intermittently during the following 25 years. Instream habitat, water temperature, and trout density in section B were in all years similar to the upstream reference section, C. In section A, summer maximum stream temperatures reach 30° C immediately after logging but had moderated by 1975 and were similar to the reference section by 1983; the proportion of wetted area that was in pools was 14% in 1975, 33% in 1985, and 49% in 1997; trout density was low (0.05 fish/m^2) after logging but had returned to the reference level (0.21 fish/m^2) by 1983 and was double (0.49 fish/m^2) the reference level in 1997. The recent increase in fish density in section A may have been influenced by instream habitat enhancement and riparian thinning conducted in 1985. Trout density in section A is presently similar to that found in a nearby low-gradient stream with an undisturbed riparian zone. Our results suggest that large pieces of wood that are left in an over small streams after logging although a contravention of current logging regulations in British Columbia, may help protect resident trout populations following riparian logging.

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^o F were predicted to within 1^o 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-1 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 bank-full 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 1^{st} through 4^{th} 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.

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543) Abernethy, B., and I.D. Rutherfurd. 1998. Where along a river's length will vegetation most effectively stabilize stream banks? Geomorphology. 23: 55-75. (F)

Author abstract: Riparian vegetation has different impacts on stream processes depending upon its position in a catchment. Native riparian vegetation is increasingly becoming the favoured stream management tool but managers need to locate revegetation schemes where they will most effectively achieve ecological, geomorphological, or other, project goals. Using the Latrobe River in SE Australia as an example, this paper illustrates a structured decision-making approach for assessing the role of vegetation in stream bank erosion at different points throughout a catchment. Three bank-erosions process groups are identified: subaerial preparation, fluvial entrainment, and mass failure. Although these processes act on banks throughout the catchment there exists spatial zoning in the dominance of each process group over the others. Bank erosion in upper reaches is dominated by subaerial preparation, in mid-basin reaches by fluvial entrainment, and in the lower reaches by mass failure. We find that in upper reaches, windthrown trees are responsible for most bank sediment transfer to the flow. Where direct fluvial entrainment of bank material is the dominant erosion process, flow resistance due to vegetation becomes crucial. In reaches where bank slumping is the dominant erosion process, increased bank shear strength due to root reinforcement is the major role of vegetation is stabilizing banks. Other effects, such as tree surcharge, and altered bank hydrology appear to exert only minor influences on the slumping process. Considering the above variable we are able to define a critical zone in which revegetation will be most effective in reducing bank erosion. On the Latrobe River, this zone occurs in that portion of the river where it first leaves the mountain front and meanders across a broad floodplain. This research occupies the second quarter of the river's length. This information, combined with other scale analyses (e.g. ecological, hydrological), will assist river manager to plan physically based riparian revegetation strategies.

544) Abernethy, B., and I.D. Rutherfurd. 2000. Does the weight of riparian trees destabilize riverbanks? Regulated Rivers: Research & Management. 16: 565-576. (F)

Author abstract: In contrast to the generally accepted stabilizing effects of riparian vegetation, the surcharge of trees on riverbanks has been widely implicated as a source of bank instability. Fieldwork conducted along the Latrobe River in Victoria, Australia shows that the bank-destabilizing effects of surcharge, due to silver wattle (Acacia dealbata), are minimal. Field observations indicate that it is unlikely that the weight of silver wattles growing on an otherwise stable bank section will directly cause mass failure. Observations of deep-seated failures and silver wattle stands on the Latrobe River indicate that where average-sized slump-blocks support an average number of average-sized silver wattles, the trees represent only 4.1% of the total saturated slump mass. Infinite slope stability analysis indicates a threshold of around 48° where banks become prone to shallow-planar slide failures as they steepen. Where bank sections are inherently unstable and prone to shallow-planar slide failure, the additional weight of the trees may contribute to overall instability. However, manipulation of other stability parameters within reasonable constraints negates the effect of surcharge so it is not possible to demonstrate conclusively a destabilizing influence of silver wattles.

545) Abernethy, B., and I.D. Rutherfurd. 2000. The effect of riparian tree roots on the mass-stability of riverbanks. Earth Surface Processes and Landforms. 25: 921-937. (F)

Author abstract: Plants interact with and modify the processes of riverbank erosion by altering bank hydrology, flow hydraulics and bank geotechnical properties. The physically based slope stability model GWEDGEM was used to assess how changes in bank geotechnical properties due to the roots of native Australian riparian trees affected the stability of bank sections surveyed along the Latrobe River. Modelling bank stability against mass failure with and without the reinforcing effects of River Red Gum (*Eucalyptus camaldulensis*) or Swamp Paperbark (*Melaleuca ericifolia*) indicates that root reinforcement of the bank substrate provides high levels of bank protection. The model indicates that the addition of root reinforcement to an otherwise unstable bank section can raise the factor of safety (F_s) from F_s = 1·0 up to about F_s = 1·6. The addition of roots to riverbanks improves stability even under worst-case hydrological conditions and is apparent over a range of bank geometries, varying with tree position. Trees growing close to potential failure plane locations, either low on the bank or on the floodplain, realize the greatest bank reinforcement.

546) Anderson, D.M., and L.H. Macdonald. 1998. Modelling road surface sediment production using a vector geographic information system. Earth Surface Processes and Landforms. 23: 95-107. (K)

Author abstract: Field investigations indicate that unpaved roads are the largest sediment source on St John, US Virgin Islands. Cross-sectional measurements of eroded road surfaces were used to establish an empirical relationship to predict annual road surface erosion as a function of road gradient and contributing drainage area. A model (ROADMOD) for estimating and mapping average annual sediment production from a road network was developed by combining this empirical relationship with a series of network algorithms to analyse road data stored in a vector geographic information system.

ROADMOD was used to estimate road surface erosion in two St John catchments with very different road densities but similar land cover, topography and soils. Unpaved roads were found to increase sediment production in the more densely roaded catchment by a factor of three to eight, and in the less-roaded catchment by a factor of 1·3-2·0. Turbidity measurements in the receiving bays of these two catchments are consistent with model predictions and observed sediment delivery processes.

Although this model was developed specifically for St John, it can easily be adapted to other locations by substituting a locally derived predictive equation for road erosion. Model assumptions, limitations and potential improvements are discussed.

547) Arscott, D.B., K. Tockner, and J.V. Ward. 2001. Thermal heterogeneity along a braided floodplain river (Tagliamento River, northeastern Italy). Canadian Journal of Fisheries and Aquatic Sciences. 58: 2359-2373. (J)

Author abstract: Daily and seasonal water temperature patterns were investigated at 22 habitats in five geomorphic reaches along an Alpine-Mediterranean river. Study reaches spanned 2nd- to 7th-order river segments. Habitats included headwater streams, main and secondary channels,

backwaters, and isolated pools. Multiple linear regression analyses extracted elevation and azimuth (aspect) out of eight geographical and environmental variables to explain average daily temperature patterns among habitats. Azimuth and, to a lesser degree, slope, depth, velocity, and canopy were primary determinants of diel temperature amplitude and maximum rates of diel heating and cooling. Within lowland floodplain reaches, the relative influence of groundwater and surface water varied substantially among habitats. Thermal variation among habitats was greatest in lowland floodplain reaches (nearly 15°C difference). In summer and autumn, variation between lowland floodplain aquatic habitats exceeded thermal variation observed in the main channel along the entire river corridor (120 km; 5–1100 m above sea level). Spatiotemporal variation in temperature was greatest in lower reaches owing to the interaction of water level and connectivity of isolated water bodies. Influence of groundwater and cool-water tributaries exemplified the importance of local factors (geomorphology and hydrology) superimposed on regional factors (climate and altitude) in determining large-scale thermal patterns.

548) Baeza, C., and J. Corominas. 2001. Assessment of shallow landslide susceptibility by means of multivariate statistical techniques. Earth Surface Processes and Landforms. 26: 1251-1263. (K)

Author abstract: Several multivariate statistical analyses have been performed to identify the most influential geological and geomorphological parameters on shallow landsliding and to quantify their relative contribution. A data set was first prepared including more than 30 attributes of 230 failed and unfailed slopes. The performance of principal component analysis, t-test and one-way test, allowed a preliminary selection of the most significant variables, which were used as input variables for the discriminant analysis. The function obtained has classified successfully 88.5 percent of the overall slope population and 95.6 percent of the failed slopes. Slope gradient, watershed area and land-use appeared as the most powerful discriminant factors. A landslide susceptibility map, based on the scores of the discriminant function, has been prepared for Ensija Range in the Eastern Pyrenees. An index of relative landslide density shows that the results of the map are consistent.

549) Boothroyd, I.K.G., J.M. Quinn, E.R. Langer, K.J. Costley, and G. Steward. 2004. Riparian buffers mitigate effects of pine plantation logging on New Zealand streams. 1. Riparian vegetation structure, stream geomorphology and periphyton. Forest Ecology and Management. 194: 199-213. (A, C, F, H)

Author abstract: Influences of the riparian zone vegetation characteristics on bank erosion, stream geomorphology, irradiance and periphyton were examined at 28 sites in the Whangapoua area of the Coromandel Peninsula, North Island, New Zealand. Riparian buffers were defined as areas alongside streams that were not managed for production forestry, and which contained native indigenous vegetation or mixed indigenous and introduced flora. Five forest and riparian zone types were selected: (i) harvested pine plantation with a clearcut to stream edge, (ii) harvested pine plantation with a vegetated riparian buffer, (iii) mature pre-harvest pine plantation with a riparian buffer dominated by native vegetation, (iv) mature pre-harvest pine plantation with a riparian zone of plantation pines and a native vegetation understory, and (v) mature native forest reference sites. Up to eight replicates were selected for each management regime. Species composition and canopy cover were measured from bounded plots, and stream bank vegetation was recorded separately. Bank erosion was measured along the full length of each study reach, and stream water width and bankfull width were measured at ten transects within each study reach. Stream and bank lighting were measured using a canopy analyzer. Periphyton standing crop was measured as Chlorophyll *a* and ash-free dry weight.

Although channel width increased with catchment area for all of the study reaches, bank erosion and channel widths were greater at harvested sites where plantation pines occurred at the stream edge (i.e. within the riparian zone), than other forest and riparian treatments. Stream lighting was heavily influenced by the presence of riparian vegetation as well as stream size for these small to moderate size streams. Mature radiata pine in riparian areas of pre-harvest sites provided shading which was similar but less variable than that recorded in the native reference sites. Mature pine forest may be shading out the taller growing native broadleaved canopy, and thus creating a denser 5–11.9 m height class, reducing light penetration. The lack of native species >12 m in height is likely to be due to the length of time which native conifers and hardwoods take to develop as these are the species which normally dominate the greater than 12 m height class. Periphyton biomass was lowest at pre-harvest sites with native riparian buffers present and greatest at clearcut harvested sites with clearcut riparian zones. This work shows that riparian vegetation composition and maturity can influence the physical characteristics of afforested and harvested New Zealand streams

550) Casagli, N., M. Rinaldi, A. Gargini, and A. Curini. 1999. Pore water pressure and streambank stability: Results from a monitoring site on the Sieve River, Italy. Earth Surface Processes and Landforms. 24: 1095-1114. (F, G)

Author abstract: To investigate the role of pore water pressures in the stability of a streambank, a series of tensiometers and piezometers was installed in a bank of the Sieve River, Tuscany, Italy. Fluvial entrainment at the bank toe was monitored by repeated cross-profiling, erosion pins and marked pebbles. Fluctuations in matric suction measured at the tensiometers reflected the overall response of pore water pressures to rainfall, evapotranspiration, rising and drawdown of the river stage, and variations in water table. An expression was derived for the safety factor with respect to mass movement of the upper bank, incorporating the failure criterion for unsaturated soils and the normal Mohr-Coulomb criterion for saturated conditions. Variations in matric suction have important effects on the stability of the streambank. During low-flow periods, the shear strength term due to the matric suction allows the bank to remain stable at a steep angle. However, during rainfall and flow events, reduction in matric suction and increase in unit weight of the material from vertical and lateral infiltration may be sufficient to trigger a mass failure, without development of significant positive pore water pressures. During the rising limb of high-flow events, the factor of safety increases as a consequence of the stabilizing confining pressure of the water in the river, despite a reduction in matric suction. During drawdown in the river, when the suction values are still low and the confining pressure in the river decreases to zero, the factor of safety falls to lower values than those experienced prior to the runoff event. Measurements of fluvial entrainment reveal that, although the processes, mechanisms and the frequency of retreat of basal and upper bank zones differ significantly, the amount of retreat at the bank toe due to fluvial erosion is comparable to that of the upper portion of the bank due to mass failure.

551) Collier, K.J., and J.N. Halliday. 2000. Macroinvertebrate-wood associations during decay of plantation pine in New Zealand pumice-bed streams: Stable habitat or trophic subsidy? Journal of the North American Benthological Society. 19: 94-111. (C, D, E)

Author abstract: Extensive areas of production pine forest in New Zealand have been planted in the North American native *Pinus radiata.* We investigated the use of pine large woody debris (LWD) by aquatic invertebrates in central North Island spring-fed streams with pumice beds to provide an improved basis for managing LWD inputs following logging. Invertebrate faunas in early summer were dominated by Ephemeroptera and Diptera on inorganic substrates, and by these groups and Trichoptera (predominantly *Pycnocentria funerea*; Conoesucidae) on wood. Densities of total invertebrates and *P. funerea*, *Eukiefferiella* sp. (Diptera), and the Ephemeropterans *Coloburiscus humeralis* (Coloburiscidae), *Zephlebia dentata*, and *Austroclima sepia* (both Leptophlebiidae) were significantly higher on wood than on inorganic substrates in summer. These dominant species showed varying preferences for wood at different stages of decay. *Austroclima sepia* appeared to prefer wood at early to intermediate stages of decay, *P. funerea* and *Z. dentata* preferred wood at intermediate to advanced stages of decay, and *C. humeralis* and *Eukiefferiella* preferred severely decayed wood. *Pycnocentria funerea* larvae excavated feeding grooves 1–2 mm deep along LWD, and gut analyses of larvae collected in summer confirmed ingestion of pine wood. This material dominated the gut contents of large larvae collected from wood at intermediate to advanced stages of decay. Stable isotope analyses of potential C sources and selected wood-dwelling invertebrates discriminated between pine wood and other types of allochthonous organic matter, and indicated that some larvae could derive substantial proportions of their nutrition from pine wood at certain times of year. In a laboratory experiment, *P. funerea* larvae produced significantly more fine particulate organic matter from wood at advanced stages of decay than from less-decayed wood or controls (PVC tubes) over 8 and 26 d. However, growth rates did not differ significantly between wood-decay treatments. Our findings 1) indicate that wood in pumice-bed streams enhances habitat for lotic invertebrates, and 2) suggest invertebrate community succession as wood passes through different stages of decay. Some predominantly xylophagous species, such as *P. funerea*, appear to be responding partly to enhanced food resources, indicating that inputs of pine woody debris can provide a trophic subsidy to pumice-bed streams in production forest environments.

552) Costard, F., L. Dupeyrat, E. Gautier, and E. Carey-Gailhardis. 2003. Fluvial thermal erosion investigations along a rapidly eroding river bank: Application to the Lena River (central Siberia). Earth Surface Processes and Landforms. 28: 1349-1359. (F)

Author abstract: In Central Yakutia, frozen river banks are affected by a combination of thermal and mechanical erosion. Exceptional bank retreat of up to 40 m per year is observed. This results from ground thawing produced by heat transfer from the flow of water through the frozen ground, followed by mechanical transport of the thawed sediments. A one-dimensional model is proposed to estimate the thermal erosion efficiency. A test of this model is a comparison of results obtained from experiments carried out in a cold room. A hydraulic channel allows measurements of the thaw front propagation, as well as the thermal erosion rate, in simulated ground ice that is subjected to warm water flow. Various laboratory simulations

demonstrate the validity of the mathematical model for the range of laboratory conditions. A hierarchy of parameters (Reynolds number, water and ground ice temperatures) is proposed to explain the present efficiency of thermal erosion along the Siberian rivers. From the characteristics of the Lena River (geometry, temperature and discharge) during the flood season, the erosion of banks with different ice content predicted by the model is in agreement with field observations.

553) Couper, P.R., and I.P. Maddock. 2001. Subaerial river bank erosion processes and their interaction with other bank erosion mechanisms on the River Arrow, Warwickshire, UK. Earth Surface Processes and Landforms. 26: 631-646. (F)

Author abstract: River bank erosion occurs primarily through a combination of three mechanisms: mass failure, fluvial entrainment, and subaerial weakening and weathering. Subaerial processes are often viewed as 'preparatory' processes, weakening the bank face prior to fluvial erosion. Within a river basin downstream process 'domains' occur, with subaerial processes dominating the upper reaches, fluvial erosion the middle, and mass failure the lower reaches of a river. The aim of this paper is to demonstrate that (a) subaerial processes may be underestimated as an erosive agent, and (b) process dominance has a temporal, as well as spatial, aspect. Bank erosion on the River Arrow, Warwickshire, UK, was monitored for 16 months (December 1996 to March 1998) using erosion pins. Variations in the rate and aerial extent of erosion are considered with reference to meteorological data. Throughout the first 15 months all erosion recorded was subaerial, resulting in up to 181 mm a^{-1} of bank retreat, compared with 13 to 27 mm a^{-1} reported by previous researchers. While the role of subaerial processes as 'preparatory' is not contended, it is suggested that such processes can also be erosive. The three bank erosion mechanisms operate at different levels of magnitude and frequency, and the River Arrow data demonstrate this. Thus the concept of process dominance has a temporal, as well as spatial aspect, particularly over the short time-periods often used for studying processes in the field. Perception of the relative efficacy of each erosive mechanism will therefore be influenced by the temporal scale at which the bank is considered. With the advent of global climate change, both these magnitude-frequency characteristics and the consequent interaction of bank erosion mechanisms may alter. It is therefore likely that recognition of this temporal aspect of process dominance will become increasingly important to studies of bank erosion processes.

554) Dahlström, N., and C. Nilsson. 2004. Influence of woody debris on channel structure in old growth and managed forest streams in central Sweden. Environmental Management. 33: 376-384. (A, D)

Author abstract: Anecdotal information suggests that woody debris have had an important channel-forming role in Swedish streams and rivers, but there are few data to support this view. We identified 10 streams within near-natural and 10 streams within managed forest landscapes in central Sweden, and quantified their channel characteristics and content of woody debris. All pieces of woody debris greater than 0.5 m in length and greater than 0.05 m in base diameter were included. The near-natural forests were situated in reserves protected from forest cutting, whereas the managed forests had previously faced intensive logging in the area adjacent to the stream. The two sets of streams width, slope, or boulder cover, but the number of wood pieces was twice as high and the wood volume almost four times as high in the near-natural streams.

This difference resulted in a higher frequency of debris dams in the nearnatural streams. Although the total pool area did not differ between the two sets of streams, the wood-formed pools were larger and deeper, and potentially ecologically more important than other pools. In contrast to what has been believed so far, woody debris can be a channel-forming agent also in steeper streams with boulder beds. In a stepwise multiple regression analysis, pool area was positively and most strongly related to the quantity of woody debris, whereas channel gradient and wood volume were negatively related. The frequency of debris dams increased with the number of pieces of woody debris, but was not affected by other variables. The management implications of this study are that the wood quantity in streams in managed forests would need to be increased if management of

555) Dapporto, S., M. Rinaldi, N. Casagli, and P. Vannocci. 2003. Mechanisms of riverbank failure along the Arno River, central Italy. Earth Surface Processes and Landforms. 28: 1303-1323. (F)

Author abstract: Riverbanks along the Arno River have been investigated with the aims of defining the main mechanisms of failure and retreat, their spatial distribution, and their causes. Geomorphological aspects were investigated by a reconnaissance of riverbank processes, for a number (26) of representative sites. Laboratory and *in situ* tests were then performed on a selected number of riverbanks (15). Based on the material characteristics, six main typologies of riverbanks have been defined, with homogeneous fine-grained and composite banks representing the most frequent types. Slab-type failures are the most frequent mechanism observed on fine-grained banks, while cantilever failures prevail on composite banks.

The role of river stage and related pore water pressure distributions in triggering the main observed mechanisms of failure has been investigated using two different types of stability analysis. The first was conducted for 15 riverbanks, using the limit equilibrium method and considering simplified hypotheses for pore water pressure distribution (annulment of negative pore pressures in the portion of the bank between low water stage and peak stage). Stability conditions and predicted mechanisms of failure are shown to be in reasonably good agreement with field observations. Three riverbanks, representative of the main alluvial reaches of the river, were then selected for a more detailed bank stability analysis, consisting of: (a) definition of characteristic hydrographs of the reach with different return periods; (b) modelling of saturated and unsaturated flow using finite element seepage analysis; and (c) stability analysis with the limit equilibrium method, by adopting pore water pressure values derived from the seepage analysis. The results are compared to those obtained from the previous simplified analysis, and are used to investigate the different responses, in terms of stability, to different hydrological and riverbank conditions.

556) Díez, J.R., S. Larrañaga, A. Elosegi, and J. Pozo. 2000. Effect of removal of wood on streambed stability and retention of organic matter. Journal of the North American Benthological Society. 19: 621-632. (A, C, D)

Author abstract: We tested the hypothesis that wood influences stream channel morphology, sediment composition, retention, and storage of organic matter by experimentally removing all wood from 2 first-order reaches (ca 90 m length) of 2 neighboring tributaries (Salderrey and Cuchillo streams) in the Agüera catchment (Basque Country, Spain). We established 2 *control* reaches upstream from these *treatment* reaches. We completed maps of substrate, fill/scour transects, and wood surveys in 1997 (prior) and 1998 (after) wood removal. We measured monthly inputs of fine wood to the treatment reaches. In addition, we measured seston every 2 wk, benthic coarse organic particulate matter (CPOM) every 2 mo, and the retention capacity of reaches every 3 mo. All reaches were scoured during the study period, but the volume of sediment lost was higher in the treatment reaches (53 m^3) than in the controls (14.2 m^3 in Salderrey, 2.7 m^3 in Cuchillo). As a result, the area of coarse substrate increased in the treatments, but remained unaltered in the controls. The capacity of the reaches to retain CPOM decreased after the treatment, but affected neither seston concentration nor the benthic storage of CPOM. Wood is an important constituent of Basque streams, and removal of wood significantly impacts channel structure and organic matter storage.

557) Fransen, P.J.B., C.J. Phillips, and B.D. Fahey. 2000. Forest road erosion in New Zealand: Overview. Earth Surface Processes and Landforms. 26: 165-174. (K)

Author abstract: New Zealand research relating to erosion impacts of plantation forest roads, tracks and landings has been carried out since the mid-1970s. Methods include paired catchment studies, storm-induced mass movement surveys, and surface erosion plot experiments from both natural and simulated rainfall-runoff. Road surface erosion data exist only for indurated conglomerate, granitic, schist and pumice terrains, with annual sediment yields up to 15 kg m^{-2} for a range of treatments and source types including graded, ungraded and gravelled road surface-ditch, cutbank and sidecast. Sediment generated from infrequent storm-induced landslides over entire forest road networks range from *c*. 40 to 8000 t km^{-1} road, or one to three orders of magnitude greater than combined surface road erosion processes. Young roads tend to have greater landslide susceptibility. Despite predicted increases in sediment yields from road surfaces during forest establishment and harvesting activities, annual sediment yields from catchments appear to be within natural levels.

558) Graça, M.A.S., R.C.F. Ferreira, and C.N. Coimbra. 2001. Litter processing along a stream gradient: The role of invertebrates and decomposers. Journal of the North American Benthological Society. 20: 408-420. (A, C, E)

Author abstract: Dissolved nutrients and temperature tend to increase in a downstream direction, whereas shredder density tends to decrease. As a result, the relative importance of microbes (bacteria and fungi) and invertebrates in leaf litter processing may gradually shift along a stream gradient. Therefore, we hypothesized that differences in litter decay between fine-mesh (invertebrates excluded) and coarse-mesh (accessible to invertebrates) bags will be high in low-order streams (i.e., <4) and low in high-order streams (i.e., >4). To test this hypothesis, we investigated the processing of alder (*Alnus glutinosa*) litter in 12 sites ranging from 2nd to 6th order in central Portugal during autumn/winter and spring/summer seasons. Mass loss rates (measured as % ash-free dry mass [AFDM]) were higher in spring/summer than in autumn/winter and higher in coarse- than in fine-mesh bags. No clear relationship was observed between river order and litter processing (% AFDM loss). In spring/summer, the difference in remaining mass between fine- and coarse-mesh bags was higher in low-order than in high-order streams and decreased in a downstream direction, supporting our hypothesis. Other evidence for shifting in processing vectors includes the observations that 1) the biomass and % of shredders were generally higher in low-order than in high-order streams and tended to decrease downstream, 2) high microbial biomass was reached earlier in high-order than in low-order rivers, and 3) the density of fungal conidia tended to increase with increasing stream order. No pattern of shifting in processing vectors was observed in autumn/winter, possibly because food was nonlimiting.

559) Gurnell, A.M., G.E. Petts, N. Harris, J.V. Ward, K. Tockner, P.J. Edwards, and J. Kollmann. 2000. Large wood retention in river channels: The case of the Fiume Tagliamento, Italy. Earth Surface Processes and Landforms. 25: 255-275. (A, D)

Author abstract: After more than 300 years of widespread and intensive river management, few examples of complex, unmanaged river systems remain within Europe. An exception is the Fiume Tagliamento, Italy, which retains a riparian woodland margin and unconfined river channel system throughout almost the entire 170 km length of its river corridor. A research programme is underway focusing on a range of related aspects of the hydrology, fluvial geomorphology and ecology of the Tagliamento. This paper contributes to that programme by focusing on large wood retention. The paper adopts a simple force:resistance approach at the scale of the entire river corridor in order to identify reaches of the river with a high wood retention potential. Information on the character of the river corridor is derived from 1:10 000 scale topographic maps. A range of indices measured at 330 transects across the river corridor supports a classification of the geomorphological style of the river which reflects the presence and abundance of properties previously identified in the literature as large wood retention sites. This classification provides a qualitative representation of the ‘resistance’ of the corridor to wood movement and thus its overall wood-retention potential. The map-derived indices are also used to extrapolate estimates of the ten year return period flood to each of the 330 transects so that the downstream pattern of unit stream power can be quantified as an index representing ‘force’ in the analysis. Although input of wood is an important factor in many river systems, it is assumed not to be a limiting factor along the Tagliamento, where riparian woodland is abundant.

Field observations of large wood storage illustrate that wood retention at eight sites along the river reflects the presence and abundance of the features incorporated in the classification of geomorphological style, including the complexity of the channel network, the availability of exposed gravel areas, and the presence of islands. In general at the time of survey in August 1998, open gravel areas were estimated to store approximately 1 t ha^{-1} of wood in single-thread reaches and 6 t ha^{-1} in multiple-thread reaches. Established islands were estimated to store an average of 80 t ha^{-1} of wood. Nevertheless, there was considerable variability between sites, and pioneer islands, which are not represented on maps or readily identified from air photographs because of their small size, were estimated to store an order of magnitude more wood than established islands. Furthermore, the wood storage from this sample of eight sites did not reflect variability in estimated unit stream power.

A series of areas for further research are identified, which can be explored using field data, and which will throw more light on the processes of wood retention in this extremely dynamic fluvial environment.

560) Harwood, K., and A.G. Brown. 1993. Fluvial processes in a forested anastomosing river: Flood partitioning and changing flow patterns. Earth Surface Processes and Landforms. 18: 741-748. (A, D, G, F)

Author abstract: In an effort to further our understanding of multiple channel systems, this paper presents data on the flood response of channels in one of the last wooded, semi-natural anastomosing systems in Europe. The Gearagh, Ireland, is characterized by hundreds of small islands separated by interconnected channels of low slope. These include channels that cross islands at right angles to the main flow and blind anabranching channels. Islands are relatively stable and wooded, with evidence of division by channel erosion and growth by in-channel sedimentation. Four active zone cross-profiles were surveyed, each containing between seven and 13 channels. Velocities were measured in several channels before and during two separate floods. From these observations channels have been categorized into three types: fast (shallow and trapezoidal); slow (deep and more irregular); and flood channels. During the floods, interchannel flows were caused by variations in water surface elevations due to backing-up behind debris dams, and it is suggested that this is the origin of the anomalous cross-island channels and one cause of island division. Another potential cause of island division, blind anabranching channels, is the result of concentrated bank scour between root masses. Biotic components such as debris dams, tree root masses and tree-throw pits play a key role in the partitioning of flow, and cause variations in channel velocities and the overbank velocity distribution. The implications of these observations for channel pattern maintenance are briefly discussed.

561) Huisink, M., J.J.W. de Moor, C. Kasse, and T. Virtanen. 2002. Factors influencing periglacial fluvial morphology in the northern European Russian tundra and taiga. Earth Surface Processes and Landforms. 27: 1223-1235. (A, F, G)

Author abstract: The influence of geology, discharge regime, slope, vegetation type, vegetation density and permafrost conditions on periglacial channel morphology has been investigated in the USA catchment (northern European Russia). Rivers are dominated by meandering or anabranching plan forms and rarely show braiding characteristics, despite a nival discharge regime, the presence of discontinuous permafrost and locally steep slopes.

The dense vegetation cover is an important factor in determining the meandering morphology as it inhibits the sediment supply and hence braided conditions. Differences in vegetation types (taiga in the south, tundra in the north) have no effect on channel plan form

562) Jeffries, R., S.E. Darby, and D.A. Sear. 2003. The influence of vegetation and organic debris on flood-plain sediment dynamics: Case study of a low-order stream in the New Forest, England. Geomorphology. 51: 61-80. (D)

Author abstract: The presence of large woody debris (LWD) has important implications for the physical and ecological behaviour of rivers, and these aspects have been researched extensively in recent years. However, this research has so far focused primarily on interactions between LWD and in-channel processes, and the role of LWD in flood-plain genesis is still poorly understood. Established conceptual models of flood-plain evolution are, therefore, lacking because they neglect the complex interaction between water, sediment, and vegetation in systems with accumulations of LWD. This study examines the effect of LWD on patterns of sediment deposition within a small area of forest flood plain along the Highland Water, S. England. In-channel debris dams locally increase the frequency and extent of overbank flows, and the impact of such dam on flood-plain sedimentation was observed. Nine separate flood events were monitored through the exceptionally wet winter of 2000–2001. During each of these, water and sediment fluxes were quantified and correlated with general rates of overbank sedimentation. Flood-plain topography, vegetation, and LWD were surveyed and related to micro- and mesoscale patterns of sediment accretion. The amount of overbank sediment deposition was correlated most closely with flood hydrology and sediment input. The amounts (0–28 kg m^{-2}) and patterns of sediment deposition were both greater and more variable than have been observed on nonforest flood plains. The highly variable pattern of accretion can be explained by the combined effects of topography and organic material present on the surface of the flood plain.

563) Jones, A. 1971. Soil piping and stream channel initiation. Water Resources Research. 7: 602-610. (K)

Author abstract: The hydrologic significance of soil piping has been generally ignored. Piping has been associated primarily with drylands, yet evidence of piping is available from a large range of climatic regions. In particular, soil piping is found to be widespread in the United Kingdom. Preferred locations for piping are either just above or within a horizon of low relative permeability and low aggregate stability. Chemical environment may range from acidic moorland soils to saline marshes. There are significant trends to lower aggregate stability and coarser grain size (particularly in the range above 250 µm) in the bed of a pipe than in the roof. Many pipes in the areas studied appear to be dormant or relatively inactive and may well be in approximate equilibrium with the soil pore and channel subsystems. However, when equilibrium is destroyed (e.g., by stream incision) pipes can form loci for channel extension. Studies of the spatial distribution of outlets show that to create normal channel networks, pipe clusters within the ensemble and, similarly, individual pipes within those clusters must be selected on an unequal basis. A low density random selection from piped located on percolines would fulfill the requirements. The presence of piping may have a significant effect on the form of the hydrograph.

564) Kail, J. 2003. Influence of large woody debris on the morphology of six central European streams. Geomorphology. 51: 207-223. (A, D)

Author abstract: The impact of large fallen trees on channel form is described for six short stream sections in central Europe influenced by large woody debris (LWD sections), five of which are compared to nearby reference sections free of LWD (reference sections). Three-dimensional models of streambed topography were generated by surveying cross-sections with a spacing of 1 per 1/15 channel width. Parameters derived from digital terrain models and cross-sections compared between LWD sections and reference sections include the extent of pools, bars, and cutbanks, streambed and bank complexity, cross-sectional area, width, depth, and cross-section complexity as described by Andrle's [Math. Geol. 26 (1994) 83] `angle-measurement-technique' (AMT analysis), a measure of the deviation of a cross-section line from a straight line. Structural diversity is greater in LWD sections at almost all spatial scales, particularly in terms of pool volume (Mann–Whitney *U*-test, $p<0.01$) and cross-section complexity described by median angle of AMT analysis (Mann–Whitney *U*-test, $p<0.05$). Large pools are clearly associated with large fallen trees and attain volumes up to 36 m^3. With the exception of the ratio of one LWD section where the fallen tree is oriented parallel to flow, the ratio of pool volume to bed planimetric area ranges from 424 to 693 m^3/ha, which is in the upper range reported for small, high-gradient streams in Oregon, NW America (229–755 m^3 /ha) [Can. J. Fish. Aquat. Sci. 47 (1990) 1103]. Pool volume of LWD sections is strongly correlated to the blockage ratio (Spearman rank order correlation, r_s=0.93, p<0.01). Differences in channel morphology between the LWD sections and reference sections indicate a strong morphologic control of large woody debris in these central European stream sections.

565) Kobayashi, S., and T. Kagaya. 2004. Litter patch types determine macroinvertebrate assemblages in pools of a Japanese headwater stream. Journal of the North American Benthological Society. 23: 78-89. (C)

Author abstract: In forested streams, litter patches are important microhabitats for macroinvertebrates, and the nature of litter patches can affect structure and function of macroinvertebrate assemblages. We examined whether litter patch types with different characteristics could be predicted by their location within stream pools (pool middle, alcove, edge) and, if so, whether patch types had different macroinvertebrate assemblages. Mean mass of leaves per unit area of streambed was 2 to 3x higher in edge patches than in other patches, whereas mean mass of wood and small litter particles was 2 to 6x higher in middle patches. Densities of nemourid stonefly taxa were higher in edge patches than other patches, with density of *Nemoura* being highly correlated with leaf mass, whereas densities of lepidostomatid caddisfly taxa were higher in middle patches, with density of *Goerodes complicatus* being highly correlated with mass of small litter particles. Mean biomass and annual secondary production of shredders, collectors, and predators were 1.6 to 4x higher in middle patches than in other patches. Our results indicate that macroinvertebrate community structure and production may differ within and among forested streams according to relative composition of litter patch types, even if overall litter abundance is similar.

566) Quinn, J.M., I.K.G. Boothroyd, and B.J. Smith. 2004. Riparian buffers mitigate effects of pine plantation logging on New Zealand streams. 2. Invertebrate communities. Forest Ecology and Management. 191: 129-146. (C, F, G, H, I, J)

Author abstract: The influences on forest stream invertebrate communities of riparian forest type (native/exotic *Pinus radiata*) and logging, with or without native forest riparian buffers, were investigated at 28 stream sites on Coromandel Peninsula, New Zealand. Stream reaches were surveyed under summer, baseflow conditions in six riparian/forest vegetation types: native forest, mature pine plantations with pines planted to the stream edge, mature pine plantations with native forest in the riparian area, clearcut pine plantations, and logged pine plantations with patch buffers of native forest vegetation (upstream areas clearcut) or continuous buffers along the perennially flowing stream length. Multivariate analyses showed that clearcut reaches differed in invertebrate community structure from pine and native forested reaches, and from logged reaches with continuous riparian buffers. Communities at patch buffer sites were intermediate between these groups. Amongst the common taxa, mayflies were the most sensitive to clearcut logging, with three species less abundant at clear-cut and/or patch buffer sites; only the algal-piercing caddis *Oxyethira albiceps* (Hydroptilidae) responded positively to logging. Clearcut reaches had lowest diversity, taxon richness, relative abundance and numbers of the

sensitive mayfly, stonefly and caddisfly taxa, and index of biotic integrity. In contrast, sites that had been logged leaving continuous buffers did not differ in these biometrics from those in intact native or mature plantation forest, indicating that buffers greatly reduced disturbance associated with logging. Logged sites with patch buffers had biometric values intermediate between clearcut and forested/continuous buffered reaches, indicating less protection from logging impact. Correlation and multiple regression analyses showed that logging impacts are strongly related to increases in periphyton biomass and water temperature, associated with changes in stream lighting, and increased channel instability/fine sediment. The findings indicate that late-rotation exotic pine plantations can support very similar stream invertebrate communities to native forests, and highlight the benefit of retaining forested buffers along stream riparian areas to avoid harvesting impacts on stream habitat and invertebrate communities.

567) Rinaldi, M., and N. Casagli. 1999. Stability of streambanks formed in partially saturated soils and effects of negative pore water pressures: The Sieve River (Italy). Geomorphology. 26: 253-277. (F)

Author abstract: Streambanks of alluvial channels are usually composed of loose materials, which are unsaturated in ambient conditions. Unsaturated soils are subject to negative pore water pressures, which cause an apparent cohesion. The latter is the main factor in allowing the stability of near-vertical banks. Even during moderate in-bank flow events, the apparent cohesion can be strongly reduced as the material approaches full saturation; therefore, during the drawdown phase, as the confining pressure of the water in the channel disappears, a bank failure is likely to occur. Channel bed-level lowering along the Sieve River, Central Italy, has caused widespread bank instability. A geomorphological reconnaissance of forms and processes was followed by in situ tests to determine the shear strength of the banks. Interpretation of the tests and a streambank stability analysis were based on the concepts of soil mechanics for unsaturated soils, in order to obtain relations between bank angle and height in limit equilibrium conditions. A stability chart was obtained with curves for different apparent cohesion values, and a stability analysis was performed taking in account the effects of flow events. In order to investigate the pore pressure effects, a series of piezo-tensiometers were installed in a streambank of the Sieve River. Data from a 1 year monitoring period show variations in pore water pressure and matric suction as a consequence of rainfall, evapotranspiration, and water stage variations. A planar failure with a tension crack occurred in the upper cohesive part of the bank during December 1996. The safety factor has been expressed as a function of the geometry of the bank and of the shear strength of the material. Safety factor variations through time are therefore shown as a function of seasonal variations in matric suction.

568) Rinaldi, M., N. Casagli, S. Dapporto, and A. Gargini. 2004. Monitoring and modelling of pore water pressure changes and riverbank stability during flow events. Earth Surface Processes and Landforms. 29: 237-254. (F, G)

Author abstract: Pore water pressures (positive and negative) were monitored for four years (1996-1999) using a series of tensiometer-piezometers at increasing depths in a riverbank of the Sieve River, Tuscany (central Italy), with the overall objective of investigating pore pressure changes in response to flow events and their effects on bank stability.

The saturated/unsaturated flow was modelled using a finite element seepage analysis, for the main flow events occurring during the four-year monitoring period. Modelling results were validated by comparing measured with computed pore water pressure values for a series of representative events. Riverbank stability analysis was conducted by applying the limit equilibrium method (Morgenstern-Price), using pore water pressure distributions obtained by the seepage analysis.

The simulation of the 14 December 1996 event, during which a bank failure occurred, is reported in detail to illustrate the relations between the water table and river stage during the various phases of the hydrograph and their effects on bank stability. The simulation, according to monitored data, shows that the failure occurred three hours after the peak stage, during the inversion of flow (from the bank towards the river). A relatively limited development of positive pore pressures, reducing the effective stress and annulling the shear strength term due to the matric suction, and the sudden loss of the confining pressure of the river during the initial drawdown were responsible for triggering the mass failure.

Results deriving from the seepage and stability analysis of nine selected flow events were then used to investigate the role of the flow event characteristics (in terms of peak stages and hydrograph characteristics) and of changes in bank geometry. Besides the peak river stage, which mainly controls the occurrence of conditions of instability, an important role is played by the hydrograph characteristics, in particular by the presence of one or more minor peaks in the river stage preceding the main one.

569) Rowntree, K.M., and E.S.J. Dollar. 1999. Vegetation controls on channel stability in the Bell River, Eastern Cape, South Africa. Earth Surface Processes and Landforms. 24: 127-134. (A, F)

Author abstract: Channel instability has occurred in the Bell River in the form of meander cutoffs, a number of which have occurred since 1952. Increased sediment loading from widespread gully erosion in the catchment has been proposed as the trigger for this instability. Willow species of the *Salix* family, in particular *S. caprea*, have been planted along the banks in an effort to prevent further channel shifting. This study reports the results of an investigation into the effect of vegetation on channel form and stability over a 17 km stretch of channel. Results indicate that riparian vegetation has significant effects on channel form which have implications for channel stability. Riparian vegetation increases bank stability and reduces channel cross-sectional area, thereby inducing stability at flows less than bankfull. Evidence indicates that narrow stable stretches are associated with relatively high levels of riparian vegetation. Wider, unstable channels are associated with relatively less riparian vegetation. The effectiveness of riparian vegetation relative to bank sediments was investigated. A dense growth of willows was found to have an equivalent effect to banks with a silt-clay ratio of about 70 per cent. The channel narrowing induced by vegetation may contribute to channel shifting at high flows. The reduced channel capacity is thought to result in more frequent overbank flooding which may ultimately lead to channel avulsion. Thus where increased sediment loading is pushing the channel towards instability, vegetation may be effective in imparting local stability, but it is unable to prevent long-term channel shifts, and may rather help to push the system towards more frequent avulsions.

570) Sabater, F., A. Butturini, I. Muñoz, A. Romaní, S. Sabater, E. Martí, and J. Wray. 2000. Effects of riparian vegetation removal on nutrient retention in a Mediterranean stream. Journal of the North American Benthological Society. 19: 609-620. (C, E, H, I)

Author abstract: We examined the effects of riparian vegetation removal on algal dynamics and stream nutrient retention efficiency by comparing NH_4-N and PO_4 -P uptake lengths from a logged and an unlogged reach in Riera Major, a forested Mediterranean stream in northeastern Spain. From June to September 1995, we executed 6 short-term additions of N (as NH_4Cl) and P (as Na_2HPO_4) in a 200-m section to measure nutrient uptake lengths. The study site included 2 clearly differentiated reaches in terms of canopy cover by riparian trees: the first 100 m were completely logged (i.e., the logged reach) and the remaining 100 m were left intact (i.e., the shaded reach). Trees were removed from the banks of the logged reach in the winter previous to our sampling. In the shaded reach, riparian vegetation was dominated by alders (*Alnus glutinosa*). The study was conducted during summer and fall months when differences in light availability between the 2 reaches were greatest because of forest canopy conditions. Algal biomass and % of stream surface covered by algae were higher in the logged than in the shaded reach, indicating that logging had a stimulatory effect on algae in the stream. Overall, nutrient retention efficiency was higher (i.e., shorter uptake lengths) in the logged than in the shaded reach, especially for PO_4-P. Despite a greater increase in PO_4-P retention efficiency relative to that of NH_4-N following logging, retention efficiency for NH_4-N was higher than for PO_4-P in both study reaches. The PO_4 -P mass-transfer coefficient was correlated with primary production in both study reaches, indicating that algal activity plays an important role in controlling PO_4-P dynamics in this stream. In contrast, the NH_4 -N mass-transfer coefficient showed a positive relationship only with % of algal coverage in the logged reach, and was not correlated with any algal-related parameter in the shaded reach. The lack of correlation with algal production suggests that mechanisms other than algal activity (i.e., microbial heterotrophic processes or abiotic mechanisms) may also influence NH_4-N retention in this stream. Overall, this study shows that logging disturbances in small shaded streams may alter in-stream ecological features that lead to changes in stream nutrient retention efficiency. Moreover, it emphasizes that alteration of the tight linkage between the stream channel and the adjacent riparian zone may directly and indirectly impact biogeochemical processes with implications for stream ecosystem functioning.

571) Stott, T. 1997. A comparison of stream bank erosion processes on forested and moorland streams in the Balquhidder Catchments, central Scotland. Earth Surface Processes and Landforms. 22: 383-399. (F)

Author abstract: Stream bank erosion rates measured over a two-year period on a moorland and a forested stream in the Institute of Hydrology's Balquhidder Paired Catchments in central Scotland were compared. Bank erosion rates are generally higher on the mainstream of the moorland catchment and highest in winter on both streams. Bank erosion is correlated with the incidence of frost: minimum temperatures measured on stream banks of the forested stream were an average of 3.7°C higher than on stream banks both outside the forest and on the moorland stream. This makes the incidence of frost on forested stream banks half as frequent. Volumes of material eroded from the mainstreams were combined with bulk density measurements and it is

estimated that erosion of the mainstream banks is contributing 1.5 and 7.3 per cent of the sediment yield of the forested and moorland catchments, respectively. Analysis of the vertical distribution of erosion on the banks of both streams suggests an undercutting mechanism which is more pronounced in the moorland stream. The influence of trees on bank erosion and possible implications for the management of forest streams are discussed.

572) van der Nat, D., K. Tockner, P.J. Edwards, and J.V. Ward. 2003. Large wood dynamics of complex alpine river floodplains. Journal of the North American Benthological Society. 22: 35-50. (A, D)

Author abstract: Despite a considerable amount of literature on large wood (LW) in freshwater ecosystems, its dynamic nature in large rivers has hardly been investigated. Our study focused on the mass and turnover of LW in braided floodplains of the Tagliamento River (northeastern Italy), the last morphologically intact large river flowing out of the Alps. LW masses and turnover were quantified by establishing 165 permanent plots (100 m^2 each) and then revisiting them after 4 floods of differing magnitude. The following hypotheses were tested: 1) presence of vegetated islands increases LW densities; 2) masses of LW remain constant through time; 3) species composition of LW matches the species composition of woody plants on vegetated islands; 4) lateral erosion is the most significant source of LW; and 5) the probability that a LW deposit survives a flood increases with the presence of islands, the size of the deposit, and its location within vegetation, but decreases with flood magnitude. During the study, LW mass was high and constant in the island-braided reach, reaching values (100–150 t/ha) comparable to those reported for pristine mountain streams. In the bar-braided reach, LW mass was significantly lower (15–70 t/ha) and more variable. Although the total quantities of LW on the floodplain remained relatively constant, turnover rates of LW were very high (up to 95% during one major flood). An analysis of the species composition of LW showed that, although it was similar to that of woody plants on vegetated islands, at least 30% of the wood originated from upstream. Analysis of deviance from stepwise forward logistic regression models showed that the probability that a LW deposit survives a flood depends on flood magnitude, deposit volume, and position of the LW within the channel.

573) Webb, A.A., and W.D. Erskine. 2003. Distribution, recruitment, and geomorphic significance of large woody debris in an alluvial forest stream: Tonghi Creek, southeastern Australia. Geomorphology. 51: 109-126. (D, F)

Author abstract: The complex yet poorly understood interactions between riparian vegetation, large woody debris and fluvial geomorphology in an anthropogenically undisturbed reach of an alluvial, sand-bed forest stream in SE Australia have been determined. Riparian vegetation exhibits lateral and vertical zonation of understorey and overstorey species. The dominant riparian tree species, *Tristaniopsis laurina* (water gum), grows within the channel and on the floodplain within one channel width of the stream. Larger *Eucalyptus* species only grow on the highest parts of the floodplain and on a low Pleistocene river terrace. A complete large woody debris (LWD) census conducted in the 715-m-long study reach revealed that water gum comprises 17.6% of the total LWD loading, which, at 576 m^3 ha^{-1}, is high for a stream with a catchment area of 187 km^2. Although most LWD has a small diameter (0.1–0.3 m), the greatest contribution to the total volume of LWD is by pieces with a diameter between 0.3 and 0.7 m. A high proportion of LWD (10.4%) has a blockage ratio greater than 10%. The spatial distribution of LWD is random both longitudinally and within individual meander bends. Dominant recruitment processes of LWD vary by species. *T. laurina* trees are recruited to the channel by minor bank erosion and senescence, while the *Eucalyptus* species are predominantly recruited from the highest parts of the floodplain/low-river terrace by episodic windthrow during large storms. Multiple radiocarbon dates of outer wood of immobile LWD indicate a maximum residence time of 240±40 years BP for *T. laurina* timber. The high loading of LWD combined with the extensive root systems of riparian vegetation stabilize Tonghi Creek. Log steps form natural wooden drop-structures with a mean height of 29 mm that were responsible for 20.5% of the total head loss under base flow conditions (Q=0.08 m^3 s^{-1}). Large woody debris is buried in the bed at depths of up to 2.3 m and is responsible for an estimated 49% of the 11, 600 m^3 of sand stored in the study reach. Pools are spaced at 0.8 channel widths and 82% of pools are formed by scour over, under, around, or beside LWD or by the impoundment of water upstream of debris dams. Due to the high density of hardwood timber species, debris dams, however, do not readily form in Tonghi Creek as the timber is difficult to transport and LWD usually sinks to the bed of the stream. Despite the high degree of channel stability provided by LWD, high blockage ratios in the channel result in relatively frequent overbank flows. These flows are often concentrated in chutes across the neck of meanders or multiple loops, which can develop into cutoffs and channel avulsions, respectively.

Miscellaneous

574) Abe, K., and R.R Ziemer. 1991. Effect of tree roots on shallow-seated landslides. In: Proceedings, Geomorphic Hazards in Managed Forests, XIV IUFRO World Congress, 5-11 August 1990, Montreal, Canada. USDA Forest Service, General Technical Report PSW-130. Pages 11-20. (K)

Author abstract: Forest vegetation, especially tree roots, helps stabilize hillslopes by reinforcing soil shear strength. To evaluate the effect of tree roots on slope stability, information about the amount of roots and their strength should be known. A simulation model for the root distribution of *Cryptomeria japonica* was proposed where the number of roots in each 0.5.cm diameter class can be calculated at arbitrary depths. The pull-out strength of roots was used to analyze the stability of four different types of forested slopes. Root reinforcement is important on slopes where roots can extend into joints and fractures in bedrock or into a weathered transitional layer between the soil and bedrock. Root reinforcement of soil increases quickly after afforestation for about the first 20 years, then remains about constant thereafter.

575) Alabyan, A.M., and R.S. Chalov. 1998. Types of river channel patterns and their natural controls. Earth Surface Processes and Landforms. 23: 467-474. (A, G)

Author abstract: River channel patterns are thought to form a morphological continuum. This continuum is two-dimensional, defined by plan features of which there are three (straight, meandering, branching), and structural levels of fluvial relief of which there are also three (floodplain, flood channel, low-water channel). Combinations of these three categories define the diversity of patterns. One of the most important factors in channel development is stream power, defined by water discharge and river slope. The greater the stream power, the stronger the branching tendency, but threshold values of stream power are different for the three different hierarchical levels of channel relief. The critical stream power values and hydrological regime together define the channel pattern, and analysis of the pattern type can be undertaken using effective discharge curves.

576) Anderson, L., and M. Bryant. 1980. Fish passage at road crossings: An annotated bibliography. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-117. 10pp. (K)

Author abstract: A report of special interest to fishery biologists, resource managers, hydrologists, and road engineers, this bibliography lists publications pertinent to road crossings of salmon and trout streams. Topics include bridge and culvert installation, design criteria, mechanics, hydraulics, and economics, as well as their biological effects.

577) Anonymous. 2000. abstracts. International Conference on Wood in World Rivers, 23-27 October 2000, Oregon State University, Corvallis. 139pp. (A, C, D, F)

Compiler abstract: This document contains all of the abstracts from plenary sessions, contributed papers, and posters presented at the International Conference on Wood in World

Rivers. Major topics included geomorphology, budgets and modeling, and biological relationships and restoration.

578) Armour, C.L. 1991. Guidance for evaluating and recommending temperature regimes to protect fish. US Fish and Wildlife Service, Fort Collins, Colorado, Biological Report 90(22). 13pp. (J)

Author abstract: Procedures are presented for evaluating temperature regimes for fish. Although examples pertain to spring chinook salmon (*Oncorhynchus tshawytscha*), the principles apply to other species. Basic temperature tolerance relationships for fish are explained and three options are described for comparing alternative temperature regimes. The options are to base comparisons on experimental temperature tolerance results, suitability of a simulated temperature regime for key life stages, or population statistics and predicted responses to simulated temperatures.

579) Bartholow, J.M. 2000. Estimating cumulative effects of clearcutting on stream temperatures. Rivers. 7: 284-297. (H, J)

Author abstract: The Stream Segment Temperature Model was used to estimate cumulative effects of large-scale timber harvest on stream temperature. Literature values were used to create parameters for the model for two hypothetical situations, one forested and the other extensively clearcut. Results compared favorably with field studies of extensive forest canopy removal. The model provided insight into the cumulative effects of clearcutting. Change in stream shading was, as expected, the most influential factor governing increases in maximum daily water temperature, accounting for 40% of the total increase. Altered stream width was found to be more influential than changes to air temperature. Although the net effect from clearcutting was a 4^{o}C warming, increased wind and reduced humidity tended to cool the stream. Temperature increases due to clearcutting persisted 10 km downstream into an unimpacted forest segment of the hypothetical stream, but those increases were moderated by cooler equilibrium conditions downstream. The model revealed that it is a complex set of factors, not single factors such as shade or air temperature, that governs stream temperature dynamics.

580) Belt, G.H., J. O'Laughlin, and T. Merrill. 1992. Design of forest riparian buffer strips for the protection of water quality: Analysis of scientific literature. Idaho Forest, Wildlife and Range Policy Analysis Group Report No. 8. written by the Idaho Forest, Wildlife and Range Policy Analysis Group, and the Idaho Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow. 35pp. (C, D, E, F, H, I, J)

Author abstract (Author Executive Summary): The primary purpose of this report is to identify, evaluate, and synthesize research-based information relating riparian buffer strips to forest practices, water quality, and fish habitat.

Scientific literature documenting the role and importance of buffer strips in reducing the impacts of forest practices is extensive. More than 300 scientific papers were located and reviewed; nearly 100 papers and documents were found to be relevant and are cited in this report. Information was extensive on some topics and surprisingly limited on others. A substantial amount of information was found regarding stream temperature changes resulting from the removal of riparian vegetation. Much recent research has focused on the importance of large organic debris (LOD) and how it can be affected by timber harvest. In contrast, little information was found on slash burning and sediment production within buffer strips. Research on some topics was in a case study format, making generalization difficult.

Objectives for this report are stated as five focus questions around which the report is organized: [1] What is a buffer strip? [2] How do forest practices within buffer strips affect water quality and fish habitat? [3] How effective are buffer strips in reducing impacts of forest practices? [4] What are the issues in buffer strip design? [5] What models are available for use in buffer strip design? A summary of replies to these focus questions is provided in a short section immediately following this executive summary.

This literature review suggests that scientists are at different stages in their understanding of the several important functions provided by buffer strips, which include temperature moderation, sediment filtration, and LOD recruitment. The importance of buffer strips in moderating the impacts of forest practices on water quality and fish habitat is generally understood, even though quantitative relationships are difficult to establish. Research on the effects of canopy removal on stream temperature has resulted in a practical understanding of the problem and some useful predictive models. In two other areas that have received recent emphasis--the impacts of forest practices on LOD recruitment and the aquatic food chain--knowledge is more descriptive. Some predictive models have been developed, but their utility is limited.

Information on the sediment filtering function of riparian buffer strips is limited. Much of what is known is inferred from the special case of buffer strips between a road and a stream. The important problem of cumulative effects within buffer strips has not yet been satisfactorily addressed. Existing studies, including those on slash burning, point out the potential for the accumulation of nutrients and chemicals along with sediment from both agricultural and forestry operations in riparian areas and the possible impacts on water quality and fisheries.

Studies describing different approaches to establishing buffer strip widths are limited. Despite literature describing the utility of variable width buffer strip models and their use in other states in the Pacific Northwest, no studies were found documenting the advantages or disadvantages of variable width buffer strips, as compared to minimum fixed width buffer strips.

Based on this literature review, two ideas seem to stand out as having some potential to enhance the effectiveness of buffer strips: (1) the use of a simplified field procedure (such as the TFW model in the State of Washington) for determining the impact of canopy removal on stream temperature, and (2) the use of variable width buffer strip models to address site-specific biological or physical requirements of the stream or riparian zone.

581) Bragg, D.C., and J.L. Kershner. 2002. Influence of bank afforestation and snag angle-of-fall on riparian large woody debris recruitment. 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 65-70. (D)

Author abstract: A riparian large woody debris (LWD) recruitment simulator (Coarse Woody Debris [CWD]) was used to test the impact of bank afforestation and snag fall direction on delivery trends. Combining all cumulative LWD recruitment across bank afforestation levels averaged 77.1 cubic meters per 100 meter reach (both banks forested) compared to 49.3 cubic meters per 100 meter reach (one side timbered). Both bank afforestation and snag fall patterns generated significant differences in riparian LWD delivery, but there was no noticeable interaction. Scenarios with only one bank forested delivered 15 to 50 percent less LWD than their two bank counterparts. Snag fall patterns also produced statistically different LWD recruitment, with some registering only 35 to 52 percent of the most productive fall patterns. These results suggest testing the assumptions of random snag fall from two forested banks before modeling riparian LWD recruitment.

582) Braudrick, C.A., and G.E. Grant. 2000. When do logs move in rivers? Water Resources Research. 36: 571-583. (D)

Author abstract: throughout the world, yet we know little about hydraulic thresholds for movement and transport of logs. We developed theoretical models of entrainment and performed flume experiments to examine thresholds for wood movement in streams. Both the model and the experiments indicate that log entrainment is primarily a function of the piece angle relative to flow direction, whether or not the log had a rootwad, the density of the log, and the piece diameter. Stability increased if the pieces had rootwads o r were rotated parallel to flow. Although previously reported as the most important factor in piece stability, piece length did not significantly affect the threshold of movement in our experiments o r our physically based model, for logs shorter than channel width. These physically based models offer a first-order approach to evaluating the stability of either naturally derived woody debris or material deliberately introduced to streams for various management objectives. Large woody debris is an integral component of forested, fluvial systems

583) Center for Transportation and the Environment. 2002. Aquatic organism passage at road-stream crossings. CTE Information Services, North Carolina State University, Raleigh. 39pp. (K)

Compiler abstract: This document summarizes research projects on aquatic organism passage at road-stream crossings that were in progress at the time the literature search was conducted. Projects summaries include abstracts as well as contact information, funding sources, project status, and funding amount. Project summaries are divided into sections on hydrology, culverts, habitat, and fish passage.

584) Center for Transportation and the Environment. 2002. Impacts of culverts on anadromous and non-anadromous fish passage II. CTE Information Services, North Carolina State University, Raleigh. 10pp. (K)

Compiler abstract: This annotated bibliography focused on the effects of culverts on aquatic organisms. The references focused primarily on the effects of culverts on fish passage. Few of the studies mention bridges, and none of them addressed bridges versus culverts.

585) Church, M., and B. Eaton. 2001. Hydrological effects of forest harvest in the Pacific Northwest. Riparian Decision Tool Technical Report #3 written by the Department of Geography, University of British Columbia, Vancouver. Written for the Joint Solutions Project, reporting to the Central Coast Land and Resource Management Plan. 55pp. (B, D, F, G, I)

Author abstract (Author Introduction): This report reviews experience in the coastal part of the Pacific Northwest region of North America of the effects of forest harvest upon hydrological regime and water quality, upon sediment mobilisation and delivery to stream systems, and their impacts upon hydroriparian habitat and ecosystems. For purposes of review, the "Pacific Northwest" is understood to encompass the forested Pacific slope between northern California and southern Alaska. This forested coastal region of broadly similar marine climate is distinguished by the massive size and remarkable longevity of the principal coniferous tree species. Climate and physiography impose a distinctive hydrological regime throughout the region. In consequence, practice and effects of forest management, including road building and forest harvest, are also in many respects regionally distinctive. These circumstances dictate that a review of land management impacts upon hydrology and sedimentation be regional in character. Knowledge of the environment and patterns of environmental disturbance within the Pacific Northwest are at least qualitatively indicative of conditions that may be expected at any particular place within the region.

The report has two major sections. The first gives a review of hydrological and sediment-related effects of forestry practices in the coastal Pacific Northwest. The second makes an interpretation of hydrological and sediment-related effects and presents recommendations for management of hydrology and hydroriparian zones, based on the documented experience, that should lead to sustainable land use. These recommendations are similar to ones made in the final report of the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound.

586) Copstead, R.L., K. Moore, T. Ledwith, and M. Furniss. 1998. An annotated bibliography. San Dimas Technology and Development Center, San Dimas, California. 160pp. (G, I))

Author abstract (Author Introduction—First paragraph): This document contains references comprises a snapshot of references relating to interactions between low volume roads and hydrology, particularly for forested land. It is intended to be a companion to the water/road interaction technology series of publications coordinated by the San Dimas Technology Development Center and sponsored by USDA Forest Service Engineering Staff to identify information and methods on hydrological aspects of developing, operating, and managing forest roads. The goals of the effort are to 1) help communicate state-of-the-art water/road interaction information effectively among field personnel, 2) identify knowledge gaps, and 3) provide a framework for addressing future research, development and technology needs on this subject.

587) Cordone, A.J., and D.W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. California Fish and Game. 47: 189-228. (I)

Author abstract (Author Scope): This report is essentially a review of investigations made of the effects of inorganic sediment on the aquatic life of streams. It is not a complete literature review but rather a summary of most of the pertinent investigations that we believe will assist the fisheries worker faced with sediment problems. No references are included on studies of any type of chemical pollutants even though the waste material contained large amounts of sediment, such as when tailings from heavy-metal mining operations are discharged to waterways. In such cases, the physical influence of inorganic sediment on aquatic life cannot readily be separated from damage done by toxic heavy metals in solution. This is true also for chemicals used in floatation processes during mineral extraction.

Of fundamental importance in comprehending the modes by which sediment modifies the aquatic habitat is knowledge of the physical nature of sediment and its movements in flowing waters. Sediment arises from a multitude of soil types, varies greatly in shape, size and density, and enters flowing waters which vary in velocity, temperature, flow, and turbulence. The complex problems involved here are studied by the geologist, the soil scientist, and the hydraulic engineer. Fisheries biologists working on sedimentation problems should be aware of this work and familiar with the basic concepts of erosion and sedimentation, but a review of the literature on this subject was beyond the scope of this report. We mention it here only to mark its extreme importance.

For comprehensive reviews of the problems created by sediment in our waterways which confront land and water uses other than aquatic life, see Einstein and Johnson (1956) and Gleason (1958). See Cordone (1956) for a review of the literature on the effects of logging on fish production.

Detailed physical descriptions of how rainfall and runoff erode soil were presented by Osborn (1955) and Gottschalk and Jones (1955). These reports are helpful in understanding the factors governing sediment movement into or within a streambed.

588) Fischer, R.A., and J.C. Fischenich. 2000. Design recommendations for riparian corridors and vegetated buffer strips. US Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, Mississippi, ERDC TN-EMRRP-SR-24. 17pp. (B, C, F, I, J)

Compiler abstract: Effective riparian buffers are those that are designed to meet specific management objectives, such as protection of water quality, wildlife habitat, or steam bank stabilization. As a result, there is no one-size-fits-all riparian buffer that can achieve all objectives. General design criteria for riparian buffers include placement within watersheds, composition and density of vegetation, buffer width and length, and slope. For example, buffers along headwater streams (i.e. 1^{st}-3^{rd} order) are the most effective for protecting water quality, and continuous buffers are more effective at moderating stream temperatures and reducing gaps in protection from non-point source pollution. The authors summarize recommended buffer widths identified in the scientific literature for various management objectives. Tables of recommended buffer widths are provided for water quality considerations; for maintaining plant species diversity, reptiles and amphibians, mammals, invertebrates, fish, and birds; stream stabilization; flood attenuation; and detrital input. The authors also identify the relative effectiveness of different vegetation types (i.e. grass, shrub, tree) for specific benefits, such as stabilizing bank erosion, trapping sediment, filtering nutrients, preventing bank failures, providing aquatic habitat, providing wildlife habitat, providing visual diversity, and providing economic products.

589) Fortino, K., A.E. Hershey, and K.J. Goodman. 2004. Utility of biological monitoring for detection of timber harvest effects on streams and evaluation of Best Management Practices: A review. Journal of the North American Benthological Society. 23: 634-646. (C, I)

Author abstract: Best Management Practice (BMP) guidelines have been developed to reduce the negative impacts of timber harvest on streams. BMPs are widely implemented, but the effectiveness of timber harvest BMPs has not been evaluated using modern biological monitoring techniques. Most current biological monitoring is based on 1 of 2 main approaches: multimetric monitoring or predictive modeling. These approaches differ considerably, and their respective merits and failings have been debated extensively in the literature. Our review evaluated the ability of these biological monitoring approaches to detect timber harvest effects and to assess the effectiveness of BMPs. Both techniques detect impairment via changes in macroinvertebrate community structure, despite their differences in approach. Most of the negative effects of timber harvest result in changes in the macroinvertebrate community, so we have concluded that both techniques should be effective for the evaluation of timber harvest and BMPs.

590) Gende, S.M., R.T. Edwards, M.F. Willson, and M.S. Wipfli. 2002. Pacific salmon in aquatic and terrestrial ecosystems. BioScience. 52: 917-928. (C, D, E)

Compiler abstract: Salmon runs have been declining for many years in the Pacific Northwest. Interest in preserving these runs and the importance of salmon derived nutrients has sparked much research on the impacts of salmon on both freshwater and riparian communities. This article reviews what is currently understood about how salmon can function as important elements in ecological systems. Focus is directed on five species of Pacific salmon which have similar life histories: chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), sockeye (*O. nerka*), chum (*O. keta*), and pink (*O. gorbuscha*). The authors expand on previously written reviews involving salmon and include current research that has changed and expanded earlier notions about how salmon contribute to ecosystem processes. The authors also give details on the magnitude, composition, and distributions of salmon inputs into both terrestrial and aquatic systems and consider how natural variations may affect them. A schematic is drawn based on previously conducted studies, which depicts the pathways and products of salmon-derived nutrients and how they are retained in other systems. The authors discuss how variation in salmonid ecosystems could influence the efforts of managers and conservationists and offer some new direction for research to fill in existing gaps in our understanding.

591) Gomi, T., R.C. Sidle, and J.S. Richardson. 2002. Understanding processes and downstream linkages of headwater systems. BioScience. 52: 905-916. (A, B, C, D, E, F, G, H, I, J)

Compiler abstract: The authors of this article state that the roles of headwater streams in a watershed and the linkages between headwaters and down stream systems are poorly understood. The objectives of this article as per the authors are to review characteristics of headwaters and larger watershed systems and the differences that exist between them. The authors also demonstrate both spatial and temporal variations of biological and geomorphic processes in headwater systems and how they link to downstream systems. The primary area of focus in this article is on steep headwater systems of >4^{o} gradient in forested areas. The authors cite many studies conducted in this area of research and present an informative table of characteristics of hydrological, biological, and geomorphic processes that occur specifically in the Pacific Northwest. Conclusions reached by the authors are bulleted points on how headwater systems are characterized by the above mentioned processes that occur in and along hillslopes, transition channels, zero-order basins, and first- and second-order channels. One such conclusion is that the expansion of hydrologically active areas increases the chance of mass movements and can alter the flow paths between the aquatic and terrestrial environments in periods of increasing wetness. Conclusions are also offered as to how hydrological, geomorphic, and biological processes are affected by headwater tributaries that flow into the downstream reaches. One such example is that spatial and temporal variations in processes that occur in headwater streams are critical in the dynamics of the ecosystems of streams and can affect the heterogeneity of channel networks in riparian and riverine landscapes.

592) Gregory, S.V., K.L. Boyer, and A.M. Gurnell (Editors). 2003. The ecology and management of wood in world rivers. American Fisheries Society, Bethesda, Maryland, Symposium 37. 444pp. (D)

Electronic abstract: This book is the proceedings of the "International Conference on Wood in World Rivers" held in Corvallis, Oregon. The volume (1) synthesizes world knowledge about large wood in streams and rivers in relation to physical and ecological processes and stream restoration; (2) presents the status of knowledge of the physical dynamics and ecological interactions of large wood in streams and rivers in different geographical regions; (3) creates a framework for interpreting and potentially applying the results of research in different geographical regions and management systems; (4) identifies different management systems for large wood in rivers; (5) assesses physical and biological responses of large wood in stream restoration; and (6) explores links between primary information of the physical and ecological dynamics of large wood resource management systems, and the communities and cultures in which they are applied.

593) Gregory, S.V., A.M. Gurnell, K.J. Gregory, S. Bolton, L.A. Medvedeva, A. Semenchenco, A.N. Mahkinov, D. Sobota, J. Baurer, and K. Staley. 2000. Bibliography: World literature on wood in streams, rivers, and riparian areas. International Conference on Wood in World Rivers, 23-27 October 2000, Oregon State University, Corvallis. 74pp. (D)

Compiler abstract: This bibliography is the first draft of an effort by researchers in the United States, England, and Russia to assemble a comprehensive bibliography of wood in aquatic systems and riparian areas as part of the International Conference on Wood in World Rivers. The document contains 1,192 citations.

594) Gurnell, A.M., H. Piégay, F.J. Swanson, and S.V. Gregory. 2002. Large wood and fluvial processes. Freshwater Biology. 47: 601-619. (A, D, G, I)

Electronic abstract:

1. Large wood forms an important component of woodland river ecosystems. The relationship between large wood and the physical characteristics of river systems varies greatly with changes in the tree species of the marginal woodland, the climatic and hydrological regime, the fluvial geomorphological setting and the river and woodland management context.
2. Research on large wood and fluvial processes over the last 25 years has focussed on three main themes: the effects of wood on flow hydraulics; on the transfer of mineral and organic sediment; and on the geomorphology of river channels.
3. Analogies between wood and mineral sediment transfer processes (supply, mobility and river characteristics that affect retention) are found useful as a framework for synthesising current knowledge on large wood in rivers.
4. An important property of wood is its size when scaled to the size of the river channel. 'Small' channels are defined as those whose width is less than the majority of wood pieces (e.g. width < median wood piece length). 'Medium' channels have widths greater than the size of most wood pieces (e.g. width < upper quartile wood piece length), and 'Large' channels are wider than the length of all of the wood pieces delivered to them.
5. A conceptual framework defined here for evaluating the storage and dynamics of wood in rivers ranks the relative importance of hydrological characteristics (flow regime, sediment transport regime), wood characteristics (piece size, buoyancy, morphological complexity) and geomorphological characteristics (channel width, geomorphological style) in 'Small', 'Medium' and 'Large' rivers.
6. Wood pieces are large in comparison with river size in 'small' rivers, therefore they tend to remain close to where they are delivered to the river and provide important structures in the stream, controlling rather than responding to the hydrological and sediment transfer characteristics of the river.
7. For 'Medium' rivers, the combination of wood length and form becomes critical to the stability of wood within the channel. Wood accumulations form as a result of smaller or more mobile wood pieces accumulating behind key pieces. Wood transport is governed mainly by the flow regime and the buoyancy of the wood. Even quite large wood pieces may require partial burial to give them stability, so enhancing the importance of the sediment transport regime.
8. Wood dynamics in 'Large' rivers vary with the geometry of the channel (slope and channel pattern), which controls the delivery, mobility and breakage of wood, and also the characteristics of the riparian zone, from where the greatest volume of wood is introduced. Wood retention depends on the channel pattern and the distribution of flow velocity. A large amount is stored at the channel margins. The greater the contact between the active channel and the forested floodplain and islands, the greater the quantity of wood that is stored.

595) Heintz, R.A., B.D. Nelson, J. Hudson, M. Larsen, L. Holland, and M. Wipfli. 2004. Marine subsidies in freshwater: Effects of salmon carcasses on lipid class and fatty acid composition of juvenile coho salmon. Tansactions of the American Fisheries Society. 133: 559–567. (C, E)

Author abstract: Returning adult salmon represent an important source of energy, nutrients, and biochemicals to their natal streams and may therefore have a quantitative effect on the energy levels of stream-resident salmonids. We tested this hypothesis by constructing simulated streams for coho salmon *Oncorhynchus kisutch* to which we added 0, 1, and 4 carcasses/m^2 (0, 0.71, and 2.85 kg wet mass/m^2) of pink salmon *O. gorbuscha*. After 60 d we evaluated the lipid class and fatty acid composition of rearing coho salmon from the simulated streams; the lipid content and triacylglycerols of the coho salmon increased with increasing carcass density whereas phospholipids decreased. Increased amounts of triacylglycerols accounted for most of the lipid increase. In addition to increasing in concentration, the fatty acid composition of the triacylglycerols also changed with carcass density. Triacylglycerols of juvenile coho salmon from the control streams had significantly higher omega-3 : omega-6 ratios as a result of fivefold and sixfold increases in the concentrations of eicosapentanoic and docosahexanoic fatty acids, respectively. These data demonstrate an immediate nutritional benefit resulting from the introduction of salmon carcasses in juvenile coho salmon rearing habitat and indicate the utility of fatty acid and lipid class analysis for examining the effects of marine-derived nutrients on juvenile salmonids.

596) Kahler, T.H., and T.P. Quinn. 1998. Juvenile and resident salmonid movement and passage through culverts. Research Report No. WA-RD 457.1 written by the Fisheries Research Institute, School of Fisheries, and the Washington State Transportation Center (TRAC), University of Washington, Seattle. Written for the Washington State Department of Transportation, Olympia, Washington, in cooperation with the US Department of Transportation, Federal Highway Administration. Research Project T9903, Task 96. 38pp. (K)

Author abstract: An outcome of the Washington State Department of Transportation's Juvenile Fish Passage Workshop on September 24, 1997, was agreement that a literature review was necessary to determine the state of knowledge about juvenile salmonid movement and passage through culverts at road crossings. This report summarizes the findings of the literature review. The conclusion of this literature review is that stream dwelling salmonids are often highly mobile. Upstream movement was observed in nearly all studies that were designed to detect it, and in all species, age classes, and seasons. There are variations in the movement patterns of fish populations both between and within river systems. The role of turbulence in affecting the ability of fish to pass through culverts is poorly understood and deserves further investigation. Countersunk culverts have proved to be better for fish passage than culverts with or without other modifications for fish passage.

597) Kepkay, M., and J. Cathro. 1998. Riparian ecosystem management literature review. Silva Forest Foundation, Slocan Park, British Columbia, Canada. 21pp. (D, E, I, J)

Author abstract (Author Introduction): The value of a fully functioning ecosystem cannot be overstated. Sensitive ecosystems, such as riparian zones, are especially valuable because of the unique and essential ecological functions they perform. From high elevation sub-alpine tarns to wide intertidal estuaries, riparian ecosystems and the adjacent upland slopes provide protection to a natural system that performs a range of essential ecological functions from providing wildlife habitat to distributing nutrients across the landscape. One study suggests that the cleansing action alone of aquatic zones supported by riparian areas is worth anywhere from $400 to $1,500 per acre, per year (Tellman et al 1993).

This review encompasses a wide body of current literature on the ecological function of riparian ecosystems. The purpose is to examine the scientific rationale behind establishing protected riparian ecosystems, and discuss riparian zone management options in practice today. Specifically, this review is comprised of the following five sections: Section 2 presents several definitions of the term *riparian ecosystem* and explores the particular role this ecosystem plays in the fully functioning forest including wildlife habitat, nutrient cycling, temperature regulation, and movement corridors for plants and animals. Section 3 examines a number of studies which help us to understand the ecological sensitivity to disturbance of riparian ecosystems, including windthrow, stream bank wasting, and downstream sedimentation. Section 4 discusses the effects of modification, in particular logging, on riparian ecosystem ecological function. Several studies that focus on the impact of industrial modification on the ecological function of riparian ecosystems are examined. Section 5 documents selected riparian ecosystem management policies in place in North America today, with special attention paid to the protective riparian buffer widths recommended in the Forest Practices Code of British Columbia.

We hope that this literature review will help clarify the importance of protecting fully functioning riparian ecosystems within an adequate margin of safety. In this light, timber management may progress towards truly ecologically responsible practices.

598) **Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. Transactions of the American Fisheries Society. 129: 262-281. (B)**

Author abstract: Much of the recent literature on salmonid spawning gravels has been devoted to the search for a single statistic drawn or computed from the streambed particle size distribution to serve as an index of gravel quality. However, a natural gravel mixture cannot be fully described by any single statistic, because gravel requirements of salmonids differ with life stage, and thus the appropriate descriptor will vary with the functions of gravel at each life stage. To assess whether gravels are small enough to be moved by a given salmonid to construct a redd, the size of the framework gravels (the larger gravels that make up the structure of the deposit) is of interest, and the *d50 or d84* of the study gravel (the sizes at which 50% or 84% of the sediments are finer) should be compared with the spawning gravel sizes observed for the species elsewhere. To assess whether the interstitial fine sediment content is so high as to interfere with incubation or emergence, the percentage of fine sediment of the potential spawning gravel should be adjusted for probable cleansing effects during redd construction, and then compared with rough standards drawn from laboratory and field studies of incubation and emergence success. An assessment should also consider that the fine sediment content of gravel can increase during incubation by infiltration, that the gravels may become armored over time, or that downwelling and upwelling currents may be inadequate. These considerations are incorporated in a ninestep, life-stage-specific assessment approach proposed here.

599) **Lassettre, N.S. 1999. Annotated bibliography on the ecology, management, and physical effects of large woody debris (LWD) in stream ecosystems. Written by the Department of Landscape Architecture and Environmental Planning, University of California, Berkeley. Written for the California Department of Forestry. 124pp. (A, D, F)**

Compiler abstract: This annotated bibliography focuses on large woody debris (LWD) and its interaction with stream ecosystems. The bibliography is indexed by various categories, including: LWD dynamics and functions (e.g. abundance, accumulation rate, bar formation, bedload transport, sediment storage, wood movement); various fish species referenced in the citations; geomorphic function of LWD; harvesting impacts on LWD; various water bodies (e.g. lakes, high mountain streams, coastal streams); locations referenced in the citations (i.e. states and countries); log jams; logging debris; macroinvertebrates; tree species referenced in the citations; and various forest types referenced in the citations (e.g. old growth forests, mixed-conifer forests, northern hardwoods, deciduous forests).

600) Lisle, T.E. 1983. The role of structure in the physical habitat of anadromous salmonids. In: Report of the First California Salmon and Steelhead Restoration Conference, 22-23 January 1983, Bodega Bay, California. C. Toole, B. Wyatt, S. Sommarstrom, and K. Hashagen, Editors. California Sea Grant College Program. Pages 43-46. (A, D, G)

Author abstract: A fundamental difference between a canal and a natural stream is structure. Structure includes all the typical anomalies of natural streams that deflect the general downstream flow, such as bends, bars, bedrock knobs, boulders, landslide deposits, and large woody debris. This results in the storage of watershed products in the channel, and in a great heterogeneity in depth, velocity, stream gradient, and substrate conditions. In this paper, I will discuss these functions of structure in salmon habitat and some implications for restoration of habitat.

601) Lisle, T.E. 1987. Overview: Channel morphology and sediment transport in steepland streams. In: Erosion and Sedimentation in the Pacific Rim. Proceedings of the Corvallis Symposium, August 1987, Corvallis, Oregon. R. Beschta, T. Blinn, G. E. Grant, F. J. Swanson, and G. G. Ice, Editors. International Association of Hydrological Sciences Publication No. 165. Pages 287-297. (A)

Author abstract: New understanding of how steepland channels are formed is being pursued over a large range of scales, from entrainment of bed particles to the transfer of stored sediment down channel systems. Low submergence of bed particles during transport and wide heterogeneity in particle sizes strongly affect bedload transport. At the scale of a reach, scour-lobes are becoming widely recognized as common constructional units governing behavior of braided, meandering, and pool-riffle channels. Channel morphology and sediment transport can be radically altered by infrequent debris flows and torrents, however, which provide a common linkage between mass movement on hillslopes and sediment transport in channels. Because of the impracticality of monitoring the downstream progress of sediment over meaningful periods, sediment routing is best approached by mathematical models that incorporate the age and volume of sediment in storage reservoirs.

602) Lisle, T.E. 2002. How much dead wood in stream channels is enough? 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 85-93. (D)

Author abstract: Private forest managers often seek guidelines on how much dead wood should be retained in streams in order to adequately fulfill ecosystem functions. There are three approaches to answering this question for a particular reach of channel. The first approach uses an understanding of *ecologic functions* of dead wood in streams to determine the amount needed to fulfill ecologic and geomorphic functions. This approach fails because the complexities of sizes, shapes, and arrangements of dead wood in a variety of lotic ecosystems overwhelm any scientific specification of target loadings. Another approach uses *reference loadings* to evaluate departures in amounts of dead wood in streams from reference amounts in unaltered systems. A precise threshold cannot be defined using this approach because dead wood volumes are highly variable, even within pristine channels in similar settings, and distributions for managed and pristine channels overlap. A third approach constructs a *wood budget* by evaluating past, present, and projected supplies in streams and riparian areas. This is a cumulative-effects analysis that shifts the focus from channels to riparian forests. In combination, the three approaches provide the best information to determine how much wood is enough, but they do not offer simple, formulaic prescriptions. The demands for performing the necessary analyses before harvesting riparian wood suggest that management of riparian forests will continue to be guided most often by general prescriptions.

603) Luce, C.H., and T.A. Black. 2001. Spatial and temporal patterns in erosion from forest roads. In: Influence of Urban and Forest Land Uses on the Hydrologic-Geomorphic Responses of Watersheds. M.S. Wigmosta and S.J. Burges, Editors. Water Resources Monographs, American Geophysical Union, Washington, D.C. Pages 165-178. (K)

Author abstract: Erosion from forest roads is an important contribution to the sediment budget of many forested basins, particularly over short time scales. Sediment production from 74 road segments was measured over three years to examine how road slope, segment length, cutslope height, and soil texture affect sediment production and how these relationships change with time. In the first year, differences in sediment production between plots could be explained by differences in sediment transport capacity of the plots. With time, differences between plots of different slope, length, cutslope height, and soil were reduced as all plots produced less and less sediment. Recovery was rapid with around 70% recovery between by the second year and 90% recovery by the third year.

604) McCullough, D.A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to chinook salmon. US Environmental Protection Agency, Water Division, Region 10, Seattle, Washington, Water Resources Assessment EPA 910-R-99-010. 279pp. (J)

Author abstract (from author Introduction): The objectives of this review of the literature are to: (1) interpret and synthesize the literature on temperature effects to salmonids and other coldwater species and their life stages, (2) consider not simply effects during a single short-term exposure to a sustained high temperature but effects of altered temperature regimes under short-term and long-term exposure to constant or fluctuating temperatures, (3) compare and contrast response to temperature of several coldwater fish species, stocks, or family groups, (4) recommend standards that are biologically defensible, (5) review and recommend methods for evaluating water temperature regime to determine whether it meets biological requirements.

To meet these objectives this review will focus on the life stages of spring chinook (*Oncorhynchus tshawytscha*) as a template. Upon this foundation the results and conclusions from related studies on other coldwater fish species will be evaluated. This approach to review of salmonid response is reasonable because of the high degree of similarity exhibited among these species. Frequently, it will be found that when information on certain effects of temperature are lacking in chinook technical literature, information will be available for other salmonids. Taking the salmonid literature as a whole and by comparing and contrasting, the understanding of response to thermal experience by salmon and trout can become very robust. Selected coldwater non-salmonid literature will be considered to indicate those temperature conditions that both salmonids and other coldwater species would find suitable. Temperature requirements for common warmwater exotic species will also be noted to indicate the ecological problems faced by salmonids in competitive and predator-prey interactions and to provide a relative index by which to judge salmonid requirements (e.g., contrasting optimum conditions for coldwater and warmwater fishes). Significant differences among salmonids occur frequently via separate life histories. For example, spring chinook, which immigrate in the spring and spawn in 3rd to 5th order streams, face different migration and adult holding temperature regimes because of life history variation, fish size, and habitat selection than do summer or fall chinook, which spawn in streams of 5th order or greater as a rule. However, for similar life stages experiencing the same thermal regime (e.g., if spring and summer chinook juveniles have overlapping habitats), biological responses do not vary so much that different temperature standards are warranted, with a few exceptions.

It is important to gain a comprehensive understanding of responses to temperature regimes in order to adequately evaluate their suitability with respect to a given life stage or the entire life cycle. This kind of understanding can only be gained by synthesizing both field and laboratory observations. This review is an attempt to synthesize experience on salmonids during their life stages and their associated responses (avoidance, preference, growth, survival, reproductive success, migration (upstream, downstream, intrabasin) success, disease, feeding, territoriality, aggressiveness). All of these aspects of fish ecology are useful in identifying temperature requirements and the potential consequences of temperature modification. Cursory evaluations of the literature can be prone to overlooking synergistic effects, cumulative effects during the life cycle, and can mistake tolerable for optimal in the short term and long term.

605) Moore, K., M. Furniss, S. Firor, and M. Love. 1999. Fish passage through culverts: An annotated bibliography. Six Rivers National Forest Watershed Interactions Team, Eureka, California. 38pp. (K)

Author abstract: This bibliography includes 96 annotated citations on culvert design for fish passage, risk analysis, and fish swimming ability. This collection is a subset of a larger bibliography on culverts and sizing, repair, maintenance, installation, failure, hydraulics, and hydrology. Author's abstracts were included if available, if not, each paper was read and abstracted. This work was funded, in part, by the San Dimas Technology and Development Center of the USDA-Forest Service. See also: Copstead, Moore, Ledwith and Furniss. 1998. Water/road interaction: An annotated bibliography. Water/road interactions technology series. USDA Forest Service, Technology and Development Program. (http://www.stream.fs.fed.us/water-road).

606) Naiman, R.J., R.E. Bilby, and P.A. Bisson. 2000. Riparian ecology and management in the Pacific coastal rain forest. BioScience. 50: 996-1011. (A, C, D, F, H)

Compiler abstract: Because riparian areas are so ecologically complex, there have been large research efforts on a global scale to understand the dynamics and managerial consideration in the last twenty years. In this article, the authors summarize the research advances that have been made in the last ten years on the understanding of the ecology of riparian zones in the Pacific coastal ecoregion. This article also focuses on how the advances made have contributed overall to better stream and watershed management. The authors discuss what was known about riparian zones before the 1990s and then delve into the important advances that have been made in the last ten years. Specifically the authors discuss watershed processes, debris flows, large woody debris, riparian plants, forest structure, species richness, microclimes, and exotic plants. Hyporheic zones are also considered, as well as how animals use and shape riparian corridors. Several schematic drawings are included to depict relationships among processes and disturbance regimes in riparian systems. Graphs are also included which show the relationship between many factors (such as tree height and soil moisture) that are integral parts of riparian ecosystems. Management implications for riparian zones are also discussed.

607) Nakano, S., and M. Murakami. 2001. Reciprocal subsidies: Dynamic interdependence between terrestrial and aquatic food webs. Proceedings of the National Academy of Sciences. 98: 166-170. (C)

Author abstract: Mutual trophic interactions between contiguous habitats have remained poorly understood despite their potential significance for community maintenance in ecological landscapes. In a deciduous forest and stream ecotone, aquatic insect emergence peaked around spring, when terrestrial invertebrate biomass was low. In contrast, terrestrial invertebrate input to the stream occurred primarily during summer, when aquatic invertebrate biomass was nearly at its lowest. Such reciprocal, across-habitat prey flux alternately subsidized both forest birds and stream fishes, accounting for 25.6% and 44.0% of the annual total energy budget of the bird and fish assemblages, respectively. Seasonal contrasts between allochthonous prey supply and *in situ* prey biomass determine the importance of reciprocal subsidies.

608) O'Loughlin, C., and R.R. Ziemer. 1982. The importance of root strength and deterioration rates upon edaphic stability in steepland forests. In: Proceedings of I.U.F.R.O. Workshop P.1.07-00, Ecology of Subalpine Ecosystems as a Key to Management, 2-3 August 1982, Oregon State University, Corvallis. 70pp. (K)

Author abstract: The additional strength provided by roots to the soil is generally considered to be in the form of a cohesive strength hC which may range in magnitude from 1 kPa to 20 kPa. Studies of the tensile strength of tree roots show that small roots sampled from living trees range in mean tensile strength from about 10 MPa to about 60 MPa. After tree felling small roots lose their strength at average rates between 300 and 500 kPa per month. Root biomass also decreases rapidly after clearfelling. The reduction in K after forest removal is a prime cause of landsliding on many steep slopes.

609) Oregon Forest Industries Council and Washington Forest Protection Association. 2000. Annotated bibliography: Information and studies relevant to temperature, salmonids, and water quality. Written for the US Environmental Protection Agency, Region 10; the U.S. Fish and Wildlfie Service; and the National Marine Fisheries Service. 32pp. plus 5 page cover letter. (A, H, J)

Author abstract (Author Introduction): This annotated bibliography of *Information and Studies Relevant to Temperature, Salmonids, and Water Quality* has been prepared in response to the April 20, 2000 request by the US EPA Region 10; the States of Oregon, Washington, and Idaho; and the US Fish and Wildlife Service and the National Marine Fisheries Service. It was prepared as a joint effort of the Oregon Forest Industries Council, the Washington Forest Protection Association, and their members.

The information and studies are relevant to the interagency regional temperature criteria guidance development project. All are believed to be pertinent to the regional temperature criteria guidance that US EPA expects to deliver to states and tribes, and any proposed revisions by US EPA to temperature standards in the Pacific Northwest. None of the information and studies included in this annotated bibliography is included in the Literature List currently in possession of the project's Technical Workgroup.

The annotated bibliography is organized primarily by the six categories of information that are of special interest to US EPA Region 10:

1. Physiological response of salmonids to water temperature.
2. Behavioral responses of salmonids to water temperature.
3. Changes in salmonid population distributions attributable to changes in water temperature.
4. Multiple stressors that may interact with water temperature to affect salmonids.
5. Expected patterns of water temperature across space and time at multiple scales and anthropogenic changes thereto (including cumulative effects).
6. Measurement and monitoring of water temperature.

Within each of the six information categories, information and studies are listed by title. Each contribution contains:

1. A complete bibliographic citation.
2. A statement of the objectives or subjects addressed.
3. A summary of the significant findings.
4. A conclusion suggesting the relevance of the information to the regional temperature criteria guidance development project.

Full copies of cited papers, reports, and pertinent excerpts are included in a separate attachment.

Note: The cover letter attached to this bibliography contains the key findings that the authors recommended be incorporated into the development of regional temperature standards.

610) Pentec Environmental, Inc. 1991. The importance of riparian vegetation to salmonid habitat in lakes and estuaries. Project No. 44-004 Information Report written by Pentec Environmental, Inc., Edmonds, Washington. Written for Sealaska Corporation, Juneau, Alaska. 13pp. (C, D, F, H, J)

Compiler abstract: The riparian standard (i.e. 66-ft buffer) mandated by the 1990 revised Alaska Forest Resources and Practice Act (FRPA) along Type A water bodies on private land is intended to protect fish habitat and water quality from potential adverse effects of timber harvest. The riparian standard was designed to maintain physical and biological functions of stream habitats because most of the anadromous fish spawning and rearing habitat is located in streams. Many of the physical and biological functions intended to be maintained by FRPA through retention of riparian buffers do not apply to lakes and estuaries, and FRPA does not offer guidance on this issue. This report identifies physical and biological relationships between riparian vegetation and fish habitats in both lakes and estuaries, and provides an evaluation of the importance of these relationships to salmonid habitat. Salmonid habitat features discussed in this report include: (1) influence of shading on water temperature and hiding cover, (2) influence of slope stabilization, (3) influence of debris input as hiding cover and as a detrital food source, and (4) influence of riparian vegetation as habitat for salmonid predators.

611) Poole, G.C., and C.H. Berman. 2001. An ecological perspective on in-stream temperature: Natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management. 27: 787-802. (A, G, H, J)

Author abstract: While external factors (drivers) determine the net heat energy and water delivered to a stream, the internal structure of a stream determines how heat and water will be distributed within and exchanged among a stream's components (channel, alluvial aquifer, and riparian zone/floodplain). Therefore, the interaction between external drivers of stream temperature and the internal structure of integrated stream systems ultimately determines channel water temperature. This paper presents a synoptic, ecologically based discussion of the external drivers of stream temperature, the internal structures and processes that insulate and buffer stream temperatures, and the mechanisms of human influence on stream temperature. It provides a holistic perspective on the diversity of natural dynamics and human activities that influence stream temperature, including discussions of the role of the hyporheic zone. Key management implications include: (1) Protecting or reestablishing in-stream flow is critical for restoring desirable thermal regimes in streams. (2) Modified riparian vegetation, groundwater dynamics, and channel morphology are all important pathways of human influence on channel-water temperature and each pathway should be addressed in management plans. (3) Stream temperature research and monitoring programs will be jeopardized by an inaccurate or incomplete conceptual understanding of complex temporal and spatial stream temperature response patterns to anthropogenic influences. (4) Analyses of land-use history and the historical vs. contemporary structure of the stream channel, riparian zone, and alluvial aquifer are important prerequisites for applying mechanistic temperature models to develop management prescriptions to meet in-channel temperature goals.

612) Rice, R.M., J.S. Rothacher, and W.F. Megahan 1972. Erosional consequences of timber harvesting: An appraisal. In: Proceedings of the National Symposium on Watersheds in Transition. American Water Resources Association, Ft. Collins, Colorado. Pages 321-329. (K)

Author abstract: This paper summarizes our current understanding of the effects of timber harvesting on erosion. Rates of erosion on mountain watersheds vary widely but the relative importance of different types of erosion and the consequences of disturbances remain fairly consistent. Therefore these conclusions seem to be valid for most circumstances: Most of man's activities will increase erosion to some extent in forested watersheds; erosion rarely occurs uniformly; sediment production declines rapidly following disturbance; landslides and creep are the chief forms of natural erosion in mountainous regions; cutting of trees does not significantly increase erosion, but clearcutting on steep unstable slopes may lead to increased mass erosion; accelerated erosion is a possible undesirable side effect of use of fire in conjunction with logging; the road system built for timber harvesting far overshadows logging or fire as a cause of increased erosion; and potentially hazardous areas can be identified in advance of the timber harvest.

613) Schuett-Hames, D., B. Conrad, A. Pleus, and K. Lautz. 1996. Literature review and monitoring recommendations for salmonid spawning gravel scour. Timber, Fish, and Wildlife Ambient Monitoring Program. TFW-AM-9-96-001. 23pp. (A, B)

Author abstract (Author Introduction): Salmonid eggs and larvae undergo a critical period of early development while buried in stream bed gravel. During this time eggs and alevin are vulnerable to scour and disturbance of the stream bed. Mortality at this early stage in the life cycle can affect recruitment to later life stages. Scour to the depth of salmonid egg pockets typically occurs during peak discharges when bedload transport processes are active. The magnitude and frequency of peak flow discharge and sediment transport are influenced by watershed conditions that affect the hydrologic and sediment regimes. A variety of land-use activities alter peak flows and sediment transport dynamics. The Watershed Analysis fish habitat module recommends using information on the frequency of redd scour to identify potential changes in peak flow hydrology and channel stability, but does not contain methods to document scour. A standard procedure is needed to assess and monitor spawning gravel scour in the context of Watershed Analysis.

The purpose of this report is to: 1) present information on scour from the literature; 2) identify the features required in a scour monitoring method for Watershed Analysis; 3) identify key issues that need to be resolved in the development of a scour method; 4) examine how existing studies have addressed these issues, and 5) make recommendations for the design of the Watershed Analysis scour module.

614) Sullivan, K., T.E. Lisle, C.A. Dolloff, G.E. Grant, E. Gordon, and L.M Reid. 1987. Stream channels: The link between forests and fishes. In: Streamside Management: Forestry and Fishery Interactions. Proceedings of a symposium, 12-14 February 1986, University of Washington, Seattle. E.O. Salo and T.W. Cundy, Editors. Institute of Forest Resources, Seattle, Washington, Contribution No. 57. Pages 39-97. (A, D, F, G, I)

Author abstract: The hydraulic characteristics of flow through channels are an important component of fish habitat. Salmonids have evolved in stream systems in which water velocity and flow depth vary spatially within the watershed and temporally on a daily, seasonal, and annual basis. Flow requirements vary during different phases of the freshwater life cycle of salmonids: free passage is necessary during migration of adults; clean and stable gravel beds ensure successful incubation of eggs; and adequate velocity and depth of flow provide space for summer rearing and overwintering. The life cycles of salmonid species have adapted to the temporal variations in flow conditions by timing the phases of the life cycle to take advantage of the seasonal discharge characteristics. Spatial variability enhances species diversity by creating a variety of habitats within stream reaches; these are partitioned among individual species and age groups having different tolerances for velocity, depth, and cover conditions.

Channel morphology is determined largely by sediment and water input to the channels, and is formed during storm events when flow is great enough to transport the coarse sediments lining the channel bed. The resulting channel shape consists of a sequence of recognizable units known as riffles, pools, and boulder cascades. Water flowing down the stream is forced continually to adjust its velocity and depth in response to the changing channel shape: flow is shallow and fast in riffles, and slow and deep in pools. Large obstructions such as woody debris, boulders, and bedrock outcrops alter channel width, increasing the variation in velocity and depth in the vicinity of the obstruction and anchoring the position of pools. Discharge also varies through time, creating additional variations of hydraulic conditions.

Forest management can affect channel morphology by changing the amount of sediment or water contributed to the streams, thus disrupting the balance of sediment input and removal. Excessive input of coarse sediments from landslides can smooth the channel gradient by filling pools. Removing large woody debris from channels reduces sediment storage and eliminates the local hydraulic variability associated with the obstruction. Loss of habitat diversity by either mechanism may reduce or change the fish species found in a stream reach. If the changes result in decreased space, populations may also decrease. Strategies to minimize the effects of land management on channel morphology and fish habitat should include practices that minimize increases in coarse sediment input, and that preserve the morphologic complexity of the channel.

615) Teti, P. 1998. The effects of forest practices on stream temperature: A review of the literature. B.C. Ministry of Forests, Cariboo Forest Region, Williams Lake, British Columbia. 10pp. (J)

Author abstract (Author Introduction): A literature search was done in 1998 by a combination of computer searches at the UBC Library, searches of a personal collection, and a search of the World Wide Web. This yielded more than 40 references spanning 30 years. The list is not considered exhaustive but it is sufficiently complete to reflect the history and current state

of knowledge on the effects of forest management on stream temperature. Emphasis in obtaining and reviewing the references was placed on:

- increases in summertime stream temperature associated with logging, and
- publications from the last 10 years.

The literature review did not address the following topics:

- the biological effects of high stream temperatures on aquatic biology or
- the effect of lakes on stream temperature.

616) Wenger, S. 1999. A review of the scientific literature on riparian buffer width, extent, and vegetation. Written for the Office of Public Service & Outreach, Institute of Ecology, University of Georgia, Athens. 59pp. (D, E, F, H, I, J)

Compiler abstract: This document presents the results of a review of 140 articles and books with the intent to establish a legally-defensible basis for determining riparian buffer width, extent, and vegetation within the state of Georgia. This review document is organized into several sections:

- Background and Introduction;
- Sediment—Including sediment in surface runoff and channel erosion
- Nutrients and other contaminants—Phosphorus, nitrogen, other contaminants such as organic matter and biological contaminants, pesticides and metals;
- Other factors influencing aquatic habitat—Woody debris and litter inputs, temperature and light control;
- Terrestrial wildlife habitat;
- Development of riparian buffer guidelines—Review of models to determine buffer width and effectiveness, factors influencing buffer width, buffer guidelines for water quality protection, other considerations.

Based on the review of the literature, the author proposes three buffer guidelines, all of which are legally defensible based on the scientific literature.

617) Wilson, M., and J.G. Imhof. Undated. Literature review: Overview of the state of the science. An examination of the functions of riparian zones. Written in conjunction with a Riparian Zone Workshop, 28-29 October 1998, Cambridge, Ontario. 31pp. (C, D, F, G, I, J)

Compiler abstract: This document summarizes the natural functions and processes of riparian zones based upon a review of the world literature. Approximately 200 papers, annotated bibliographies and books were reviewed. Based on the review, a subset of 54 papers were summarized in four summary tables: hydrology, geomorphology, water quality and nutrient flux, and ecological characteristics. Two additional tables were also provided:

1. A proposed hierarchy for the determination of the scale of measurement for geographic, geomorphic and biotic data collection and analysis within watershed systems; and
2. Literature derived suggested riparian zone widths for the protection of water quality.

618) Wood, P.J., and P.D. Armitage. 1997. Biological effects of fine sediment in the lotic environment. Environmental Management. 21: 203-217. (A, C, I)

Electronic abstract: Although sedimentation is a naturally occurring phenomenon in rivers, land-use changes have resulted in an increase in anthropogenically induced fine sediment deposition. Poorly managed agricultural practices, mineral extraction, and construction can result in an increase in suspended solids and sedimentation in rivers and streams, leading to a decline in habitat quality. The nature and origins of fine sediments in the lotic environment are reviewed in relation to channel and nonchannel sources and the impact of human activity. Fine sediment transport and deposition are outlined in relation to variations in streamflow and particle size characteristics. A holistic approach to the problems associated with fine sediment is outlined to aid in the identification of sediment sources, transport, and deposition processes in the river catchment. The multiple causes and deleterious impacts associated with fine sediments on riverine habitats, primary producers, macroinvertebrates, and fisheries are identified and reviewed to provide river managers with a guide to source material. The restoration of rivers with fine sediment problems are discussed in relation to a holistic management framework to aid in the planning and undertaking of mitigation measures within both the river channel and surrounding catchment area.

619) Ziemer, R.R. 1981. Roots and the stability of forested slopes. In: Proceedings of the International Symposium on Erosion and SedimentTransport in Pacific Rim Steeplands, 25-31 January 1981, Christchurch, New Zealand. T.R.H. Davies and A.J. Pearce, Editors. International Association of Hydrological Sciences Publication No. 132. Pages 343-361. (K)

Author abstract: Root decay after timber cutting can lead to slope failure. In situ measurements of soil with tree roots showed that soil strength increased linearly as root biomass increased. Forests clear-felled 3 years earlier contained about one-third of the root biomass of oldgrowth forests. Nearly all of the roots < 2 mm in diameter were gone from 7-year-old logged areas while about 30 percent of the < 17 mm fraction was found. Extensive brushfields occupied areas logged 12 to 24 years earlier. The biomass of brushfield roots < 2 mm in diameter was 80 percent of that in the uncut forest, and fewer large roots were found there than in the forest. Roots < 17 mm in diameter in the brushfield accounted for 30 percent of that found in the forest, and for total root biomass, only 10 percent. Individual, live brush roots were twice as strong as conifer roots of the same size. This difference may partially compensate for reduced root biomass in brushfields. Net strength of the soil-root matrix in brushfields was about 70 percent of that in uncut forests. If soils are barely stable with a forest cover, the loss of root strength following clear-felling can seriously.

620) Ziemer, R.R. 1981. The role of vegetation in the stability of forested slopes. In: Proceedings of the International Union of Forestry Research Organizations, XVII World Congress, 6-17 September 198l, Kyoto, Japan. Volume I: 297-308. (K)

Author abstract (Author Summary): Vegetation helps stabilize forested slopes by providing root strength and by modifying the saturated soil water regime. Plant roots can anchor through the soil mass into fractures in bedrock, can cross zones of weakness to more stable soil, and can provide interlocking long fibrous binders within a weak soil mass. In Mediterranean-type climates, having warm, dry summers, forest evapotranspiration can develop a substantial soil moisture deficit which can reduce both piezometric head and slope mass. Pore water pressures change seasonally in response to precipitation and are often the driving mechanism which ultimately leads to slope failure. When trees are cut, the root system begins to decay, and the soil-root fabric progressively weakens. The loss of root strength or increased soil moisture content or both after-tree removal can lower the slope safety factor sufficiently that a moderate storm and associated rise in pore water pressure can result in slope failure. After trees are removed, the frequency of landslides can increase.

621) Ziemer, R.R., J. Lewis, T.E. Lisle, and R.M. Rice. 1991. Long-term sedimentation effects of different patterns of timber harvesting. In: Proceedings of the Symposium on Sediment and Stream Water Quality in a Changing Environment: Trends and Explanation. XX General Assembly, International Union of Geodesy and Geophysics, 11-24 August 1991, Vienna, Austria. International Association of Hydrological Sciences Publication No. 203. Pages 143-150. (B, I)

Author abstract: It is impractical to address the long-term effect of forest management strategies on erosion, sedimentation, and the resultant damage to fish habitat experimentally because to do so would require studying large watersheds for a century or more. Monte Carlo simulations were conducted on three hypothetical 10 000 ha, fifth-order forested watersheds. One watershed was left undisturbed, one was completely clearcut and roaded in a decade, and one was cut at the rate of 1% each year. Each cutting strategy was repeated in succeeding centuries.

ACKNOWLEDGEMENTS

This project was funded by an ACMP Coastal Nonpoint Source Pollution (Section 6217) Grant through the Alaska Clean Water Actions (ACWA) Program, with in-kind contributions by the Alaska Department of Natural Resources, Division of Forestry; the Tanana Chiefs Conference, Forestry Program; the Alaska Department of Natural Resources, Office of Habitat Management and Permitting; Cook Inlet Keeper; and the Northern Alaska Environmental Center. We thank the following people for reviewing draft versions of this bibliography: Martha Welbourn Freeman, Doug Hanson, Jeff Davis, Sue Mauger, Nancy Fresco, Bruce Johnson, James Durst, and Doug Martin.

APPENDIX

Reference Location Matrix

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A (channel morphology)	B (clean spawning gravels)	C (food sources)	D (large woody debris)	E (nutrient cycling)	F (stream bank stability)	G (stream flow)	H (sunlight)	I (water quality)	J (water temperature)	K (other)
Abbe, T.B., and D.R. Montgomery. 1996	358						X			X			X							
Abbe, T.B., and D.R. Montgomery. 2003	359						X			X			X							
Abe, K., and R.R. Ziemer. 1991	360						X													X
Abe, K., and R.R. Ziemer. 1991	574								X											
Abernethy, B., and I.D. Rutherfurd. 1998	543							X							X					
Abernethy, B., and I.D. Rutherfurd. 2000	544							X							X					
Abernethy, B., and I.D. Rutherfurd. 2000	545							X							X					
Acker, S.A., S.V. Gregory, G. Lienkaemper, W.A. McKee, F.J. Swanson, and S.D. Miller. 2003	361						X						X							
Alabyan, A.M., and R.S. Chalov. 1998	575								X	X						X				
Aldrich, J.W., and C.W. Slaughter. 1983	159			X																X
Aldrich, J.W., and R.A. Johnson. 1979	160			X																X
Allan, J.D., M.S. Wipfli, J.P. Caouette, A. Prussian, and J. Rodgers. 2003	1	X										X								
Amaranthus, M.P., R.M. Rice, N.R. Barr, and R.R. Ziemer. 1985	362						X													X
Anderson, D.M., and L.H. Macdonald. 1998	546							X												X
Anderson, G.S. 1970	161			X												X				
Anderson, L., and M. Bryant. 1980	576								X											X
Anonymous. 2000	577								X	X		X	X		X					
Arians, A (Compiler). 2003	224				X					X	X	X	X	X	X	X	X	X	X	
Armour, C.L. 1991	578								X										X	
Arscott, D.B., K. Tockner, and J.V. Ward. 2001	547							X											X	
Ashton, W.S., and R.F. Carlson. 1984	225				X											X				
Ashton, W.S., and S.R. Bredthauer. 1986	162			X						X					X					
Ashton, W.S. 1983	145		X													X				

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region			Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables										
		I	II	III						A	B	C	D	E	F	G	H	I	J	K
Baeza, C., and J. Corominas. 2001	548							X												X
Balding, G.O. 1976	226				X											X		X		
Bartholow, J.M. 2000	579								X								X		X	
Bartos, L. 1989	2	X														X				
Bartos, L.R. 1993	3	X														X				
Bash, J., C. Berman, and S. Bolton. 2001	363						X											X		
Bates, K., B. Barnard, B. Heiner, J.P. Klavas, and P.D. Powers. 2003	364						X													X
Bauer, S.B., and S.C. Ralph. 1999	227				X					X	X				X	X			X	
Baxter, C.V., and F.R. Hauer. 2000	365						X				X					X				
Baxter, C.V., Frissell, C.A. and F.R. Hauer. 1999	366						X				X									
Beaudry, P.G. 1989	277					X												X		
Beaudry, P.G., and A. Gottesfeld. 2001	278					X				X										
Behlke, C.E., D.L. Kane, R.F. McLean, and M.D. Travis. 1991	228				X															X
Belt, G.H., J. O'Laughlin, and T. Merrill. 1992	580								X			X	X	X	X		X	X	X	
Benda, L., C. Veldhuisen, and J. Black. 2003	367						X			X			X							
Benda, L.E., P. Bigelow, and T.M. Worsley. 2002	368						X						X							
Benson S.L., D.L. Hess, D.F. Meyer, K.A. Peck, and W.C. Swanner. 1997	229				X											X		X		
Berg, N.H., D. Azuma, and A. Carlson. 2002	369						X						X							
Berube, P. and F. Levesque. 1998	279					X														X
Bethlahmy, N. 1975	370						X									X				
Bigelow, B.B., R.D. Lamke, P.J. Still, J.L. Van Mannen, and J.E. Vaill. 1985	230				X											X		X		
Bigelow, B.B., R.D. Lamke, P.J Still, J.L. Van Mannen, and J.E. Vaill. 1986	231				X											X		X		
Bigelow, B.B., R.D. Lamke, P.J. Still, J.L. Van Mannen, and R.L. Burrows. 1989	232				X											X		X		
Bilby, R.E., and G.E. Likens. 1980	371						X					X		X				X		
Bilby, R.E., and P.A. Bisson. 1998	372						X					X	X							
Bilby, R.E., B.R. Fransen, and P.A. Bisson. 1996	373						X					X		X						
Bilby, R.E., E.W. Beach, B.R. Fransen, and J.K. Walter. 2003	374						X							X						
Binkley, D., and T.C. Brown. 1993	375						X											X		
Bird, S.A. 2001	280					X				X			X		X					
Bjornn, T.C., S.C. Kirking, and W.R. Meehan. 1991	4	X																		X

REFERENCE	Ref. No.	AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	A	B	C	D	E	F	G	H	I	J	K
Blevins, V., and R.F. Carlson. 1988	233				X															X
Bonin, H.L., R.P. Griffiths, and B.A. Caldwell. 2000	376						X					X		X						
Boothroyd, I.K.G., J.M. Quinn, E.R. Langer, K.J. Costley, and G. Steward. 2004	549							X		X		X			X		X			
Bovis, M.J., and M. Jakob. 1999	281					X														X
Brabets, T.P. 1995	5	X								X						X		X		
Brabets, T.P. 1996	234				X											X				
Brabets, T.P., B. Wang, and R.H. Meade. 2000	163			X												X		X		
Bragg, D.C., and J.L. Kershner. 2002	581								X				X							
Brardinoni, F., M.A. Hassan, and H.O. Slaymaker. 2002	282					X														X
Braudrick, C.A., and G.E. Grant. 2000	582								X				X							
Braudrick, C.A., and G.E. Grant. 2001	377						X			X			X			X				
Brookshire, E.N.J, and K.A. Dwire. 2003	378						X			X		X	X	X		X				
Brown, G.W. 1969	379						X												X	
Brownlee, K. 1991	6	X										X								
Bryant, M.D. 1980	7	X								X			X							
Bryant, M.D. 1981	8	X																		X
Bryant, M.D. 1984	9	X																		X
Bryant, M.D. 1985	10	X											X							
Bryant M.D., and F.H. Everest. 1998	11	X																		X
Bryant, M.D., B.E. Wright, and B.J. Davies. 1992	12	X								X										
Bryant, M.D., J.P. Caouette, and B.E. Wright	13	X								X										
Bryant, M.D., N.D. Zymonas, and B.E. Wright. 2004	14	X								X										
Bryant, M.D., D.N. Swanston, R.C. Wissmar, and B.E. Wright. 1998	15	X												X				X		
Buffington, J.M., and D.R. Montgomery. 1999	16	X								X	X		X			X				
Buffington, J.M., T.E. Lisle, R.D. Woodsmith, and S. Hilton. 2002	17	X								X			X							
Burns, J.W. 1970	380						X				X							X		
Burns, J.W. 1972	381						X				X	X			X			X		
Burrows, R.L. 1980	164			X											X	X		X		
Burrows, R.L., and P.E. Harrold. 1983	165			X												X		X		
Burrows, R.L., B. Park, and W.W. Emmett. 1979	166			X												X		X		
Burrows, R.L., W.W. Emmett, and B. Parks. 1981	167			X												X		X		

REFERENCE	Ref. No.	AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	A	B	C	D	E	F	G	H	I	J	K
Buttle, J.M., I.F. Creed, and R.D. Moore. 2003	283					X								X		X		X		
Cafferata, P.H., and T.E. Spittler. 1998	382						X													X
Campbell, A.J., and R.C. Sidle. 1985	18	X																X		
Cannon, S.H., R.M. Kirkham, and M. Parise. 2001	383						X													X
Carignan, R., P. D'Arcy, and S. Lamontagne. 2000	284					X											X	X		
Carver, M. 2001	285					X														X
Casagli, N., M. Rinaldi, A. Gargini, and A. Curini. 1999	550							X							X	X				
Cederholm, C.J., and L.M. Reid. 1987	384						X				X		X					X		
Cederholm C.J., L.M. Reid, E.O. Salo. 1980	385						X				X							X		
Cederholm, C.J., R.E. Bilby, P.A. Bisson, T.W. Bumstead, B.R. Fransen, W.J. Scarlett, and J.W. Ward.1997	386						X			X			X			X				
Cenderelli, D.A., and J.S. Kite. 1998	387						X			X								X		
Center for Transportation and the Environment. 2002	583								X											X
Center for Transportation and the Environment. 2002	584								X											X
Chaloner, D.T., and M.S. Wipfli. 2002	19	X										X		X						
Chaloner, D.T., M.S. Wipfli, and J.P. Caouette. 2002	20	X										X		X						
Chaloner, D.T., K.M. Martin, M.S. Wipfli, P.H. Ostrom, and G.A. Lamberti. [2002]	21	X										X		X						
Chaloner, D.T., G.A. Lamberti, R.W. Merritt, N.L. Mitchell, P.H. Ostrom, and M.S. Wipfli. 2004	22	X										X		X						
Cheng, J.D. 1989	286					X										X				
Chew, L.C., and P.E. Ashmore. 2001	287					X				X										
Chikita, K.A., R. Kemnitz, and R. Kumai. 2002	168			X												X		X	X	
Childers, J.M. 1975	235				X					X					X					
Childers, J.M., J.W. Nauman, D.R. Kernodle, and P.F. Doyle. 1977	236				X											X		X		
Church, M., and B. Eaton. 2001	585								X		X		X		X	X		X		
Church, M., and J.M. Ryder. 2001	288					X				X			X		X	X		X		
Clague, J.J., R.J.W. Turner, and A.V. Reyes. 2003	289					X				X					X					
Clark, R.A. 1992	169			X												X				
Clay, J.R. 1973	170			X								X				X	X		X	
Clinton, S. M., R.T. Edwards, and R.J. Naiman. 2002	388						X					X		X				X		
Cole, M.B., K.R. Russell, and T.J. Mabee. 2003	389						X					X						X		
Collier, K.J., and J.N. Halliday. 2000	551							X				X	X	X						
Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002	290					X				X			X							

REFERENCE	Ref. No.	AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	A	B	C	D	E	F	G	H	I	J	K
		Bibliography Section								**FRPA Variables**										
Collins, C.M. 1990	171			X						X					X					
Commandeur, P.R., B.T. Guy, and H. Hamilton. 1996	291					X					X		X					X		
Copstead, R.L. and K. Moore, T. Ledwith, and M. Furniss. 1998	586								X							X		X	X	
Cordone, A.J. and D.W. Kelley. 1961	587								X									X		
Costard, F., L. Dupeyrat, E. Gautier, and E. Carey-Gailhardis. 2003	552							X							X					
Couper, P.R., and I.P. Maddock. 2001	553							X							X					
Cowan, C.A. 1983	172			X								X								
Cowan, C.A., and M.W. Oswood. 1983	173			X								X								
Cowan, C.A., and M.W. Oswood. 1984	174			X								X								
Crenshaw, C.L., H.M. Valett, and J.L. Tank. 2002	390						X					X				X				
Cross, J. 2002	391						X						X				X			
Curran, J.H., and E.E. Wohl. 2003	392						X			X			X			X				
Dahlström, N., and C. Nilsson. 2004	554							X		X			X							
Damian, F. 2003	393						X											X		
Daniels, M.D., and B.L. Rhoads. 2003	394						X			X			X		X	X				
Danylchuk, A.J., and W.M. Tonn. 2003	292					X												X		
Dapporto, S., M. Rinaldi, N. Casagli, and P. Vannocci. 2003	555							X							X					
Darby, S.E., D. Gessler, and C.R. Thorne. 2000	395						X								X					
de Boer, D.H., M. Hassan, B. McVicar, and M. Stone. 2003	293					X				X					X			X		
Deal, R.L. 1997	23	X											X							
Deal, R., M. Wipfli, A. Johnson, T. De Santo, P. Hennon, and T. Hanley. 2001	24	X										X	X		X					
del Rosario, R.B., and V.H. Resh. 2000	396						X			X		X								
DeLong, S.C., S.A. Fall, and G.D. Sutherland. 2004	294					X														X
Dent, C.L., N.B. Grimm, and S.G. Fisher. 2001	397						X							X		X		X		
Dettmers, J.M., D.H. Wahl, D.A. Soluk, and S. Gutreuter. 2001	398						X			X		X		X						
Dhakal, A.S., and R.C. Sidle. 2003	295					X														X
Dietrich, W.E., R. Real de Asua, J. Coyle, B. Orr, and M. Trso. 1998	399						X													X
Díez, J.R., S. Larrañaga, A. Elosegi, and J. Pozo. 2000	556							X		X		X	X							
Dingman, S.L. 1971	175			X												X				
Dingman, S.L. 1973	237				X											X				
Dion, C.A. 2002	238				X							X							X	
Dolloff, C.A. 1983	25	X											X							

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	II	III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Dolloff, C.A. 1986	26	X											X							
Downs, P.W., and A. Simon. 2001	400						X			X			X		X					
Doyle, P.F., and J.M. Childers. 1975	239				X					X					X					
Doyle, P.F., and J.M. Childers. 1976	240				X					X					X					
Duncan, W.F.A., and M.A. Brusven. 1985	27	X																		X
Duncan, W.F.A., and M.A. Brusven. 1986	28	X										X								
Duncan, W.F.A., M.A. Brusven, and T.C. Bjornn. 1989	29	X										X								
Eaton, L.S., B.A. Morgan, R.C. Kochel, and A.D. Howard. 2003	401						X													X
Ebersole, J.L., W.J. Liss, and C.A. Frissell. 2003	402						X			X						X			X	
Edgington, J. 1976	30	X									X									
Edgington, J.R. 1984	31	X									X							X		
Edmundson, J.A. 1997	241				X														X	
Egan, A.F. 1999	403						X											X		
Elliot, S.T. 1986	32	X										X	X							
Elliot, S.T., and D.J. Hubartt. 1984	242				X															X
Emmett, W.W. 1972	243				X					X						X				
Emmett, W.W., R.L. Burrows, and B. Parks. 1978	176			X												X		X		
Environmental Law Institute. 2003	404						X					X	X	X	X			X	X	
Estep, M.A., and R.L. Beschta. 1985	33	X								X			X			X		X		
Everest, F.H., and R.D. Harr. 1982	244				X													X	X	
Everest, F.H., and W.R. Meehan. 1981	245				X					X			X		X			X		
Faustini, J.M., and J.A. Jones. 2003	405						X			X			X		X			X		
Feulner, A.J. 1971	146		X													X		X		
Fischer, R.A. and J.C. Fischenich. 2000	588								X		X	X			X			X	X	
Fischer, R.A., C.O. Martin, and J.C. Fischenich. 2000	406						X											X		
Fish Habitat Analysis Team. 1994	34	X								X	X		X		X			X	X	
Florsheim, J.L., J.F. Mount, and L.T. Rutten. 2000	407						X			X								X		
Flory, E.A., and A.M. Milner. 1999	35	X										X								
Flory, E.A., and A.M. Milner. 2000	36	X										X								
Fortino, K., A.E. Hershey, and K.J. Goodman. 2004	589								X			X						X		
Fox, J.D., Jr. 1989	177			X												X				
France, R. 1997	296					X													X	
France, R.L. 1997	297					X						X	X							
Fransen, P.J.B., C.J. Phillips, and B.D. Fahey. 2000	557							X												X

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	II	III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Freeman, M.W. (ed.). 2000	178			X						X			X		X			X		
Freeman, M.W., and J. Durst (eds.). 2004	147		X							X	X	X	X	X	X	X	X	X	X	
Frey, P.J., E.W. Mueller, and E.C. Berry. 1970	179			X								X						X		
Fuchs, S.A., S.G. Hinch, and E. Mellina. 2003	298					X				X	X	X	X							
Fulton, S., and B. West. 2002	408						X							X		X		X	X	
Furbish, D.J., and R.M. Rice. 1983	409						X											X		
Gatto, L.W. 1984	180			X						X					X					
Gay, G.R., H.H. Gay, W.H. Gay, H.A. Martinson, R.H. Meade, and J.A. Moody. 1998	410						X								X					
Geist, D.R., and D.D. Dauble. 1998	411						X				X					X				
Gende, S.M., R.T. Edwards, M.F. Willson, and M.S. Wipfli. 2002	590								X			X	X	X						
Gende, S.M., T.P. Quinn, M.F. Willson, R. Heintz, and T.M. Scott. 2004	37	X										X		X						
Gillilan, S.E. 1989	38	X										X	X							
Glass, R.L., and T.P. Brabets. 1988	39	X														X		X		
Gluns, D.R. 2001	299					X										X				
Gomi, T., R.C. Sidle, and D.N. Swanston. 2004	40	X									X		X		X			X		
Gomi, T., R.C. Sidle, and J.S. Richardson. 2002	591								X	X	X	X	X	X	X	X	X	X	X	
Gomi, T., R.C. Sidle, M.D. Bryant, and R.D. Woodsmith. 2001	41	X									X	X	X							
Gomi, T., R.C. Sidle, R.D. Woodsmith, and M.D. Bryant. 2003	42	X								X			X							
Graça, M.A.S., R.C.F. Ferreira, and C.N. Coimbra. 2001	558							X		X		X		X						
Grady, J., Jr. 2001	412						X					X								
Grant, G.E., F.J. Swanson, and M. G. Wolman. 1990	413						X			X										
Gregory, S.V., K.L. Boyer, and A.M. Gurnell (editors). 2003	592								X				X							
Gregory, S.V., A.M. Gurnell, K.J. Gregory, S. Bolton, L.A. Medvedeva, A. Semenchenco, A.N. Mahkinov, D. Sobota, J. Baurer, and K. Staley. 2000	593								X				X							
Grissinger, E.H. 1982	414						X								X					
Gritzner, M.L., W.A. Marcus, R. Aspinall, and S.G. Custer. 2001	415						X													X
Grotefendt, R.A. 1996	43	X								X			X		X					
Gucinski, H., M.J. Furniss, R.R. Ziemer, and M.H. Brookes. 2001	416						X			X	X	X	X		X	X	X	X	X	
Gurnell, A.M., H. Piégay, F.J. Swanson, and S.V. Gregory. 2002	594								X	X			X			X		X		

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Gurnell, A.M., G.E. Petts, N. Harris, J.V. Ward, K. Tockner, P.J. Edwards, and J. Kollmann. 2000	559							X		X			X							
Guthrie, R.H. 2002	300					X														X
Guyette, R.P., and W.G. Cole. 1999	301					X							X							
Hagans, D.K., W.E. Weaver, and M.A. Madej. 1986	417						X			X					X			X		
Haggerty, S.M., D.P. Batzer, and C.R. Jackson. 2004	418						X			X		X						X	X	
Hairston-Strang, A.B., and P.W. Adams. 1998	419						X						X							
Halupka, K.C., M.F. Willson, M.D. Bryant, F.H. Everest, and A.J. Gharrett. 2003	44	X																		X
Harding, R.D. 1993	45	X								X			X							
Harr, R.D. 1976	420						X									X				
Harris, A.S., and W.A. Farr. 1974	46	X																		X
Harrold, P.E., and R.L. Burrows. 1983	181			X												X		X		
Hartman, G.F., J.C. Scrivener, and M.J. Miles. 1996	302					X				X	X				X					
Hartman, G.F., J.C. Scrivener, and T.E. McMahon. 1987	303					X							X						X	
Hartman, G.F., L.B. Holtby, and J.C. Scrivener. 1984	304					X													X	
Harvey, B.C. 1998	421						X						X							
Harwood, K., and A.G. Brown. 1993	560							X		X			X			X				
Hauer, F.R., G.C. Poole, J.T. Gangemi, and C.V. Baxter. 1999	422						X			X			X							
Heede, B.H., 1971	423						X													X
Heifetz, J., M.L. Murphy, and K.V. Koski. 1986	47	X								X			X							
Heintz, R.A., B.D. Nelson, J. Hudson, M. Larsen, L. Holland, and M. Wipfli. 2004	595								X			X		X						
Helfield, J.M. 2002	246				X							X	X	X				X		
Hemming, C.R., and W.A. Morris. 1999	182			X														X		
Henderson, G.S., and D.A.A. Toews. 2001	305					X										X		X		
Hennon, P., M. Wipfli, R. Deal, A. Johnson, T. De Santo, M. Schultz, T. Hanley, E. Orlikowska, G. Takashi, M. Bryant, and R. Edwards. 2002	48	X										X	X							
Hess, L.J. 1969	424						X					X								
Hession, W.C., J.E. Pizzuto, T.E. Johnson, and R.J. Horwitz. 2003	425						X			X					X					
Hetrick, N.J., M.A. Brusven, W.R. Meehan, and T.C. Bjornn. 1998	49	X										X		X			X		X	

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Hetrick, N.J., M.A. Brusven, T.C. Bjornn, R.M. Keith, and W.R. Meehan. 1998	50	X										X								
Hicks, B.J., and J.D. Hall. 2003	426						X			X										
Hicks, M. 2002	427						X												X	
Hildebrand, R.H., A.D. Lemly, C.A. Dollof, and K.L. Harpster. 1997	428						X			X		X	X							
Hines, D.H. and J.M. Ambrose. 1998	429						X												X	
Hogan, D. 2001	306					X				X										
Hogan, D.L. 1989	307					X				X										
Hogan, D.L., and D.J. Wilford. 1989	308					X												X		
Hughes, N.F. 1991	183			X																X
Huisink, M., J.J.W. de Moor, C. Kasse, and T. Virtanen. 2002	561							X		X					X	X				
Hyatt, T.L., and R.J. Naiman. 2001	430						X						X							
Irons, J.G. III, and M.W. Oswood. 1992	184			X															X	
Irons, J.G. III, and M.W. Oswood. 1997	185			X												X		X		
Irons, J.G., J.P. Bryant, and M.W. Oswood. 1991	186			X								X		X						
Irons, J.G., S.R. Ray, L.K. Miller and M.W. Oswood. 1989	187			X															X	
Jackson, W.L., and B.P. Van Haveren. 1987	188			X						X						X				
Jeffries, R., S.E. Darby, and D.A. Sear. 2003	562							X					X							
Johnson, A.C., and P. Wilcock. 2002	51	X																		X
Johnson, A.C., and R.T. Edwards. 2002	52	X												X						
Johnson, A.C., D.N. Swanston, and K.E. McGee. 2000	53	X																		X
Johnson, R.B. 1979	431						X													X
Johnson, S.L., and J.A. Jones. 2000	432						X										X		X	
Johnson, S.W., and J. Heifetz. 1985	54	X								X		X		X		X		X		
Johnson, S.W., J. Heifetz, and K.V. Koski. 1986	55	X																		X
Johnston, J.G., Jr. 2002	433						X										X		X	
Johnston, N.T., E.A. MacIsaac, P.J. Tschaplinski, and K.J. Hall. 2004	309					X						X	X	X						
Jones, A. 1971	563							X												X
Jones, E.B.D., III, G.S. Helfman, J.O. Harper, and P.V. Bolstad. 1999	434						X			X	X					X		X		
Jones, J.A., F.J. Swanson, B.C. Wemple, and K.U. Snyder. 2000	435						X						X			X		X		
Jones, S.H., R.J. Madison, and C. Zenone. 1978	56	X																X		

REFERENCE	Ref. No.	Bibliography Section								FRPA Variables										
		AK FRPA Region			Alaska General	Canada	Lower 48	Intl	Misc											
		I	II	III						A	B	C	D	E	F	G	H	I	J	K
Jordan, M.C., and R.F. Carlson. 1987	247				X															X
Jordan, P. 2001	310					X														X
Jordan, P. 2001	311					X												X		
Kahler, T.H., and T.P. Quinn. 1998	596								X											X
Kahler, T.H., P. Roni, and T.P. Quinn. 2001	436						X													X
Kail, J. 2003	564							X		X			X							
Kane, D.L., and C.W. Slaughter. 1973	189			X												X				
Kane, D.L, and P.M. Wellen. 1985	190			X																X
Keim, R.F., and S.H. Schoenholtz. 1999	437						X			X								X	X	
Keim, R.F., A.E. Skaugset, and D.S. Bateman. 2002	438						X			X			X							
Keith, R.M., T.C. Bjornn, W.R. Meehan, N.J. Hetrick, and M.A. Brusven. 1988	57	X											X							
Kelly, D.J., M.L. Bothwell, and D.W. Schindler. 2003	312					X						X					X			
Kemnitz, R.T., K.M. Novcaski, R.L. Rickman, W.C. Swanner, and K.R. Linn. 1993	248				X											X		X		
Kepkay, M., and J. Cathro. 1998	597								X				X	X				X	X	
Keppeler, E.T. 1986	439						X									X				
Keppeler, E.T., and R.R. Ziemer. 1990	440						X									X				
Keppeler, E.T., R.R. Ziemer, and P.H. Cafferata. 1994	441						X													X
Kessler, S.J., S.J. Paustian, and S. Russell. 1989	58	X								X										
Kirchhofer, D.A. 1984	59	X										X								
Kirkpatrick, B., Shirley, T.C., and C.E. O'Clair. 1998	60	X																		X
Kline, T.C. Jr., J.J. Goering, O.A. Mathisen, P.H. Poe, and P.L. Parker. 1990	61	X												X						
Knott, J.M., S.W. Lipscomb, and T.W. Lewis. 1986	148		X													X		X		
Knott, J.M., S.W. Lipscomb, and T.W. Lewis. 1987	149		X													X		X		
Kobayashi, S., and T. Kagaya. 2004	565							X				X								
Kondolf, G.M. 2000	598								X		X									
Kondolf, G.M., H. Piégay, and N. Landon. 2002	442						X			X					X			X		
Konopacky Environmental. 1996	62	X								X										
Kopperdahl, F.R., J.W. Burns, and G.E. Smith. 1971	443						X											X	X	
Koski, K.V. 1966	444						X				X							X		
Koski, K.V. 1981	63	X																		X
Koski, K.V. 1992	445						X			X			X		X					
Koski, K.V., and D.A. Kirchhofer. 1984	64	X										X								

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	II	III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Koski, K.V., and M.L. Murphy. 1989	65	X											X							
Kraft, C.E., and D.R. Warren. 2003	446						X						X							
Kreutzweiser, D.P., and S.S. Capell. 2001	313					X												X		
Kyle, R.E., and T.B. Brabets, 2001	150		X																X	
La Marche, J.L., and D.P. Lettenmaier. 2000	447						X									X				
Lamke, R.D., J.L. Van Maanen, B.B. Bigelow, P.J. Still, and R.T. Kemnitz. 1990	249				X											X		X		
Lamke, R.D., P.J. Still, B.B. Bigelow, H.R. Seitz, and J.E. Vaill. 1983	250				X											X		X		
Lamke, R.D., R.T. Kemnitz, M.R. Carr, D.S. Thomas, and K.M. Novcaski. 1992	251				X											X		X		
Lammert, M., and J.D. Allan. 1999	448						X			X		X				X				
Landwehr, D. 1993	66	X																		X
LaPerriere, J.D. 1980	191			X								X		X				X		
LaPerriere, J.D. 1983	192			X								X				X		X		
LaPerriere, J.D. 1994	193			X								X		X				X	X	
LaPerriere, J.D., E.E. Van Nieuwenhuyse, and P.R. Anderson. 1989	194			X								X		X				X		
Larkin, G.A., P.A. Slaney, P. Warburton and A.S. Wilson. 1998	314					X					X							X		
Larsen, D.P., P.R. Kaufmann, T.M. Kincaid, and N.S. Urquhart. 2004	449						X													X
Larsen, E.W., and S.E. Greco. 2002	450						X													X
Lassettre, N.S. 1999	599								X	X			X		X					
Latterell, J.J., R.J. Naiman, B.R. Fransen, and P.A. Bisson. 2003	451						X			X										
Lewis, J. 1998	452						X								X	X		X		
Lewis, J.C., S.R. Mori, E.T. Keppeler, and R.R. Ziemer. 2001	453						X									X		X		
Ligon, F., A. Rich, G. Rynearson, D. Thornburgh, and W. Trush (Scientific Review Panel). 1999	454						X													X
Lilly, M.R., J. Mendez, R. McCaffrey, D.M. Nyman, and S. Swenson. 2001	195			X												X		X	X	
Lisle, T.E. 1982	455						X			X	X				X	X				
Lisle, T.E. 1983	600								X	X			X			X				
Lisle, T.E. 1986	67	X								X			X							
Lisle, T.E. 1987	601								X	X										

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Lisle, T.E. 1989	456						X				X							X		
Lisle, T.E. 2002	602								X				X							
Lisle, T.E., and M.B. Napolitano. 1998	457						X			X	X		X							
Lloyd, D.S. 1987	252				X													X		
Lloyd, D.S., J.P. Koenings, and J.D. LaPerriere. 1987	253				X							X						X		
Loeffler, R.M., and J.M. Childers. 1977	254				X					X					X					
Loftus, W.F. 1976	196			X								X								
Lohr, S.C., and M.D. Bryant. 1999	68	X																		X
Lorenz, J.M., M.L. Murphy, and K.V. Koski. 1989	69	X								X						X				
Lotspeich, F.B., and A.E. Helmers. 1974	197			X																X
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	458						X											X		
Lubinski, B.R. 1995	198			X						X						X				
Luce, C.H. and T.A. Black. 1999	459						X													X
Luce, C.H. and T.A. Black. 2001	603								X											X
Macdonald, E., C.J. Burgess, G.J. Scrimgeour, S. Boutin, S. Reedy, and B. Kotak. 2004	315					X														X
Macdonald, J.S., E.A. MacIsaac, and H.E. Herunter. 2003	316					X													X	
Macdonald, J.S., P.G. Beaudry, E.A. MacIsaac, and H.E. Herunter. 2003	317					X										X		X		
MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991	255				X					X						X		X		
MacLean, R. 1997	199			X														X		
Maclean, S.H. 2003	200			X							X					X		X	X	
Magnan, P., and I. St-Onge. 2000	318					X														X
Marcogliese, D.J., M. Ballm and M.W. Lankester. 2001	319					X														X
Marcus, W.A., R.A. Marston, C.R. Colvard, Jr., and R.D. Gray. 2002	460						X			X			X							
Martin, C.W., J.W. Hornbeck, G.E. Likens, and D.C. Buso. 2000	461						X									X		X		
Martin, D.C. 1988	151		X									X							X	
Martin, D.J. 1993	70	X								X	X		X		X		X		X	
Martin, D.J. 1995	71	X								X	X		X		X	X		X	X	
Martin, D.J. 1996	72	X								X	X		X		X	X				

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	II	III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Martin, D.J. 1996	152		X								X									
Martin, D.J. 2001	73	X								X			X							
Martin, D.J., and A. Shelly. 2004	74	X								X	X		X							
Martin, D.J., and J.A. Kirtland. 1995	75	X								X	X		X			X				
Martin, D.J., and L.E. Benda. 2001	76	X											X							
Martin, D.J., M.E. Robinson and R.A. Grotefendt. 1997	77	X								X			X		X		X			
Martin, D.J., M.E. Robinson, and R.A. Grotefendt. 1998	78	X								X			X							
Martin, D.J., M.E. Robinson, S.J. Perkins, and R.A. Grotefendt. 1997	79	X								X			X					X		
Martin, D.J., W.M. Young, Jr., S.D. Edland, T.S. Lin, and R.B. Morrow. 1990	80	X								X	X		X		X		X			
Martin Environmental. 1997	81	X																X		
Martin, J.R. 1993	82	X																		X
Mauger, S. 2004	153		X											X		X		X	X	
Maurer, M.A. 1987	201			X								X						X		
May, C.L., and R.E. Gresswell. 2003	463						X			X			X							
May, C.L., and R.E. Gresswell. 2003	464						X			X			X					X		
May, C.L. 2002	462						X						X							
McCaffrey, R. 2001	202			X												X			X	
McCashion, J.D., and R.M. Rice. 1983	465						X													X
McCullough, D.A. 1999	604								X										X	
McEachern, G. 2003	320					X						X	X	X	X	X	X	X	X	
McFadden, T., and M. Stallion. 1976	203			X									X							
McGreer, D.J. 2000	83	X														X				
McNeil, W.H. 1966	84	X														X		X		
Meehan, W.R. 1970	85	X															X		X	
Meehan, W.R. 1971	86	X									X	X								
Meehan, W.R. 1974	87	X									X		X			X		X	X	
Meehan, W.R. 1996	466						X					X								
Meehan, W.R., F.B. Lotspeich, and E.W. Mueller. 1975	88	X																X		
Megahan, W.F., M. Wilson, and S.B. Monsen. 2000	467						X													X
Meleason, M.A., S.V. Gregory, and J.P. Bolte. 2002	468						X						X							
Meleason, M.A., S.V. Gregory, and J.P. Bolte. 2003	469						X						X							
Mellina, E., R.D. Moore, S.G. Hinch, J.S. Macdonald, and G. Pearson. 2002	321					X													X	

REFERENCE	Ref. No.	AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	A	B	C	D	E	F	G	H	I	J	K
Michel, B. 1971	322					X														X
Micheli, E.R., and J.W. Kirchner. 2002	470						X								X					
Millar, R.G. 2001	323					X				X					X					
Miller, A.J. 1990	471						X													X
Miller, M.C., and J.R. Stout. 1989	204			X								X								
Milner, A.M. 1987	89	X										X				X		X	X	
Milner, A.M. 1996	90	X										X						X		
Milner, A.M. and G.E. Petts. 1994	256				X							X				X		X	X	
Milner, A.M. and G.S. York. 2001	91	X										X		X				X		
Milner, A.M., and R.G. Bailey. 1989	92	X														X		X	X	
Milner, A.M., D.M. Bishop, and L.A. Smith. 1985	93	X														X			X	
Minakawa, N, and R.I. Gara. 2003	472						X					X								
Montgomery, D.R., T.M. Massong, and S.C.S. Hawley. 2003	473						X			X			X							
Montgomery, D.R., E.M. Beamer, G.R. Pess, and T.P. Quinn. 1999.	474						X			X	X									
Montgomery, D.R., K.M. Schmidt, H.M. Greenberg, and W.E. Dietrich. 2000	475						X													X
Montgomery, D.R., J.M. Buffington, R.D. Smith, K.M. Schmidt, and G. Pess. 1995	94	X								X			X							
Moody, J.A., and D.A. Martin. 2001	476						X													X
Moore, K. 1991	324					X														X
Moore, K., M. Furniss, S. Firor, and M. Love. 1999	605								X											X
Moore, R., T. Gomi, and A. Dhakal. 2003	325					X				X							X		X	
Morse, B., and F. Hicks. 2003	326					X				X					X	X		X		
Mossop, B., and M.J. Bradford. 2004	327					X				X			X							
Murphy, M.L. 1985	95	X																		X
Murphy, M.L. 1995	257				X															X
Murphy, M.L., and A.M. Milner. 1997	258				X															X
Murphy, M.L., and K.V. Koski. 1989	96	X											X							
Murphy, M.L., J.F. Thedinga, K.V. Koski, and G.B. Grette. 1984	97	X								X			X							
Murphy, M.L., J. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989	98	X								X										
Murphy, M.L., J. Heifetz, S.W. Johnson, K.V. Koski, and J.F. Thedinga. 1986	99	X								X		X	X		X		X			
Myren, R.T., and R.J. Ellis. 1984	100	X														X				

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region								FRPA Variables										
		I	II	III	Alaska General	Canada	Lower 48	Intl	Misc	A	B	C	D	E	F	G	H	I	J	K
Naiman, R.J., R.E. Bilby, and P.A. Bisson. 2000	606								X	X		X	X		X		X			
Naiman, R.J., E.V. Balian, K.K. Bartz, R.E. Bilby, and J.J. Latterell. 2002	477						X						X							
Nakano, S., and M. Murakami. 2001	607								X			X								
Neatrour, M.A., J.R. Webster, and E.F. Benfield. 2004	478						X					X								
Negishi, J.N., and J.S. Richardson. 2003	328					X						X								
Neill, C.R., J.S. Buska, E.F. Chacho, C.M. Collins, and L.W. Gatto. 1984	205			X						X					X	X		X		
Newbrey, M.G. 2002	479						X						X							
Nicholls, K.H., R.J. Steedman, and E.C. Carney. 2003	329					X						X								
Nislow, K.H., and W.H. Lowe. 2003	480						X											X		
Nolan, K.M., T.E. Lisle and H.M. Kelsey.1987	481						X									X		X		
North Coast Regional Water Quality Control Board in cooperation with the California Department of Forestry. 1993	482						X				X							X		
O'Brien, W.J., and J.J. Showalter. 1993	259				X							X				X		X		
O'Connor, J.E., M.A. Jones, and T.L. Haluska. 2003	483						X			X			X		X			X		
O'Connor, M.D., and R.R. Ziemer. 1989	484						X			X			X		X					
O'Loughlin, C., and R.R. Ziemer. 1982	608								X											X
Olsen, J.B., W.J. Spearman, G.K. Sage, S.J. Miller, B.G. Flannery, and J.K. Wenburg. 2004	206			X																X
Oregon Forest Industries Council and Washington Forest Protection Association. 2000	609								X	X							X		X	
Orlikowska, E. H. 200	101	X																		X
Oswood, M.W. 1989	207			X								X								
Oswood, M.W., A.M. Milner, and J.G. Irons III. 1991	260				X															X
Ott, A.G., J.F. Winters, and A.H. Townsend. 1998	208			X																X
Ott, R.A. 1998	209			X																X
Ott, R.A., and W.E. Putman. 1999	210			X																X
Ott, R.A., M.A. Lee, W.E. Putman, O.K. Mason, G.T. Worum, and D.N. Burns. 2001	211			X									X		X	X				
Outhet, D.N. 1974	330					X									X	X			X	
Parks, B., and R.J. Madison. 1985	261				X											X		X		
Patoine, A., B. Pinel-Alloul, and E.E. Prepas. 2002	331					X						X						X		
Patoine, A., B. Pinel-Alloul, and E.E. Prepas. 2002	332					X						X		X						
Patoine, A., B. Pinel-Alloul, E.E. Prepas, and R. Carignan. 2000	333					X						X								

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	II	III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Paul, M.J., and R.O. Hall, Jr. 2002	485						X					X				X		X		
Paustian, S.J. 1987	102	X																X		
Pentec Environmental, Inc. 1991	103	X														X		X	X	
Pentec Environmental, Inc. 1991	610								X			X	X		X		X		X	
Pentec Environmental, Inc. 1993	104	X								X	X		X		X					
Pepin, D.M., and F.R. Hauer. 2002	486						X					X				X				
Perkins, S.J. 1999	105	X									X							X		
Perry, R.W., M.J. Bradford, and J.A. Grout. 2003	212			X								X		X						
Pess, G.R., D.R. Montgomery, E.A. Steel, R.E. Bilby, B.E. Feist, and H.M. Greenberg. 2002	487						X													X
Peterson, L.A. 1973	213			X												X		X		
Piccolo, J.J., and M.S. Wipfli. 2002	106	X										X								
Pinel-Alloul, B., and A. Patoine. 2000	334					X						X		X				X		
Poole, G.C. and C.H. Berman. 2001	611								X	X						X	X		X	
Popovics, L.M. 1999	214			X						X		X		X		X		X		
Price, K., and D. McLennan. 2002	335					X						X	X		X		X	X	X	
Price, K., A. Suski, J. McGarvie, B. Beasley, and J.S. Richardson. 2003	336					X				X		X								
Prowse, T.D. 1994	262				X											X				
Quinn, J.M., I.K.G. Boothroyd, and B.J. Smith. 2004	566							X				X			X	X	X	X	X	
Quinn, T.P., and N.P. Peterson. 1996	488						X						X							
Ray, S.R. 1988	215			X												X		X		
Reeves, G.H., K.M. Burnett, and E.V. McGarry. 2003	489						X						X							
Reid, L.M., and S. Hilton. 1998	490						X						X							
Rice, R.M. and D.J. Furbish. 1984	491						X													X
Rice, R.M., and J.D. McCashion. 1985	492						X													X
Rice, R.M. and J. Lewis. 1986	493						X													X
Rice, R.M., and J. Lewis. 1991	494						X													X
Rice, R.M., and N.H. Pillsbury. 1982	495						X													X
Rice, R.M. and P.A. Datzman. 1981	496						X													X
Rice, R.M., and P.D. Gradek. 1984	497						X													X
Rice, R.M., and S.A. Sherbin. 1977	498						X													X
Rice, R.M., J.S. Rothacher, and W.F. Megahan 1972	612								X											X
Rice, R. M., R.R. Ziemer, and J. Lewis. 2001	499						X									X		X		
Rice, S., and M. Church. 1996	337					X							X					X		

REFERENCE	Ref. No.	Bibliography Section								FRPA Variables										
		AK FRPA Region			Alaska General	Canada	Lower 48	Intl	Misc											
		I	II	III						A	B	C	D	E	F	G	H	I	J	K
Rice, S.P., M.T. Greenwood, and C.B. Joyce. 2001	338					X						X						X		
Richardson, J.S. 2000	339					X						X								
Rickard, W.E., and C.W. Slaughter. 1973	216			X																X
Rickman, R.L. 1998	107	X														X		X	X	
Rinaldi, M., and N. Casagli. 1999	567							X							X					
Rinaldi, M., N. Casagli, S. Dapporto, and A. Gargini. 2004	568							X							X	X				
Robertson, A.L., and A.M. Milner. 2001	108	X										X								
Robison, E.G. 1998	263				X					X										
Robison, E.G., and R.L. Beschta. 1990	109	X								X			X							
Robison, E.G., and R.L. Beschta. 1990	110	X								X			X							
Robison, E.G., and R.L. Beschta. 1990	500						X						X							
Rosenfeld, J., M. Porter, and E. Parkinson. 2000	340					X				X			X							
Rot, B.W., R.J. Naiman, and R.E. Bilby. 2000	501						X			X			X							
Rothacher, J. 1971	502						X									X				
Rowntree, K.M., and E.S.J. Dollar. 1999	569							X		X					X					
Sabater, F., A. Butturini, I. Muñoz, A. Romaní, S. Sabater, E. Martí, and J. Wray. 2000	570							X				X		X			X	X		
Savard, C.S., and D.R. Scully. 1984	111	X														X		X	X	
Scannell, P.K.W. 1992	264				X														X	
Schallock, E.W., and F.B. Lotspeich. 1974	217			X												X		X		
Scherer, R. 2001	341					X										X				
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Schuett-Hames, D.B. Conrad, A. Pleus, and K. Lautz. 1996	613								X	X	X									
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Schulz, B.K. 1993	154		X															X		
Scott, K.M. 1982	155		X							X					X	X				
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Shelby, B., B.P. Van Haveren, W.L. Jackson, D. Whittaker, and D. Prichard. 1990	156		X													X				
Sheridan, W.L. 1961	116	X																	X	
Sheridan, W.L. 1962	117	X																	X	
Sheridan, W.L., M.P. Perensovich, T. Faris, and K. Koski. 1984	118	X									X									

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		Bibliography Section								**FRPA Variables**										
Sidle, R.C., and A.J, Campbell. 1983	119	X													X	X		X		
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Sidle, R.C., and A.M. Milner. 1989	121	X								X					X	X				
Simon, A., and A.J.C. Collison. 2001	505						X								X					
Slaughter, C.W. 1971	218			X												X		X	X	
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Smidt, S. 1997	219			X								X								
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Smith, D.G. 1976	342					X									X					
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Smith, R.D., and J.M. Buffington. 1993	122	X								X			X							
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Starostka, V.J. 1994	124	X								X										
Stauffer, J.C., R.M. Goldstein, and R.M. Newman. 2000	509						X													X
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Still, P.J. 1980	126	X														X		X		
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Stott, T. 1997	571							X							X					
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Sullivan, K., T.E. Lisle, C.A. Dolloff, G.E. Grant, E. Gordon, and L.M Reid. 1987	614								X	X			X		X	X		X		
Surfleet, C.G., Ziemer, R.R. 1996	513						X						X							
Suttle, K.B., M.E. Power, J.M. Levine, and C. McNeely. 2004	514						X					X						X		
Swanson, F.J. and G.W. Lienkaemper. 1978	515						X			X			X		X					

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region			Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables										
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Swanson, F. J., M.D. Bryant, G.W. Lienkaemper, J.R. Sedell. 1984	127	X											X							
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Swanston, D.N. 1969	128	X																		X
Swanston, D.N. 1974	129	X																		X
Swanston, D.N. 1974	517						X													X
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Sweeney, B.W., T.L. Bott, J.K. Jackson, L.A. Kaplan, J.D. Newbold, L.J. Standley, W.C. Heesion, and R.J. Horwitz. 2004	518						X			X		X		X	X			X		
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Teti, P. 1998	615								X										X	
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Tripp, D.B., and V.A. Poulin. 1992	350					X				X	X		X		X					
Tydingco, T.A. 19	157		X								X		X						X	
USDA Forest Service, Alaska Region. 2002	135	X																		X
USDI Geological Survey. 1971	267				X											X				
USDI Geological Survey. 1976	268				X											X		X		
USDI Geological Survey. 1977	269				X											X		X		

REFERENCE	Ref. No.	AK FRPA Region I	AK FRPA Region II	AK FRPA Region III	Alaska General	Canada	Lower 48	Intl	Misc	A	B	C	D	E	F	G	H	I	J	K
USDI Geological Survey. 1978	270				X											X		X		
USDI Geological Survey. 1979	271				X											X		X		
USDI Geological Survey. 1980	272				X											X		X		
USDI Geological Survey. 1981	273				X											X		X		
USDI Geological Survey. 1982	274				X											X		X		
Vaill, J.E., P.J. Still, R.D. Lamke, B.B. Bigelow, and J.L. Van Maanen. 1988	275				X											X		X		
van der Nat, D., K. Tockner, P.J. Edwards, and J.V. Ward. 2003	572							X		X			X							
VanMaanen, J.L., R.D. Lamke, P.J. Still, J.E. Vaill, and B.B. Bigelow. 1988	276				X											X		X		
Verschuren, J.P., and M. Bristol. 1974	351					X									X	X				
Wagner, R.G. and J.M. Hagan (eds.). 2000	524						X					X		X				X	X	
Wallerstein, N.P., and C.R. Thorne. 2004	525						X			X			X							
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Walter, R.A. 1984	136	X										X		X			X			
Warren, D.R., and C.E. Kraft. 2003	527						X			X			X							
Webb, A.A., and W.D. Erskine. 2003	573							X					X		X					
Wellen, P.M., and D.L. Kane. 1985	221			X																X
Welsh, H.H., Jr., G.R. Hodgson, and B.C. Harvey. 2001	528						X												X	
Wemple, B.C., F.J. Swanson, and J.A. Jones. 2001	529						X													X
Wenger, S. 1999	616								X				X	X	X		X	X	X	
Whitaker, A., Y. Alila, and D.A.A. Toews. 2001	352					X										X				
Whitfield, P.H., and W.G. Whitley. 1986	353					X										X		X		
Wilford, D.J. 1984	354					X												X		
Wilson, M., and J.G. Imhof. Undated	617								X			X	X		X	X		X	X	
Wilson, W.J., and M.D. Kelly, and P.R. Meyer. 1987	158		X																X	
Wing, M.G., and A. Skaugset. 2002	530						X			X			X							
Winkler, R.D. 2001	355					X														X
Wipfli, M.S. 1997	137	X										X								
Wipfli, M.S., and D.P. Gregovich. 2002	138	X										X								
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Wipfli, M.S., J. Hudson, and J. Caouette.1998	140	X										X		X						

REFERENCE	Ref. No.	Bibliography Section: AK FRPA Region I	II	III	Alaska General	Canada	Lower 48	Intl	Misc	FRPA Variables: A	B	C	D	E	F	G	H	I	J	K
Wipfli, M.S., J.P. Hudson, D.T. Chaloner, and J.P. Caouette. 1999	141	X										X		X						
Wipfli, M.S., R.L. Deal, P.E. Hennon, A.C. Johnson, T.L. DeSanto, T.A. Hanley, M.E. Schultz, M.D. Bryant, R.T. Edwards, E.H. Orlikowska, and T. Gomi. 2002	142	X										X		X						
Wohl, E., J.N. Kuzma, and N.E. Brown. 2004	531						X			X			X			X				
Wolman, M.G. 1959	532						X								X					
Woo, M.K., and P. Marsh. 2003	356					X										X				
Wood, P.J. 1997	618								X	X		X						X		
Wood-Smith, R.D., and J.M. Buffington. 1996	143	X								X			X							
Wooster, J., and S. Hilton. 2004	533						X			X			X							
Worum, G.T., D.N. Burns, W.E. Putman, R.A. Ott, and M.A. Lee. 2001	222			X						X			X		X					
Wright, K.A. 1985	534						X									X				
Wright, K.K., and J.L. Li. 2002	535						X													X
Wuttig, K.G. 1997	223			X								X		X		X		X	X	
Young, K.A., S.G. Hinch, and T.G. Northcote. 1999	357					X				X			X						X	
Zelt, R.B., and E.E. Wohl. 2004	536						X						X		X					
Ziemer, R.R. 1981	619								X											X
Ziemer, R.R. 1981	620								X											X
Ziemer, R.R. 1984	537						X													X
Ziemer, R.R. 1992	538						X													X
Ziemer, R.R., and D.N. Swanston. 1977	144	X																		X
Ziemer, R.R., and R.L. Hubbard. 1991	539						X													X
Ziemer, R.R., and T.E. Lisle. 1998	540						X									X				
Ziemer, R.R., J. Lewis, R.M. Rice, and T.E. Lisle. 1991	541						X													X
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