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Wetland Buffers

An Annotated Bibliography

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Wetlands Buffers:
An Annotated Bibliography

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Shorelands and Coastal Zone Management Program
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INTRODUCTION

Wetland Buffers: An Annotated Bibliography is a compilation of abstracts dealing with the use of vegetated "buffer zones" to reduce the impact of adjacent land use on wetland ecosystems. Most of the entries in this document come from journal articles published in diverse fields: agriculture, engineering, fisheries, forestry, geology, landscape architecture, marine sciences, resource management, and wildlife biology. The bibliography also contains summaries of government publications from the federal, state, and local levels, including government-funded research, guidance documents, and adopted or proposed wetlands conservation ordinances. Also included are summaries of symposia presentations.

OBJECTIVE

The objective was to create a compilation of citations which analyze the functional requirements, composition, uses, effectiveness, or delineation of wetland buffer areas. Additional citations concern the protection of wetland functions and values from many different perspectives. Though extensive, this collection does not represent an exhaustive or exclusive listing of work conducted in each respective field concerning the protection of wetlands.

The intent of this collection is to assist landowners, planners, managers, developers, and politicians in the Pacific Northwest in understanding viable wetland ecosystems and the requirements for creating adequate protection criteria for this diminishing resource.

METHODS

The literature search focused on technical information from journal articles, government documents, proceedings from conferences and symposiums, and research reports, rather than on text or general information books. On-line searches were conducted through AFSA, Enviroline, Water Resources, NTIS, Pollution, Life Sciences, AGRICOLA, and Biosis, as well as the collections at the following University of Washington libraries: Natural Sciences, Fisheries, Forestry, Engineering, and Architecture.

The majority of this document is based on an annotated bibliography developed by Mark Young for the Department of Ecology with assistance from Sue Mauermann, Department of Ecology, and Bob Zeigler, Department of Wildlife.

RESULTS AND DISCUSSION

Whenever available, the authors' original abstracts appear. Information added to the authors' abstracts by the editors is provided in brackets, [ ], following the original abstracts. For those citations without abstracts, a synthesis of material was undertaken by the editors.

The source of each summary is noted prior to each abstract: a single * denotes the author's abstract in the citation; a double ** denotes an editors' synthesis of the material.

A complete list of articles reviewed appears at the end of the bibliography; bold-faced references are those which are included in the annotated bibliography. Exclusion of reviewed articles from the annotated bibliography is entirely due to time and budgetary constraints; no lack of scientific merit or applicability should be inferred from these or other omissions.

Many of the citations have been discussed in a companion summary report:

Castelle, A.J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, T. Erickson, S.S. Cooke. 1992. Wetland Buffers: Use and Effectiveness. Adolfson Associates, Inc., for Shorelands and Coastal Zone Management Program, Washington State Department of Ecology, Olympia, Pub. No. 92-11.

COMMENTS

All comments on this document and information on additional citations concerning buffers for wetlands are welcome. Written suggestions and inquiries should be made to:

Washington State Department of Ecology
Shorelands and Environmental Assistance Program
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Olympia, Washington 98504-7600

CITATION

This document should be cited as:

Castelle, A.J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, and M. Witter (eds.). 1992. Wetland Buffers: An Annotated Bibliography. Adolfson Associates, Inc., for Shorelands and Coastal Zone Management Program, Washington State Department of Ecology, Olympia, Publ. No. 92-11.

Adamus, P. R., and L.T. Stockwell. 1983. A Method for Wetland Functional Assessment, Vol. 1. Federal Highway Administration Rep. No. FHWA-IP-82-23.

Abstract: *
The manual presents a state-of-the-art review of wetland functions. Functions covered include groundwater recharge and discharge, flood storage and desynchronization, shoreline anchoring and dissipation of erosive forces, sediment trapping, nutrient retention and removal, food chain support (detrital export), habitat for fish and wildlife, and active and passive recreation. The manual covers all wetland types in the 48 conterminous states, and uses the U.S. Fish and Wildlife Service definition and classification system. It examines the validity, interactions, and possible significance thresholds for the functions, as well as documenting their underlying processes. With appropriate qualifying information, wetland types are ranked for each function. Wetland types ideal for each function are identified and illustrated. Potential impacts of highways upon each function are described and, where available, possible thresholds are given. Factors which regulate impact magnitude, such as location, design, watershed erodibility, flushing capacity, basin morphology, biotic sensitivity (resistance and resilience), recovery capacity, and refugia, are explained. Cumulative impacts and social factors affecting wetland significance are discussed. Effects of the following factors on wetland function are documented: contiguity, shape, fetch, surface area, area of watershed and drainage area, stream order, gradient, land cover, soils, depositional environment, climate, wetland system, vegetation form, substrate, salinity, Ph, hydroperiod, water level fluctuations, tidal range, scouring, velocity, depth, width, circulation, pool-riffle ratio, vegetation density, flow pattern, interspersion, human disturbance, turbidity, alkalinity, dissolved oxygen, temperature, and biotic diversity.

Allen, A.W. 1983. Habitat Suitability Index Models: Mink. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.61. 19 pp.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Mink depend primarily on emergent wetland vegetation for food and cover, but woody vegetation in shrub or forested wetlands may provide some cover and support for lodge construction. Mink activity and proximity ranges from region to region. In Quebec, the main activity was within 3 m (9.8 ft) of the water's edge; in Michigan, mink were observed within 30.4 m (100 ft) of the water's edge; in a British study, 10 m (32.8 ft). In Idaho, mink proximity ranged from 5 to 100 m (16.4 to 328 ft) of water, with mink never observed further than 200 m (656 ft). Mink were found to avoid open areas (wetlands with straight, open and exposed shorelines, and shorelines that were heavily grazed). Optimal wetland areas have irregular and diverse shorelines, log jams, areas of abundant downfall and debris for cover, and pools for foraging. Mink move in a core area which is generally shaped to the edge of the wetland, generally 300 m (984 ft). In Idaho, this ranged from 1 to 2 km (.6 to 1.2 mi) of shoreline length. Optimal wetland habitat has water at least 9 months of the year. Woody vegetation within 100 m (323 ft) was assumed to influence the potential quality of the habitat. In small forested or shrub/scrub wetlands, the adjacent 100 m (323 ft) of upland vegetation was assumed to have a more significant role in defining the relative importance of habitat quality for mink. In large forested and shrub/scrub wetlands 405 ha (1000 acres) or larger, significant factors were the amount of woody and persistent herbaceous vegetation, and the length of time surface water was present.]

Allen, A.W. and R.D. Hoffman. 1984. Habitat Suitability Index Models: Muskrat., U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.46. 27 pp.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Muskrat were found to tolerate human activity, living in sub-optimum conditions if enough food is present. Water level stability has a direct effect on the quality of muskrat habitat, with water fluctuations not exceeding 90 cm (35.4 in/yr). Optimal habitat provides retreat areas (log debris, downfalls, deep pools, backwaters, and undercut banks), and a dense, herbaceous, vegetated border at least 10 m (32.8 ft) wide containing a 50 to 80% canopy cover along the wetland. Intensive livestock use was found to be detrimental to muskrat habitat, due to decreased vegetation cover, increased bank erosion, and trampling of the burrow system. The home range varies between the riverine and bank dwelling muskrat: 250 to 400 m (819 to 1311 ft) of shoreline for the former, and 200 to 300 m (656 to 984 ft) for the bank dwellers. Habitats along the edge of a wetland were found to be more linear, whereas interior wetland habitats were more circular.]

Allen, Hollis H. 1978. Role of Wetland Plants in Erosion Control of Riparian Shorelines. pp. 403-414. *In*: P.E. Greeson, J.R. Clark, and J.E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. American Water Resources Association.

Abstract: *
The role of wetland vegetation in erosion abatement of lake, river, and stream shorelines and some of the work done by the U.S. Army Engineer Waterway Experiment Station as related to the use of wetland vegetation for erosion control are described. Erosion control potential of both herbs and woody plant species is discussed and various plants are identified that have special attributes for use in erosion control. Several factors are presented that influence the establishment of wetland vegetation along shorelines, such as plants' flood and desiccation tolerance and resistance to undermining, steepness in bank slope, amount and frequency of water level fluctuation, degree of wave action, and speed of currents. Discussion is devoted to the artificial establishment and value of wetland vegetation. A method is presented of employing vegetation with an engineering structure such as a revetment to mutually abate erosion and provide other values such as a cover for wildlife and the improvement of aesthetics. In addition, several suggestions are made for future research studies that could possibly enable more optimum use of wetland plants in erosion control.

Barton, David R., William D. Taylor, and R. M. Biette. 1985. Dimensions of Riparian Buffer Strips Required to Maintain Trout Habitat in Southern Ontario Streams. North American Journal of Fisheries Management 5:364-378.

Abstract: *
The relationships between riparian land use and environmental parameters that define the suitability of southern Ontario streams for trout were examined for 40 sites on 38 streams. Weekly observations of maximum and minimum temperature, coarse and fine suspended matter, and discharge were made during June, July, and August 1980. Land use was determined from aerial photographs of each stream. Fish were surveyed at each site during August by electrofishing and seining.

The only environmental variable which clearly distinguished between trout and nontrout streams was weekly maximum water temperature: streams with trimean weekly maxima less than 22°C had trout; warmer streams had, at best, only marginal trout population. Trout streams tended to have low concentrations of fine suspended solids and a more stable discharge, but so did many of the other streams. Water temperature, concentration of fine particulate matter, and variability of discharge were inversely related to the fraction of the upstream banks covered by forest. Fifty-six percent of the observed variation in weekly maximum water temperature could be explained by the fraction of bank forested within 2.5 km upstream of a site. Other land uses were not clearly related to stream variables, except that high concentrations of fine suspended solids were most often observed in reaches used as pasture.

Analysis of data from sites located within buffer strips yielded a regression relating maximum weekly temperatures to buffer strip length and width. The regression accounted for 90% of the observed variation in water temperature for these sites. The model was verified further by comparisons with observed temperatures at a second set of sites located downstream from buffer strips.

Beschta, R.L. 1978. Long-Term Patterns of Sediment Production Following Road Construction and Logging in the Oregon Coast Range. Water Resour. Res. 14:1011-1016.

Abstract : *
Suspended sediment production after road construction, logging, and slash disposal was significantly increased (P = 0.95) on two watersheds in Oregon's Coast Range. A 25% patch-cut watershed showed increases during 3 of 8 post-treatment years. These increases were caused primarily by mass soil erosion from roads. Monthly sediment concentrations before the occurrence of the annual peak flow were increased more than those following the annual peak. Surface erosion from a severe slash burn was the primary cause of increased sediment yields for 5 post-treatment years on a watershed that was 82% clearcut. Monthly sediment concentrations were generally increased throughout the winter runoff period on this watershed. The flushing of suspended sediment on Oregon Coast Range watersheds is apparent from seasonal changes of suspended sediment rating curves.

Bingham, S.C., P.W. Westerman, M.R. Overcash. 1980. Effects of Grass Buffer Zone Length in Reducing the Pollution from Land Application Areas. Transactions of the American Society of Agricultural Engineers (ASAE), 23:330-342.

Abstract: *
A field study was conducted to determine the effect of length of grass buffer zones in reducing pollutant concentration in rainfall runoff from land application areas. Evaluation of pollutant concentrations in runoff at various distances downslope from an area where caged layer poultry manure was applied regularly indicated that for the conditions of this experiment a buffer area length to waste area length area ratio of 1.0 was usually required to reduce concentrations to those measured in runoff from a similar plot receiving no manure. Less buffer area would be needed if concentrations greater than background conditions were acceptable.

Brazier, J.R. and G.W. Brown. 1973. Buffer Strips for Stream Temperature Control. Research Paper no.15, Forest Research Lab, Oregon State Univ., Corvallis, OR. 9 pp.

Abstract: *
During clearcut logging, complete removal of the forest canopy and the shade it provides to small streams can cause large increases in water temperature. Such increases in temperature

can be prevented if buffer strips of vegetation are left along the stream to provide shade. The purposes of this paper are to define the characteristics of buffer strips that are important in regulating the temperature of small streams and to describe a method of designing buffer strips that will insure no change in stream temperature as a result of logging and, at the same time, minimize the amount of commercial timber left in the strip.

Commercial timber volume alone is not an important criterion for temperature control. Further, the width of the buffer strip is also not an important criterion. For the small streams studied as part of this research, the maximum shading ability of the average buffer strip was reached within a width of 80 feet (24 m). Specifying standard 100 to 200 foot (31 to 61 meter) buffer strips for all streams generally will include more timber than necessary. The canopy density along the path of incoming solar radiation best describes the ability of the buffer strip to control stream temperature. An estimate of this value can be obtained easily by foresters laying out buffer strips in the field and will insure proper design of the buffer strip for control of stream temperature.

Broderson, J.M. 1973. Sizing Buffer Strips to Maintain Water Quality. M.S. Thesis, University of Washington, Seattle.

Abstract: *
Environmental pressure for improved logging techniques and reduced impacts of timber harvesting are placing mounting responsibilities on the forest and watershed managers to seek solutions. This paper investigates the impact of logging on water quality by identifying the parameters and recommends solutions by using buffer strips along streams. Existing laws and guidelines directly and indirectly used to size buffer strips in the Pacific Northwest are presented.

Major problems in sizing the strips are identified and explored. These problems are found to be the effectiveness of controlling sedimentation, providing ample shading along streams, controlling debris, and avoiding excessive windthrow of the buffer strip.

Brooks, R.P. and J.B. Hill. 1987. Status and Trends of Freshwater Wetlands in the Coal-mining Region of Pennsylvania, USA. Environmental Management 11:29-34.

Abstract: *
The impact of surface mining for coal on the nature and extent of freshwater wetlands was assessed on 73,200 ha in western Pennsylvania. The influence of mining on wetlands was not uniform across physiographic regions, varying with regional differences in hydrology and soils. Overall, mined lands supported 18% more palustrine wetlands than unmined lands, primarily because of a 270% gain in permanent, open-water wetlands on mined lands in the glaciated region. Open-water wetlands declined on mined lands in unglaciated regions owing to unfavorable hydrologic conditions. The number and size of emergent wetlands declined as a result of mining. Mined lands supported 81% fewer riverine

wetlands than unmined lands. This was caused primarily by avoidance of lands containing streams, and secondarily by a 10% reduction in replacement of riverine wetlands during reclamation. Land managers need to develop land use policies that maximize the ecological and social benefits that can be derived from developing diverse wetland communities on mined lands.

Brown, E.R., (ed.). 1985. Riparian Zones and Freshwater Wetlands. Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington, Part I - Chapter Narratives. pp. 57-80.

Abstract: **
This chapter provides qualitative information about riparian zones and freshwater wetlands. Riparian zones are described as transitional zones between aquatic and upland zones which are adjacent to rivers, streams, lakes, reservoirs, ponds, springs, and sometimes tidewater. Freshwater wetlands are described as areas that are permanently or intermittently flooded where the water table is normally at or near the surface, and where hydric soils and wetland vegetation occur. Riparian zones and wetlands provide some of the most important wildlife habitat in forestlands of western Oregon and Washington, because the major life requirements for many species are present. They are also important for a variety of land uses, including forestry, agriculture, mining, transportation, and recreation. Five factors are frequently mentioned in defining the character and function of riparian zones and wetlands: topography, vegetation, surface water, soil, and local climate. The habitat functions that attract wildlife to riparian zones and wetlands include foraging and watering, breeding and rearing, hiding and resting, and thermal cover.

Brown, G.W. and J.T. Krygier. 1970. Effects of Clear Cutting on Stream Temperature. Wat. Resour. Res. 6:1133-1139.

Abstract: *
The principle source of energy for warming streams is the sun. The amount of sunlight reaching the stream may be increased after clear-cut logging. Average monthly maximum temperature increased by 14°F and annual maximum temperatures increased from 57° to 85°F one year after clear-cut logging on a small watershed in Oregon's coast range. In a nearby watershed where strips of brush and trees separated logging units from the stream, no changes in temperature were observed that could be attributed to clear-cutting.

Brown, M.T. and J.M. Schaefer. 1987. Buffer Zones for Water, Wetland, and Wildlife. A Final Report on the Evaluation of the Applicability of Upland Buffers for the Wetlands of the Wekiva Basin. Prepared for the St. Johns River Water Management District by the Center for Wetlands, University of Florida, Gainesville, Florida 32611. 163 pp.

Abstract: **

This document is the result of a study evaluating the efficacy of upland buffers as a means of protecting the water resources of the Wekiva Basin in Central Florida. The purpose of the study was to determine the need for, potential applicability of, and criteria for delineating upland buffers in the Wekiva Basin.

The report provides a detailed review of the existing scientific understanding of buffer zones, their importance to the adjacent wetlands and waters, and the effects of buffer alterations on water quality and quantity, and wetland wildlife habitat values. The report also presents a methodology for determining required buffer zone widths. Four relevant factors in the methodology are: the wetland edge or boundary, the erodibility of the soils in the zone immediately upland of the wetland edge (slope and soil type), the depth of the groundwater table below the soil surface in the zone immediately upland of the wetland edge, and wildlife habitat requirements (habitat suitability, spatial requirements, access to upland or transitional habitat, and noise impacts).

Budd, W.W., P.L. Cohen, P.R. Saunders, and F.R. Steiner. 1987. Stream Corridor Management in the Pacific Northwest: I. Determination of Stream-Corridor Widths. Environ. Management 11:587-597.

Abstract: *
King County, Washington is a part of the rapidly growing Pacific Northwest region. This growth has placed pressure on stream corridors. Past studies about regional stream corridors provide a rich source of information for environmental planners and managers. This article draws on existing literature and case studies to provide guidelines for determining optimal stream corridor widths in a watershed located in King County, Washington.

Practical determinations of stream corridor widths can be efficiently and easily made using a simple field survey of select reaches of a stream system combined with an analysis of soils, vegetation, physiography and land use characteristics. This approach was found applicable over a broad range of stream characteristics. Additionally, the technique was sensitive to extreme environmental conditions such as extremely steep slopes or extensive wetland regions.

[A 15m (50 ft) buffer width was found to be an adequate protection barrier for many reaches of the Bear-Evans Creek watershed. This includes intermittent as well as continuously flowing reaches of this watershed. Under conditions of poor habitat, extremely severe bank slopes, and extensive wetland areas, practical corridor widths were variable and may require additional study.]

Butcher, G.S., W.A. Niering, W.J. Barry, and R.H. Goodwin. 1981. Equilibrium Biogeography and the Size of Nature Preserves: An Avian Case Study. Oecologia 49:29-37.

Abstract: *
The results of seven breeding bird censuses on an upland site in Connecticut from 1953-1976 are analyzed and related to changes in vegetation and surrounding urbanization during the same period. Turnover of breeding bird species on the old-field portion of the site was due to vegetational changes that caused the extinction of species preferring open shrub habitats and the colonization of species preferring forest. Turnover of breeding birds on the forest portion was due to its increasing isolation from similar forest habitat, resulting in the local extinction of forest interior species and the colonization of species characteristic of suburban habitats. The study site is too small for the preservation of forest interior bird species. It must be coordinated with larger preserves in a regional context if it is to be useful in preventing the regional extinction of forest interior bird species.

Canning, D.J. 1991. Shoreline Bluff & Slope Stability: Management Options. (Version 2.0) Shorelands Technical Advisory Paper No. 2. Shorelands and Coastal Zone Management Program, Washington Dept. of Ecology, Olympia.

Abstract: **
This Technical Advisory Paper is one part in a series assisting local governmental planners in implementing Washington State's Shoreline Management Act. Included are discussions of the basic understanding of the causes of slope instability and landsliding, slope classification & mapping, recognition of unstable slopes, and management options, including bluff setbacks. The paper also reviews bluff setback criteria from Thurston, Island, and Jefferson Counties, as well as the Wisconsin Coastal Management Program model.

Chadwick, J.W. and S.P. Canton. 1983. Coal Mine Drainage Effects on a Lotic Ecosystem in Northwest Colorado, U.S.A. Hydrobiologia 107:25-33.

Abstract: *
An aquatic biological survey was conducted in 1979-1980 to determine the effects of drainage from an active coal strip-mine on Trout Creek, in northwest Colorado, USA. Sampling was conducted over four seasons at four stations for periphyton, benthic invertebrates and fish. Periphyton in Trout Creek changed in the relative abundance of algae divisions in no apparent relation to mining. Diatoms were the predominant division at all sites. Golden-brown algae were abundant in spring at the stations upstream and adjacent to the mine. Blue-green algae were relatively important at stations upstream and downstream of the mine in winter. Benthic invertebrates exhibited a progressive increase in density, biomass and number of taxa from the upstream station to the downstream station. Shannon-Wiener diversity index for benthic invertebrates decreased slightly downstream of the mine drainage but remained indicative of a clean water community. Aquatic insects (especially Trichoptera) were the predominant invertebrates at all stations. Analysis of functional groups of benthic invertebrates revealed increased importance of collector species at the lower sites while shredders were most important upstream of the mine. Unlike the invertebrates, fish exhibited slightly lower biomass at the station adjacent to the

mine. The decrease was due to fewer salmonids. However, salmonid density and biomass increased substantially at the station just downstream of the mine. Non-game species (suckers and minnows) increased in numbers downstream and were most abundant at the lower station. This coal strip-mine had little discernable adverse effects on the periphyton and invertebrates of Trout Creek. Fish populations did not appear to be significantly affected by the mine. Apparently, the presence of settling ponds and a buffer zone of unmined land between the mine and the stream helped to minimize adverse effects. [No buffer widths are provided.]

Chescheir, G.M., J.W. Gilliam, R.W. Skaggs, and R.G. Broadhead. 1987. The Hydrology and Pollutant Removal Effectiveness of Wetland Buffer Areas Receiving Pumped Agricultural Drainage Water. North Carolina Water Resources Research Institute, Raleigh, North Carolina. Completion Rep. No. 231. 170 pp.

Abstract: **
The hydrology and pollutant-removing effectiveness of two wetland areas being used to buffer impacts of pumped agricultural drainage in Eastern North Carolina were studied. Collection and analysis of field data over a two-year period showed that buffer one, originally equipped with an efficient diffuser canal, was essentially 100% effective for pollutant removal for all observed events. Less effective flow distribution, less area and faster drainage resulting from a greater elevation at buffer two resulted in less effective removal. Hydrology of a buffer area was simulated with a wetland simulation model for overland flow through vegetated areas. A routine was added to calculate residence time of the water on the buffer and percent removal of nutrients. Hourly surface and subsurface field drainage volumes were calculated by a water management model. The two models estimated that over a 20-year period, study buffer one would remove 79% of total Kjeldahl nitrogen, 82% of nitrate nitrogen, 81% of total phosphorous, and 92% of sediment. Study of the response of wetland forest to pumped agricultural drainage showed pronounced overstory thinning and resultant increased floor regeneration, decreased plant diversity, and decreased annual tree diameter increment at buffer one, and decreased annual tree diameter increment at buffer two.

Coats, R., M. Swanson, and P. Williams. 1989. Hydrologic Analysis for Coastal Wetland Restoration. Environmental Management 13:715-727.

Abstract: *
Increasing recognition of the value of tidal wetlands has led to interest in how to restore and enhance areas that have been modified by human activity. The policy of recognizing restoration or enhancement as mitigation for destruction of other wetlands is controversial. Once policy questions are separated from technical questions, the steps in a successful project are straightforward. A key element in the design of a successful project is quantitative hydraulic and hydrologic analysis of alternatives. Restoration projects at two sites in California used a combination of empirical geomorphic relationships, numerical

modeling, and verification with field observations. Experience with these and other wetland restoration projects indicates the importance of long-term postproject monitoring, inspection, and maintenance.

Cohen, P.. 1985. Stream Corridor Management for the Pacific Northwest and King County, Washington. M.S. Thesis, Washington State University, Pullman.

Abstract: *
This paper examines stream corridor management as a protection program for riparian ecosystems generally in the Pacific Northwest and specifically in King County, Washington. Existing King County regulations are inadequate to protect riparian ecosystems that are under rapid growth and development pressures in the county. Determination of buffer widths are researched as the main criteria for establishing policies and guidelines and stream corridors. The design and criteria for effective policies and guidelines depends on the analysis of (1) scientific research correlating major elements of riparian ecosystems with prescribed buffer widths, (2) King County planning administration to determine best divisions and strategy to administer recommended policies and guidelines, (3) existing regulations to consolidate and encompass piecemeal ordinances, and (4) findings from a field survey with identified scientific research and recommended policies and guidelines. Findings from all four analyses support the design and criteria for stream corridor policies and guidelines in King County, Washington, and possibly the Pacific Northwest region.

This study illustrates a planning process that focuses on one land use issue from the comprehensive study stage through to the implementation stage. The value of this planning process is its sensitivity to ecological parameters of riparian ecosystems that fit well into the established legal system and decision-making process. Recommendations are made for further study of related issues affecting stream corridor management.

Cohen, P.L., P.R. Saunders, W.W. Budd, and F.R. Steiner. 1987. Steam Corridor Management in the Pacific Northwest: II. Management Strategies. Environ. Management, 11:599-605.

Abstract: *
King County, Washington is part of the rapidly growing Pacific Northwest region. Analysis of past and current federal, state and county regulations and administration reveals how stream corridors have been protected to date. This article draws on scientific literature and a case study to suggest future management strategies and guidelines for controlling development in King County watersheds.

[The authors recommend regulations for new development adjacent to streams. These include the reservation of an undisturbed corridor of sufficient width to maintain the natural hydraulic and habitat functions of each stream. Water Types 1 to 4 should have a corridor of not less than 15m (50 ft) from the ordinary high water mark on each side of the stream. Type 5 waters should have a corridor of not less than 7.6m (25 ft) from the ordinary high water mark. A greater width may be required for large urban developments. Although research supports buffer widths of 30.5 m (100 ft), the authors felt that these recommendations represent a compromise of the ecological findings, the political realities, and the results of their case study.]

Corbett, E.S. and J.A. Lynch. 1985. Management of Streamside Zones on Municipal Watersheds. pp. 187-190. *In*: R. Roy Johnson, Charles D. Ziebell, David R. Patton, Peter F. Folliott, and R. H. Hamre (eds.), Riparian Ecosystems and their Management: Reconciling Conflicting Uses. First North American Riparian Conference, April 16-18, 1985, Tucson, Arizona.

Abstract: *
Riparian zones play a major role in water quality management. Water supply considerations and maintenance of streamside zones from the municipal watershed manager's viewpoint are detailed. Management impacts affecting water quality and quantity on forested municipal watersheds are discussed in relation to the structure of the riparian zone.

[In citing studies from Corbett et al. 1978, the authors conclude that a 40 ft (12.2 m) buffer zone may be adequate to prevent excessive temperature increases in small streams, but that a zone of 66 to 100 ft (20.1 to 30.5 m) is usually needed to protect the stream ecosystem. A wider buffer zone may be needed where slope or soil conditions dictate, or where windthrow or sunscald may be a problem. The authors also recommend that buffer zones be maintained along intermittent streams on municipal watersheds. This is to prevent increased stream discharge following timber harvesting, which may cause intermittent streams to become perennial streams, permitting the transport of eroded material to the main stream channel.]

Culp, J.M. and R.W. Davies. 1983. An Assessment of the Effects of Streambank Clear-Cutting on Macroinvertebrate Communities in a Managed Watershed. Canadian Technical Report of Fisheries and Aquatic Sciences, No. 1208: xv + 115 p. Department of Fisheries and Oceans; Fisheries Research Branch; Pacific Biological Station; Nanaimo, British Columbia; V9R 5K6.

Abstract: *
Three macroinvertebrate sampling sites were established on Carnation Creek, Vancouver Island, British Columbia, and sampled from 1974-1980 to determine the effects of logging, with or without buffer zones, on macroinvertebrate communities. Logging without a buffer zone increased streambank erosion and the resulting sedimentation of streambank material in the substrate. Although logging opened the forest canopy and increased the light available for primary production, algal biomass did not increase after logging because phosphorus remained the limiting factor. Allochthonous litter input to the stream was significantly reduced at both logged sites, but the site with a buffer zone provided greater amounts of leaf litter to the stream, and had a higher post-logging benthic standing crop than the site without a buffer zone.

Throughout the pre- and post-logging periods, seasonal changes in macroinvertebrate community composition were strongly affected by the seasonality of discharge: high (winter), low (summer), and transitional (spring and fall). Trophic composition of the macroinvertebrate communities was not affected by logging, with collectors, collector-scrapers and collector-predators numerically dominant during all seasons and years. Logging of the streambank significantly decreased macroinvertebrate densities in the winters, primarily because post-logging sedimentation increased winter scouring. Macroinvertebrate densities at the site without a buffer zone were also reduced in the summer and transitional periods because of sediment intrusion into the substrate and the reduced standing crop of detritus. Macroinvertebrate communities were less detrimentally affected by logging when a < 10 m (33 ft) wide riparian buffer zone and natural debris dams were left along the stream. The buffer zone reduced logging-related scouring in the winter, and leaf litter input in the summer and transitional period was more similar to pre-logging conditions.

Experimental manipulations of substrate particle size, and detritus quality and quantity were conducted in the field, and established that detritus quality and quantity is (sic) more important in determining macroinvertebrate distribution and abundance than substrate particle size. The responses to detritus varied between macroinvertebrate taxa, and even among members of the same trophic guild.

Sediment addition experiments were conducted to determine the effect of downstream movement of fine sediments by siltation on macroinvertebrate drift and benthic densities, with the timing and pattern of the drift increases being related to the vertical distribution of macroinvertebrates in the substrate.

Since the streambank of coastal streams provides important energy subsidies to macroinvertebrate communities, and it mediates sediment input to the stream, logging of the streambank is detrimental to macroinvertebrates. Management guidelines must protect the streambank interface with the forest if coastal streams are to be maintained as productive salmon fry rearing habitat.

Darling, N., L. Stonecipher, D. Couch, and J. Thomas. 1982. Buffer Strip Survival Survey. Hoodsport Ranger District, Olympic National Forest.

Abstract: *
Buffer strips are often used as a management tool to maintain and protect water influence zones [WIZ] from the impacts of timber harvest. It is a documented fact that a buffer strip can offer excellent protection to the WIZ if the buffer remains stable. On the other hand, a buffer can cause more damage through debris jams and increased erosion if parts or all of it are blown down. The stability of a buffer strip is hard to assess during the planning stage. There are many factors which go into determining a buffer strip's susceptibility to blow-down. In the past a buffer strip's stability was usually determined by general observations

rather than quantitative data. In June 1977, Ivars Steinblums and Henry Froehlich from Oregon State University [OSU], computed a study of 40 streamside buffer strips in the western hemlock zone of Oregon's western Cascades (Streamside Buffer Strips: Survival, Effectiveness and Design, 1977). An equation was developed which incorporated several topographic, site and timber characteristics to predict buffer strip survival. A survey of 17 buffer strips was completed in 1981 on the Hoodsport District, Olympic National Forest. The objective of this survey was to assess the effectiveness and stability of these buffers and to determine if a correlation existed between % survival predicted by the OSU equation and actual % survival measured in the field.

Darnell, R.M., W.E. Pequegnat, B.M. James, F.J. Benson, and R.. Defenbaugh. 1976. Impacts of Construction Activities in Wetlands of the United States. US EPA, Office of Research and Development, Corvallis Environmental Research Laboratory. Corvallis, Oregon 97330. EPA-600/3-76-045, 392 pp.

Abstract: *
The primary types of construction activity which severely impact wetland environments of the United States include: floodplain surfacing and drainage, mining, impoundment, canalization, dredging and channelization, and bank and shoreline construction. Each type of construction activity is attended by an identifiable suite of physical and chemical alterations of the wetland environment which may extend for many miles from the site of construction and may persist for many years. In turn, each type of physical and chemical modification has been shown to induce a derived set of biological effects, many of which are predictable, in general, if not in specific detail. The most environmentally damaging effects of construction activities in wetland areas, in order of importance, are: direct habitat loss, addition of suspended solids, and modification of water levels and flow regimes. Major construction-related impacts also derive from altered water temperature, pH, nutrient levels, oxygen, carbon dioxide, hydrogen sulfide, and certain pollutants such as heavy metals, radioactive isotopes, and pesticides. Over one-third of the nation's wetlands have been lost through various forms of direct habitat destruction, and well over half of the remainder have been severely modified. Many aquatic species are known to have been lost or severely restricted, and a number of species and habitats are currently in jeopardy, at least in part as a result of construction activities. Deliberate and drastic action is required to reverse the present trends, and recommendations are given for specific steps which must be taken to insure the survival of the wetland ecosystems of the nation.

Davis, A.A. 1989. DER Wetlands Protection Action Plan. Water Pollution Control Association of Pennsylvania Magazine 22:18-22.

Abstract : *
The goal of the Pennsylvania DER (Department of Environmental Resources) wetlands protection policy is to prevent destruction, degradation, or significant impact to wetlands where practicable alternatives exist, and to minimize impacts or replace wetlands where impacts are unavoidable. DER will adopt the triple parameter approach found in the EPA

Wetland Identification and Delineation Manual to develop means of identifying and evaluating wetlands early in the development process. Mitigation standards will be established to replace the wetlands values which are lost or degraded. DER proposes to establish a 100 ft. impact area around all wetlands and a 300 ft. impact area around all "exceptional value" wetlands.

Doyle, R.C., G.C. Stanton, D.C. Wolf. 1977. Effectiveness of Forest And Grass Buffer Strips in Improving the Water Quality of Manure Polluted Runoff. American Society of Agricultural Engineers, Paper No. 77-2501.

Abstract: *
The objectives of this research were to determine the movement of nutrients and fecal bacteria in surface runoff from manure treated land and to evaluate the effectiveness of forest and grass buffer strips in improving the water quality of manure polluted runoff. Application of 90 mT/ha of dairy manure resulted in elevated levels of N, P, K, Na, fecal coliform and fecal streptococci in surface runoff collected at a distance of 0.0 m from the treated area. Forest buffer strips were effective in reducing the concentration of fecal coliform, fecal streptococci and total soluble N, P, and K in a distance of 3.8 m. Grass buffer strips were effective in reducing the loading rates of fecal bacteria and soluble NO3-N, P, Na, and K in a distance of 4.0 m. From these experiments, it was concluded that both forest and grass buffer strips were effective in improving the water quality of manure polluted runoff under the experimental conditions studied.

Edwards, E.A., D.A. Krieger, M. Bacteller, and O.E. Maughan. 1982. Habitat Suitability Index Models: Black Crappie. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.6.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Black crappies were found to be susceptible to turbidity, and to require abundant cover for growth and reproduction, in the form of aquatic vegetation, and submerged trees, brush or instream objects. Low velocity waters were preferred in such areas as pools and backwaters.]

Eilers, H.P., A. Taylor, and W. Sanville. 1983. Vegetative Delineation of Coastal Salt Marsh Boundaries. Environmental Management 7:443-452.

Abstract: *
Legislation mandating the protection of wetlands combined with current pressures to convert them to other uses, emphasize the need to determine accurately a wetland-upland boundary. We investigated six methods designed to establish such a boundary based on vegetation. Each method was applied to a common data set obtained from 295 quadrants along 22 transects between marsh and upland areas in 13 intertidal saline wetlands in Oregon and Washington. The multiple occurrence, joint occurrence, and five percent methods required plant species to be classified as salt marsh, upland, and non-indicator; cluster and similarity methods required no initial classification. Close agreement on wetland-upland boundaries determined by the six methods suggests that preclassification of plants and collection of plant cover data may not be necessary to determine the boundary.

Erman, D.C., J.D. Newbold, and K.B. Roby. 1977. Evaluation of Streamside Bufferstrips for Protecting Aquatic Organisms. Technical Completion Report, Contribution #165. California Water Resources Center, University of California, Davis, CA.

Abstract: *
An evaluation of logging impacts on streams was based on an extensive survey during 1975 of 62 northern California streams. Streams had been logged without stream protection measures, had been logged with protective bufferstrips, had been affected by localized disturbances (such as logging road stream crossings), and some were unaffected streams.

Benthic invertebrate communities of disturbed and undisturbed streams were compared by diversity index and ecological distance. Benthic invertebrate communities from streams logged without protective measures were significantly different from communities of unlogged (control) streams based on both diversity and ecological distance. Logging impacts were detected also in streams with buffer widths of less than approximately 30 m (98 ft). Streams with bufferstrips wider than 30 m (98 ft) did not display logging impacts. There was a direct correlation between increases in an index of diversity and increases in buffer width, and hence probably the degree of stream protection increased with buffer widths up to 30 meters (98 ft).

Invertebrate communities of logged or disturbed streams had a lower diversity index and a higher population than unlogged streams. Increased populations were primarily in three taxa - Baetis, Nemoura, and Chironomidae.

Communities in localized disturbances were significantly different from control stream sections. The differences were qualitative (i.e., different taxa) and thus contrast with the differences noted in logged or narrow buffered streams.

Stream invertebrates were far more effective in discerning logging impacts than the physical and chemical parameters measured. Variation among watersheds and sampling error contributed to the failure of physical or chemical measures to detect logging impacts. Measurements of over twenty environmental variables from the streams are included, and give an excellent catalogue of both disturbed and natural stream conditions in northern California.

Garbisch, E.W., Jr. 1977. Recent and Planned Marsh Establishment Work Throughout the Contiguous United States--A Survey and Basic Guidelines. Contr. Rep. D-77-3 U.S. Army Eng. Waterways Exp. Sta., Vicksburg, Mississippi.

Abstract: *
Information on deliberate marsh establishment work that is planned, underway, or completed throughout the contiguous United States 1970-1976 has been identified excluding WES, through (1) literature review, (2) interviewing people who, during the period of May 1975 through January 1977, have become known to be potential sources of pertinent information, and, (3) the completion of distributed information request forms by various correspondents.

Excluding U.S. Army Engineer Waterways Experiment Station (WES) projects currently underway, marsh establishment projects at 105 district locations have been completed for at least 1 year and 14 projects are planned for the immediate future. Out of the 105 completed or continuing marsh establishment projects, 9 were totally unsuccessful (due to vandalism, Canada geese eat-out, wave exposure too severe for seeding, or site surface elevations too low for seeding). Variation encountered in projects included 18 that existed in freshwater or nearly freshwater locations, 68 on the east coast, 17 on the gulf coast, 8 on the west coast, and 12 inland; 59 were purely experimental, as opposed to applied or partly so. From information received and collated, practical guidelines for site preparation, marsh establishment, and site management and maintenance were developed and are discussed. The two most important factors for preparing a site for marsh establishment were surface slopes and surface elevations. Within the tidal zone, surface slopes would be developed such that they exhibit reasonable stabilities in the absence of vegetative cover. Surface elevations must be carefully considered in the design and planning of a project and tied in with the various zones of marsh types existing in the region. Surface elevations are most important and their acceptable tolerances most stringent in areas subject to tidal amplitudes of 2 ft or less. Long term consolidation of fine sediment types is not considered of practical importance in achieving final surface elevations within acceptable tolerances. Close coordination between the site preparation and the marsh establishment stages of a project in terms of time of year is considered important; however, the use of nursery plant stock may alleviate the consequence of unacceptable marsh establishment because of unavoidable delays in the site preparation.

All aspects of marsh establishment must be an integral part of the design and planning the total project. Selection of the plant species to be used in the various available elevation zones at the site must be governed by (1) the plant species known to exist within these zones in natural marshes in the region, (2) the objectives of the project, (3) the relative growth rates and sediment stabilizing capabilities of the candidate plants, and (4) the relative food value ratings of the candidate plants stock that can be successfully used at the site will depend upon (1) the available surface elevations at the site, (2) the exposure of the site to various physical stresses, and (3) the time of planting.

Properly developed nursery stock is considered superior to all other types for sites or sections of sites subjected to high wave and debris deposition stresses and for summer, fall, and winter plantings. Marsh establishment by seeding is considered feasible only in the spring, in sheltered or confined areas, and at elevations above mean tidal level (MTL) (preferably the upper 20% of the mean tidal range). Although exceptions are discussed, a rule of thumb is that increasing the maturity of nursery transplant materials upon decreasing the elevations in the tidal zone will lead to the greatest survival of transplants and the best overall plant establishment. Transplant spacing and fertilization requirements are discussed. Although fertilizations should be conducted for all marsh establishment work in sand sediments, the need for such fertilizations in other sediment types (silt-clay) is not readily determined.

Three principal maintenance and management requirements for marsh establishment determined by the study are (1) removal of debris and litter depositions, (2) protection against waterfowl depredation, and (3) fertilization. During the growing season, particularly for late spring and summer plants, algae, submerged aquatic plants, free-floating aquatic plants, and/or sundry debris that have been washed and deposited throughout the developing marsh, may have to be periodically removed. Otherwise, the affected plants may be seriously impaired. Depending upon the prevailing populations of geese, and to a lesser extent other wildlife, marsh establishment sites may have to be protected by enclosures or other effective devices. Areas of marsh establishment sites subject to extended periods of high wave stress may require annual maintenance fertilizations to prevent the marsh from succumbing to the stress.

Gilliam, J.W., and R.W. Skaggs. 1988. Natural Buffer Areas and Drainage Control to Remove Pollutants from Agricultural Drainage Waters. pp. 145-148. *In*: J.A. Kusler, M. Quammen, and G. Brooks (eds.), ASWM Technical Report 3; Proceedings of the National Wetland Symposium: Mitigation of Impacts and Losses, October 8-10, 1986. US Fish & Wildlife Service, U.S. EPA, and U.S. Army Corps of Engineers.

Abstract: *

Because rainfall exceeds evapotranspiration, water drains via surface or subsurface flow from all land on the Atlantic Coast. This water always contains some nitrogen, phosphorus, and sediment. Even when present in low concentrations in drainage water, nitrogen and phosphorus can contribute to water quality problems in receiving streams and estuaries. For example, a forested watershed is generally considered to represent the minimum loss of nutrients to drainage water. Yet it has been estimated that 47% of both the nitrogen and phosphorus input to the Chowan river in North Carolina comes from forested areas. This river has experienced severe water quality problems in the past few years in the form of algae blooms caused by excess nutrients. Thus any increase in nutrient concentrations can be a potential problem for downstream areas.

Our work has concentrated on the contribution of agricultural to nonpoint sources of nutrients and sediment and methods of controlling this input. We first attempted to quantify the amounts of nutrients leaving cultivated fields and to determine what factors controlled these losses. Recent efforts have focused upon developing methods to minimize contributions of nutrient to drainage water utilizing methods which are compatible with sustained high agricultural production. This paper summarizes some of these findings and contains essentially the same information as an earlier summary (Gilliam and Skaggs, 1986. "Riparian Areas and Water Management to Control Nonpoint Pollutants." *In*: C. Y. Kuo (ed.), Effects of Upland and Shoreline Land Use on the Chesapeake Bay. Virginia Polytechnical University, Blacksburg, Virginia).

Grismer, M.E. 1981. Evaluating Dairy Waste Management Systems Influence on Fecal Coliform Concentration in Runoff. M.S. Thesis, Oregon State Univ., Corvallis.

Abstract: *
This paper examines the environmental factors influencing the die-off and transport of fecal coliform bacteria present in wastes applied to the land surface. These factors are examined specifically for dairy waste management systems and the net effect each system has on runoff water quality. A model is developed that considers the effects of precipitation, season, method of waste storage and application, die-off of the bacteria in storage, die-off of the bacteria on the land surface, infiltration of bacteria in the soil profile, soil characteristics, overland transport of bacteria (runoff), and buffer zones. The model is then applied to the Tillamook basin in northwestern Oregon to evaluate which waste management procedures significantly decrease bacterial pollution potential in agricultural runoff. [No buffer widths are recommended.]

Groffman, P.M., A.J. Gold, T.P. Husband, R.C. Simmons, and W.R. Eddleman. 1990. An Investigation into Multiple Uses of Vegetated Buffer Strips. Publ. No. NBP-90-44, Dept. of Natural Resources Science, Univ. of Rhode Island, Kingston, RI.

Abstract: *
While the use of buffer zones to protect wetlands and surface water bodies is mandated by Rhode Island law, there is very little information available on the factors that control the effectiveness of these zones under Rhode Island conditions. Research was needed to

determine the criteria that should be considered in the design and maintenance of buffer zones in the landscape. The goal of our study was to provide information on the suitability of any particular piece of ground as a "vegetated buffer strip (VBS)" for water quality protection and wildlife habitat given information on soils, vegetation, geomorphology and surrounding land uses. For the water quality studies, our approach was to make intensive, site specific measurements of pollutant removal from surface and subsurface flow at a small number of well instrumented buffer strips. We also developed a "microbial index" of buffer zone pollutant removal capacity that was then measured at a larger number of sites differing in soils, vegetation, geomorphology and surrounding land uses. The intensive site specific measurements of actual buffering activity were used to calibrate this index. For the wildlife studies we determined species richness of birds and herpetofauna and described wildlife habitat parameters in buffer strips. We then developed a model to prescribe buffer requirements to protect wetland-dependent wildlife species.

Guidelines for Land Development and Protection of the Aquatic Environment [British Columbia]. 1978. Land Use Unit, Habitat Protection Division, Resource Services Branch; Dept. of Fisheries and Oceans Canada, Pacific Region, Fisheries & Marine Service, 1090 West Pender Street, Vancouver, British Columbia, V6E 2P1. Fisheries & Marine Service Technical Report No. 807. 55 pp.

Abstract: **
This document presents proposed technical guidelines for the protection of riparian ecosystems from deleterious impacts of adjacent land development. The guidelines recommend that an adequate green strip, or buffer zone, be maintained in its natural state along each side of a watercourse to preserve the aquatic habitat. For residential development, the recommended buffer is the greater of 59 ft (18 m) from the stream centerline, or 49 ft (15 m) from the high water mark. For industrial development, the recommended buffer is 98 ft (30 m). For steep slopes, the buffer should be extended, where necessary, to 30 ft (9 m) inland from the top of the slope for residential development, and 49 ft (15 m) inland from the top of the slope for industrial development. Guidelines for the protection of water quality and quantity for rivers and streams are outlined and illustrated, including detention and settling basins, swales, and sediment control measures. General construction guidelines are given for instream or streamside construction activity (typically restricted to June, July, and August). Such activities include stream crossings (vehicular, pipe, aerial, and buried), storm sewer outfall structures, and erosion and flood control measures.

Harris, R.A. 1985. Vegetative Barriers: An Alternative Highway Noise Abatement Measure. Noise Control Engineering Journal 27:4-8.

Abstract: *
Excessive highway noise levels affect almost 40 percent of this country's population. Efforts to solve a problem of this magnitude will obviously require a significant expenditure

of funds, unless innovative noise abatement measures are utilized. The ability of vegetation to reduce highway noise levels has long been ignored. A primary goal of this paper is to present evidence that vegetation can be used as an effective highway noise barrier under certain circumstances. The results of previous studies of the effects of vegetation on highway traffic noise, as well as on-site field measurements conducted by the author, are presented. In addition, an actual situation where vegetation was selected as an alternative highway noise abatement measure is described.

Hart, R. 1981. Regulatory Definitions of Wetlands: Do They Maximize Wetland Function? pp. 273-283. *In*: P. McCaffrey, T. Breemer, and S. Gatewood (eds.), Proceedings of a Symposium: Progress in Wetlands Utilization and Management. Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin.

Abstract: **
Preliminary, independent analysis of data collected from two of five studies conducted for the U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi. Using quantitative sampling of vegetation in transition zones between a variety of local wetland habitat types and the adjacent uplands to that wetland type, "the study was to provide information to develop improved methods of wetland boundary delineation." The two areas analyzed were in coastal Georgia (in 5 wetland types: salt marsh, undisturbed freshwater marsh, grazed freshwater marsh, swamp forest, and shrub wetland) and in west central Florida (in 8 wetland types: freshwater marsh, cypress dome, shrub swamp, riverine cypress swamp and marsh, bayhead swamp, mangrove swamp, and salt marsh). Belt transects were used in both areas crossing from the wetland through the transition zone into the upland until the vegetation was predominantly upland type. Length of transition zone, species diversity, richness and distribution, and general characteristics were recorded. Species with a frequency of occurrence $\geq$ 20% were charted for each wetland type along the transect indicating the location of the respective transition zone. Percent number of species (trees, shrubs, and herbs) in each zone (wetland, transition, and upland) for each study area was also charted.

Preliminary information does indicate that the physiognomic diversity and added species diversity of the transition zone may enhance wetland functions. "A significant difference in plant species composition is often sought in delineating wetland boundaries. One might seek instead the point where contribution to wetland function is minimal...."

Heede, B.H. 1984. Overland Flow and Sediment Delivery: An Experiment with Small Subdrainage in Southwestern Ponderosa Pine Forests (Colorado, U.S.A.). J. Hydrology 72:261-273.

Abstract: *
Overland flow and sediment delivery were insignificant on 14 small subdrainages of southwestern Ponderosa pine forests. Sediment delivery from undisturbed forest floor

practically was nil. Sources for sediment production were roads and erosion pavements and were not universally distributed on the watersheds. When undisturbed forest floor was located between the source area and the collector, the effect of the source area was offset. The data indicated that increased infiltration into the undisturbed forest floor was responsible by reducing overland flow. Most erosion pavements were believed to be the result of selected timber harvest 42 years ago. Hypotheses on the development of these pavements were proposed.

Heifetz, J., M.L. Murphy, and K.V. Koski. 1986. Effects of Logging on Winter Habitat of Juvenile Salmonids in Alaskan Streams. North American J. of Fisheries Management 6:52-58.

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 logged on at least one bank; and a stream in a clear-cut area with strips of forest (buffer strips) along the stream banks. In order 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 the 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 (e.g., upturned 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 did 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.

Hewett, J.D., and J.C. Fortson. 1982. Stream Temperature Under an Inadequate Buffer Strip in the Southeast Piedmont. Wat. Resour. Bull. (AWRA) 18:983-988.

Abstract: *

A paired watershed experiment on the southeastern Piedmont to determine the effect of clearcutting loblolly pine on water quantity, quality, and timing has shown that stream water temperatures were increased as much as 20°F (-6.7°C) even though a partial buffer strip of trees and shrubs were left in place to shade the stream. Winter time minimum stream temperatures were lowered as much as 10°F (-12.2°C) by the same treatment. A stream temperature model now in use did not predict such elevated temperatures. The authors suggest that forest cover reductions in areas of gentle land relief may elevate the temperature of shallow ground water moving to the stream, even with a substantial buffer strip in place.

Hickman, T., and R.F. Raleigh. 1982. Habitat Suitability Index Models: Cutthroat Trout. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.5.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Cutthroat trout require streamside vegetation for cover, as a source of large organic debris, for reduction of silt, fines and water turbidity, and to maintain acceptable stream temperatures. Cutthroat trout were found to be susceptible to turbidity > 35 ppm, moving to cover when this level is exceeded. Water temperatures > 22°C (72°F) inhibited the distribution of the cutthroat trout, with preferred temperatures ranging from 9 to 12°C (48 to 54°F). In most cases, optimum habitat can be maintained with buffer strips of 100 ft, 80% of which is either well-vegetated or has stable rocky stream banks to provide erosion control and maintain undercut stream banks. Canopy cover should provide 50-75% shade at midday.]

Jacobs, T.C. and J.W. Gilliam. 1985. Riparian Losses of Nitrate from Agricultural Drainage Waters. J. Environ. Qual. 14:472-478.

Abstract: *
Increased nutrient levels in surface streams and eutrophication of some Coastal Plain waters has led to inquiries about both the amount and control of nitrate losses from agricultural fields. Nitrate concentrations in shallow groundwaters beneath cultivated fields and in the drainage waters from those fields were examined to determine the fate of nitrogen loss to drainage waters. From a Middle Coastal Plain watershed where well and moderately well-drained soils dominate agricultural fields, 10 to 55 kg ha-1 yr-1 NO3-N moved from the fields in subsurface drainage water. However, most fields are bordered by forested buffers between the cultivated areas and streams which consist of poorly and very poorly-drained soils covered by dense vegetation. The evidence strongly indicated that a substantial part of the nitrate in the drainage water was denitrified in the buffer strip and that assimilation by vegetation was insignificant. Buffer strips of > 16 m (53 ft) were effective for inducing significant losses of nitrate before drainage waters reached the stream. A field containing subsurface drainage tubing which emptied into open ditches moved more nitrogen into surface water than those fields without subsurface drainage improvements. From a Lower Coastal Plain watershed, a dense clay layer below the surface horizon reduced subsurface

drainage resulting in total losses form the field of only 6 to 12 kg ha-1 yr-1 NO3-N. These losses were mostly in surface runoff. The extensive floodplain of the natural stream had a high capacity to reduce large quantities of N but the low total loss from the watershed is largely a result of low input to the drainage water from nonpoint sources. Soils included in this study were Typic Paleudults, Arenic Paleudults, Aquic Hapludults, and Aeric Paleudults.

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 J. of Fisheries Management 6:532-537.

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 banks; 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 m3/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 I 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 the fall and winter; therefore, the effects of logging on their growth could not be assessed.

Jones, J.J., J.P. Lortie, and U.D. Pierce, Jr. 1988. The Identification and Management of Significant Fish and Wildlife Resources in Southern Coastal Maine. Maine Department of Inland Fisheries and Wildlife, Augusta, Maine. 140 pp.

Abstract: *
(Executive Summary)
This report identifies and rates the value of wildlife and fisheries habitats for 17 towns in south coastal Maine from Kittery north to Phippsburg. Inland and coastal wetlands, deer wintering areas, seabirds nesting islands, wading bird rookeries, eagle nest sites, osprey nest sites, least tern and piping plover nest sites, shorebird areas, coastal wildlife concentration areas, seal haul-outs, and other special wildlife habitats were identified and mapped. The sensitivity of each special habitat is discussed and recommendations are presented to

prevent or minimize the impacts of human activities on these areas. Maps are available from local towns, the State Planning Office, and the Maine Department of Inland Fisheries and Wildlife regional office.

A method for objectively determining the value of open space for wildlife is also included. The procedure is based on the diversity and abundance of species within 16 habitat types and incorporates the special habitats listed above, total acreage, and scarcity of the habitat type. An example field evaluation form is included.

[The authors review the importance of riparian habitat to fish, birds and mammals. From a fisheries habitat perspective, riparian vegetation along streams serves to regulate stream temperature, stabilize stream banks, regulate nutrient input, provide invertebrates as fish food, and provide cover. Riparian buffers also moderate runoff and flow rates, and prevent sedimentation. Riparian buffers around lakes and ponds provide similar functions. Riparian habitat widths suggested in pertinent literature sources range from 98 ft (30 m) to 141 ft (43 m).

Riparian habitat supports a greater diversity of birds in greater densities than does adjacent areas. In addition to providing nesting and feeding habitat, riparian buffers protect water quality, ensuring habitat for invertebrates and fish that support shorebirds, wading birds and other animals. Riparian habitat widths necessary to maintain some breeding bird populations suggested in pertinent literature sources range from 246 ft (75 m) to 656 ft (200 m).

Riparian habitat is also valuable to mammals, with riparian ecosystem alteration having significant adverse impact on small and large mammal species richness and abundance. Suggested riparian habitat widths necessary to maintain some mammal species populations include 328 ft (100 m) for large mammals and 220 to 305 ft (67 to 93 m) for small mammals.]

Kao, D.T.Y., B.J. Barfield, and A.E. Lyons, Jr. 1975. On-Site Sediment Filtration Using Grass Strips. pp. 73-82. *In*: National Symposium On Urban Hydrology and Sediment Control, July 28-31, 1975. University of Kentucky, Lexington, KY.

Abstract: *
The use of grassed areas as a sediment filter is proposed in this article for urban construction sites. The characteristics of flow of shallow water depths were studied analytically based on the momentum balance principle and experimentally using artificial grasses. The new technique developed in this study of fabricating the simulated grasses by imbedding plastic strips of various stiffness in molten paraffin in a random pattern is proven a useful one. When the right flexibility of the plastic blades is chosen, a close simulation of a given type of real grass property appears possible. The flow resistance (n vs. VR) model proposed by Ree and Palmer was first used in the presentation of the experimental results of

this study and found to be unsatisfactory when flow depth is shallow. A new mathematical model is proposed to relate the resistance factor to the blade Reynolds number. The experimental results also predicted high sediment filtration efficiency of grass filters. To solve the problems of sediment inundation and killing of the vegetation a new filter arrangement pattern which alternates the grass strips with bare ground strips is proposed. The preliminary test results conducted on the use of this pattern indicated that when the appropriate width ratio of the grass to bare ground strips is selected the filter remains operating with high trapping efficiency and all the trapped sediments were retained in the bare ground regions. [Results are primarily descriptive. No design procedure or widths are proposed.]

Karr, J.R. and I.J. Schlosser. 1978. Water Resources and the Land-Water Interface. Science 201:229-234.

Abstract: *
(Introduction)
Many channel management activities degrade rather than improve water quality and thereby decrease the effectiveness of nonpoint control programs. Our hypotheses are that (i) maintenance of more natural nearstream vegetation and channel morphology in agricultural watersheds can lead to significant improvements in water quality and stream biota, and (ii) the best management option for long-term benefit to society is an integrated effort involving sound management of the land surface and stream channels.

The approach used is a multidisciplinary synthesis. Specifically, we evaluate (i) existing data regarding the ability of nearstream vegetation to reduce nutrient and sediment transport from the terrestrial to the aquatic component of agricultural ecosystems, (ii) the effects of nearstream vegetation on water temperature and its implications for water quality, (iii) the effects of channel morphology on sediment locads, and (iv) the impact of nearstream vegetation and channel morphology on stream biota. With this information we judge the feasibility of using nearstream vegetation and channel morphology (5) to improve water quality and quality of stream biota. Finally, we propose a generalized model (6) which suggests that society should approach planning for control of nonpoint pollution in agricultural watersheds with a multidisciplinary synthesis of best management practices. Effective nonpoint control will depend on the concept of "best management systems."

Koski, K.V., J. Heifetz, S. Johnson, M. Murphy, and J. Thedinga. 1985. Evaluation of Buffer Strips for Protection of Salmonid Rearing Habitat and Implications for Enhancement. pp 138-155. *In*: Thomas J. Hassler (ed.), Proceedings: Pacific Northwest Stream Habitat Management Workshop, October 10-12, 1985. American Fisheries Society, Western Division. Humboldt State University, Arcata, California.

Abstract: **

The authors examine the effectiveness of buffer strips in protecting rearing habitat of juvenile salmonids from the effects of logging. Evaluation was through comparison of habitat and fish population density in old-growth, buffered and clear-cut reaches of streams. In summer, buffered and clear-cut reaches had more algae, benthos, and, as a result, more salmonid fry (age 0) than old-growth reaches. In winter, old-growth and buffered reaches contained the most critical habitat (i.e., pools with cover) and had the highest densities of parr. Clear-cut reaches had the least amount of debris and pool habitat, and consequently, had fewer parr than either buffered or old-growth reaches. Logging with buffer strips appears to enhance fish production by increasing fry recruitment in summer while sustaining survival of parr in winter.

Krieger, D.A., J.W. Terrell, and P.C. Nelson. 1983 Habitat Suitability Information: Yellow Perch. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.55.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Yellow perch are associated with the littoral zone of lakes and reservoirs where shoreline vegetation is present (optimally 25% cover). This vegetation provides for both cover and spawning. Riverine habitat for yellow perch requires pools and slack water areas along a vegetated shoreline edge. High turbidity lowers visibility of prey and restricts zooplankton to the upper water column, where they are unavailable for the juvenile yellow perch to eat. The high summer temperature lethal to the yellow perch is 32.2 °C (90°F).]

Lake, J., and J. Morrison. 1977. Environmental Impact of Land Use on Water Quality: Final Report on the Black Creek Project. Allen County Soil and Water Conservation District, Fort Wayne, Indiana, and the US EPA, Region 5, Great Lakes National Program Office, 230 South Dearborn Street, Chicago, Illinois 60604. EPA-905/9-77-007-A, 94 pp.

Abstract: *
This is a final non-technical summary of the Black Creek sediment control project. This project is to determine the environmental impact of land use on water quality and has completed its four and one half years of watershed activity. The project, which is directed by the Allen County Soil and Water Conservation District, is an attempt to determine the role that agricultural pollutants play in the degradation of the water quality in the Maumee

River Basin and ultimately in Lake Erie. [The report concludes that buffer zones are believed to prevent erosion and serve as filters of surface runoff.]

Lovejoy, T.E. and D.C. Oren. 1981. The Minimum Critical Size of Ecosystems. pp. 7-12. *In*: R. L. Burgess and D. M. Sharpe (eds.), Forest Island Dynamics in Man-Dominated Landscapes. Ecological Studies #41. Springer-Verlag: New York. 310 pp.

Abstract: **
The authors conclude that because natural areas are being fragmented by development, the basic theory of island biogeography may be applied towards non-island environments in order to establish the minimum critical size of ecosystems required to maintain biological integrity. The report suggests that the size of habitat reserves should be dictated by the goal of maintaining a functioning ecosystem, not strictly by species numbers. The dynamics of an ecosystem may prevent managing the biological integrity of reserves at 100%, even with additional safety factors.

Lowrance, R., R. Todd, J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen. 1984. Riparian Forests as Nutrient Filters in Agricultural Watersheds. BioScience. 34:374-377.

Abstract: *
Riparian (streamside) vegetation may help control transport of sediments and chemicals to stream channels. Studies of a coastal plain agricultural watershed showed that riparian forest ecosystems are excellent nutrient sinks and buffer the nutrient discharge from surrounding agroecosystems. Nutrient uptake and removal by soil and vegetation in the riparian forest ecosystem prevented outputs from agricultural uplands from reaching the stream channel. The riparian ecosystem can apparently serve as both a short- and long-term nutrient filter and sink if trees are harvested periodically to ensure a net uptake of nutrients.

Lynch, J.A., E.S. Corbett, and K. Mussallem. 1985. Best Management Practices for Controlling Nonpoint-Source Pollution on Forested Watersheds. J. Soil and Water Conservation 40:164-167.

Abstract: *
The Pennsylvania Department of Environmental Resources, Bureau of Forestry, developed a set of best management practices (BMPs) to limit and/or control nonpoint-source pollution from silvicultural activities. Nonpoint-source pollution in a forested watershed is characterized by changes in stream temperature turbidity/sediment levels, and nutrient concentrations and export. A watershed study conducted on the Leading Ridge Experimental Watersheds in central Pennsylvania suggested that the BMPs were effective in controlling nonpoint-source pollution from a 44.5-hectare (110 acre) commercial clearcut. Slight increases in stream temperature, turbidity, and nitrate and potassium concentrations were observed, but these increases did not exceed drinking water standards. [One of the

BMPs was the maintenance of a protective buffer strip, varying in width from site to site, but generally at least 98 ft (30 m) on each side of the stream channel.]

Mahoney, D.L., and D.C. Erman. 1984. The Role of Streamside Bufferstrips in the Ecology of Aquatic Biota. pp. 168-175. *In*: R. E. Warner and K. M. Hendrix (eds.), California Riparian Systems: Ecology, Conservation, and Productive Management.

Abstract: *
Riparian vegetation is important as a source of food to stream organisms, as shade over small-order streams, and as a bank-stabilizing force to prevent excessive sedimentation and to intercept pollutants. Logging may significantly affect each of these factors unless proper protective measures are employed. Current research is underway on the recovery of small northern Ca. streams after logging. Analysis of algal samples from 30 streams shows light intensity and chlorophyll concentrations are major factors relating to logging intensity that affect instream primary production. Transportable sediment from 24 streambeds has shown that this measure of sediment is higher (P=.001) in logged and narrow buffered streams than in controls 7 to 10 yrs after logging.

Martin, W.C., D.S. Noel, and C.A. Federer. 1984. Effects of Forest Clearcutting in New England on Stream Chemistry. J. Environ Qual. 13:204-210.

Abstract: *
Differences in stream chemistry between recently clearcut and nearby uncut watersheds were generally small in a wide variety of soil and forest types throughout New England. Water samples were collected during six periods of the year in 1978 and 1979 from 6 entirely clearcut, 32 partially clearcut, and 18 uncut watersheds. The largest differences that could be attributed to harvesting occurred in entirely clearcut watersheds, especially in the White Mountains of New Hampshire. In one area of the White Mountains, inorganic N was 4 times higher (2 mg/L), and Ca was 2 times higher (4 mg/L) in streams from a clearcut watershed than a nearby uncut watershed. Elsewhere, only minor changes in stream chemistry resulted from cutting; the amount of the cutting response was of the same magnitude as natural variations among streams draining similar watersheds. Clearcutting less than entire watersheds, patch and strip cuts, and buffer strips along streams all appear to reduce the magnitude of changes in stream chemistry.

Martinez-Taberner, A. G. Moya, G. Ramon, and V. Forteza. 1990. Limnological Criteria for the Rehabilitation of a Coastal Marsh. The Albufera of Majorca, Balearic Islands. Ambio 19:21-27.

Abstract: *
Mediterranean coastal zones have turned into popular leisure centers visited mainly by northern European tourists. The hotel industry has produced an economic boom in what were relatively undisturbed areas. Due to this fact studies dealing with the management and

preservation or rehabilitation of natural zones are essential to balance social and economic development. The aim is to preserve the natural environment and landscape in order to retain its appeal for visitors. The present work on the rehabilitation of the Albufera of Majorca is an area within this context. The geomorphological evolution of the Albufera of Majorca is discussed and the principal environmental components are analyzed. On this basis major criteria for rehabilitation are proposed; 1. To preserve the present dynamics of the lagoons and eliminate factors distributing lotic environments. 2. To increase open water zones by progressively reintroducing preexisting lagoons in order to achieve an increase in food resources and in the number of habitats. 3. To change the present water circulation pattern fractalizing its route (1), i.e., allowing water to spread throughout the Albufera thereby decreasing its renewal rate. 4. To avoid environmental homogeneity and to attempt a smoothening out of the environmental gradient so that it can be occupied by a large number of species with different environmental tolerances.

McMahon, T.E. 1983. Habitat Suitability Index Models: Coho Salmon. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.49.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Coho have four distinct life stages: adult, spawning/embryo/alevin, parr, and smolt. Habitat requirements must be met for each of these stages in order to ensure species survival. Problems with accessibility to the spawning stream (blocked by dams, debris piles, and waterfalls occurring during low flows) and water quality were found to be the major limiting factors for adult coho in their upstream migration. Temperatures > 25.5°C (78°F) were found to be lethal, and the disease rate increased with temperatures > 12.7°C (55°F). Low returns of adult coho coincide with low summer flows and high winter flows. Increased production of coho was found when winter flows were stabilized and summer flows were increased. Young coho feed primarily on drifting aquatic insects and terrestrial insects. Substrate composition, riffles, and riparian vegetation are the most important factors in the production and availability of aquatic and terrestrial insects. Young coho per unit area was greatest in pools > 0.3 m deep with large riffles upstream (gravel and rubble substrates), and the presence of insect drop and leaf litter from riparian vegetation. Cover consisted of instream debris, undercut banks, overhead vegetation, logs, and roots. The amount of wintering habitat was found to be a limiting factor in coho production. Areas of the river which were channelized or heavily grazed were found to have a very low presence of coho biomass. Streamside vegetation helps to regulate stream temperature. Warm winter temperatures from the lack of vegetation cover shift the period of emergence of fry and downstream migration of smolts to earlier and less favorable survival periods. But canopy cover > 90% was found to be an unsuitable habitat due to excessive enclosure.

Milligan, D.A. 1985. The Ecology of Avian Use of Urban Freshwater Wetlands in King County, Washington. M.S. Thesis, Univ. of Washington, Seattle.

Abstract: *
The ecology of avian use of urban freshwater wetlands in King County, Washington was examined in order to determine what factors affected bird species use of these systems. Bird species use was found to be correlated with wetland habitat complexity. Combination wetlands (those with three or more wetland classes) that had the highest number of plant communities presented had the highest bird use as measured by bird species richness, plant species richness, and more bird species breeding than in Open Water or Shrub-Scrub wetlands.

Different buffer widths were tested to determine their effects on bird community composition. The amount of buffer was positively correlated with bird community response variables such as bird species diversity. The amount of buffered wetland edge proved to have the strongest correlation. Furthermore, results showed there was only a minor increase in predicted bird species response with the increased buffer widths of 50 ft (15 m), 100 ft (31 m), and 200 ft (61 m).

Comparisons made between the created and natural Combination and Open Water wetlands indicated that it is possible to simulate natural wetlands for wildlife habitat. Results served not only as baseline biological information regarding the ecology of urban wetlands but also as the basis for design decisions when enhancing natural urban wetlands of when creating urban wetlands. Design implications and recommendations are discussed.

Moring, J.R. 1982. Decrease in Stream Gravel Permeability After Clear-cut Logging: an Indication of Intragravel Conditions for Developing Salmonid Eggs and Alevins. Hydrobiologia 88:295-298.

Abstract: *
Average gravel permeabilities decreased significantly in an Oregon, U.S.A., stream after 82% of the drainage basin was clear-cut. Patterns remained statistically normal in a stream of an unlogged drainage basin and in a stream in a drainage area that was 25% clear-cut, but with riparian buffer strips about 30 m (98 ft) wide left along the stream. It is cautioned that decreases in yearly permeability values can reflect adverse intragravel conditions for developing salmonid eggs and alevins, even if other environmental changes, particularly the amount of sediment fines in gravel, are not as apparent.

Mudd, D.R. 1975. Touchet River Wildlife Study. Applied Research Section, Environmental Management Division, Washington Game Department. Bulletin No. 4.

Abstract: *
A three-month wildlife study on the Touchet River was undertaken by the Washington Game Department in conjunction with the Bureau of Reclamation's Walla Walla Project, Touchet Division. The present characteristics, and amounts of riparian wildlife habitat along the course of the Touchet River were determined, and six distinct habitat types were found to exist. A wildlife index was determined for each habitat type, and width of that type. Habitat Type I (natural riparian, predominantly mature) supported the majority of the wildlife, and a minimum width of 75 ft (23 m) provided maximum wildlife populations. Bird, mammal, and plant species were surveyed. Populations of the most important wildlife species, ring-necked pheasant, California quail, mourning dove, white-tailed deer, and mule deer, were studied in detail.

Murphy, M.L., J. Heifetz, S.W. Johnson, K.V. Koski, J.F. Thedinga. 1986. Effects of Clear-cut Logging With and Without Buffer Strips on Juvenile Salmonids in Alaskan Streams. Can. J. Fish. Aquat. Sci. 43:1521-1533.

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 buffers. Buffered reaches did not consistently differ from old-growth reaches; clearcut 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 amounts of debris. If debris was left in clear-cut reaches, or added in buffered reaches, coho salmon parr were abundant (10-22/100 m2). If debris had been removed from clear-cut reaches, parr were scarce (< 2/100 m2). 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.

Naiman, R.J., H. Decamps, J. Pastor, and C.A. Johnston. 1988. The Potential Importance of Boundaries to Fluvial Ecosystems. Journal of the N. American Benthological Society 7:289-306.

Abstract: *
Boundaries separating adjacent resource patches are dynamic components of the aquatic landscape. This article addresses some fundamental questions about boundary structure and

function in lotic ecosystems. We give examples of longitudinal and lateral boundaries associated with stream systems, demonstrate the application of chaos theory to understanding the inherent variability of boundary properties, and compare characteristics of boundaries in an arctic-tropical transect. We conclude that studies of resource patches, their boundaries, and the nature of exchange with adjacent patches will improve our perspective of drainage basin dynamics over a range of temporal and spatial scales.

Newbold, J.D., D.C. Erman, K.B. Roby. 1980. Effects of Logging on Macroinvertebrates in Streams With and Without Buffer Strips. Can. J. Fish. Aquat. Sci. 37:1076-1085.

Abstract: *
The impact of logging with and without buffer strip protection on stream macroinvertebrates was examined through comparisons of community structure in commercially logged and control watersheds throughout northern California. A nonparametric test of community dissimilarities within matched blocks of two control and one or two treated stations showed significant ($p < 0.05$) logging effects on unprotected streams when Euclidean distance and mutual information were used as dissimilarity indices, but not when chord distance was used. Shannon diversity in unprotected streams was lower ($p < 0.01$) than in control (unlogged) streams; densities of total macroinvertebrate fauna and of Chironomidae, Baetis, and Nemoura were higher in unprotected streams than in controls ($p < 0.05$). Streams with narrow buffer strips (< 30 m; 98 ft) showed significant effects by the Euclidean distance test, but diversity varied widely and was not significantly different from that in either unprotected or control streams. Macroinvertebrate communities in streams with wide buffers (≥ 30 m; 98 ft) could not be distinguished from those of controls by either Euclidean distance of diversity; however, diversity in wide-buffered streams was significantly greater than in streams without buffer strips, indicating effective protection from logging effects.

Nieswand, G.H., R.M. Hordon, T.B. Shelton, B.B. Chavooshian, and S. Blarr. 1990. Buffer Strips to Protect Water Supply Reservoirs: A Model and Recommendations. Water Resources Bulletin 26:959-966.

Abstract: *
Buffer strips are undisturbed, naturally vegetated zones around water supply reservoirs and their tributaries that are a recognized and integral aspect of watershed management. These strips can be very effective in protecting the quality of public potable water supply reservoirs by removing sediment and associated pollutants, reducing bank erosion, and displacing activities from the water's edge that represent potential sources of nonpoint source pollutant generation. As part of a comprehensive watershed management protect for the State of New Jersey, a parameter-based buffer strip model was developed for application to all watersheds above water supply intakes or reservoirs. Input requirements for the model include a combination of slope, width , and time of travel. The application of the model to a watershed in New Jersey with a recommended buffer strip width that ranges

from 50 to 300 feet, depending upon a number of assumptions, results in from 6 to 13 percent of the watershed above the reservoir being occupied by the buffer.

Noel, D.S., C. W. Martin, and C.A. Federer. 1986. Effects of Forest Clearcutting on New England in Stream Macroinvertebrates and Periphyton. Environmental Management, 10:661-670.

Abstract: *
Clearcutting may alter stream biota by changing light, temperature, nutrients, sediment particle size, or food in the stream. We sampled macroinvertebrates during late summer of 1979 in first and second order headwater streams draining both two- and three-year-old clearcuts and nearby uncut reference areas in northern New England, USA. Periphyton were sampled throughout the summer by placing microscope slides in these streams for 13-37 days. Periphyton cell densities on these slides following incubation were about six times higher in cutover than in reference streams. Green algae (Chlorophyceae) accounted for a higher proportion of total cell numbers in cutover than in reference streams, whereas diatoms (Bacillariophyceae) dominated the reference streams. The macroinvertebrate density in cutover streams was 2-4 times greater than in the reference streams, but the number of taxa collected was similar in both cutover and reference streams. Higher numbers of mayflies (Ephemeroptera) and/or true flies (Diptera) in the cutover streams accounted for the difference. Because nutrient concentrations in the cutover streams were nearly the same as those in the reference streams, these differences in macroinvertebrates and periphyton densities were apparently caused by higher light levels and temperature in the streams in the clearcuts. Leaving buffer strips along the streams will reduce changes in stream biology associated with clearcutting.

Noss, R.F. 1983. A Regional Landscape Approach to Maintain Diversity. BioScience 33:700-706.

Abstract: *
Land managers have traditionally assumed that achieving maximum local habitat diversity will favor diversity of wildlife. Recent trends in species composition in fragmented landscapes suggest, however, that a more comprehensive view is required for perpetuation of regional diversity. A regional network of preserves, with sensitive habitats insulated from human disturbance, might best perpetuate ecosystem integrity in the long term.

Noss, R.F. 1987. Corridors in Real Landscapes: A Reply to Simberloff and Cox. Conservation Biology 1:159-164.

Abstract: *
Habitat corridors have become popular in land-use and conservation strategies, yet few data are available to either support or refute their value. Simberloff and Cox (1987) have criticized what they consider an uncritical acceptance of corridors in conservation planning.

Any reasonable conservation strategy must address the overwhelming problem of habitat fragmentation. Although Simberloff and Cox use island analogies to illustrate advantages of isolation, these analogies do not apply directly to problems in landscape planning. Genetics also does not offer unequivocal advice, but the life histories of wide-ranging animals (e.g., the Florida panther) suggest that the maintenance or restoration of connectivity in the landscape is a prudent strategy. Translocation of individuals among reserves, considered by Simberloff and Cox a viable alternative to natural dispersal, is impractical for whole communities of species that are likely to suffer from problems related to fragmentation.

Many of the potential disadvantages of corridors could be avoided or mitigated by enlarging corridor widths or by applying ecologically sound zoning regulations. Corridors are not the solution to all our conservation problems, nor should they be used as a justification for small reserves. But corridors can be a cost-effective complement to the strategy of large and multiple reserves in real-life landscapes.

Omernik, J.M., A.R. Abernathy, and L.M. Male. 1981. Stream Nutrient Levels and Proximity of Agricultural and Forest Land to Streams: Some Relationships. J. Soil Water Conservation 36:227-231.

Abstract: *
The effectiveness of forested buffer strips for controlling nutrient loss from agricultural land to streams is not well documented. To clarify this effectiveness, an attempt was made to determine whether considering the proximity of two land use types (agriculture and forest) to streams improved the ability to predict nutrient levels using the proportion of watersheds occupied by each land use. Results indicated that considering the proximity of these land uses did not improve this predictive ability. The reason may be that the long-term effects of near-stream vegetation in reducing stream nutrients is negligible.

Overcash, M.R., S.C. Bingham, and P.W. Westerman. 1981. Predicting Runoff Pollutant Reduction in Buffer Zones Adjacent to Land Treatment Sites. Transactions of the American Society of Agricultural Engineers (ASAE), pp. 430-435.

Abstract: **
Grass buffer zones (filter strips) were examined as a Best Management Practice to control nonpoint source pollution from animal waste, using one-dimensional modeling of overland flow. Three major factors contributed to the effectiveness of the grass buffer strips: pollutant concentration in the runoff from the waste area, dilution, and infiltration rates. Additional factors considered were: the nature of grass vegetation, chemical diffusion, settling, topography, and rainfall intensity. A buffer area-length to waste-area length ratio (B/W) of 1.0 was concluded to be sufficient to reduce animal waste concentrations by 90% to 100%

Palfrey, R. and E.H. Bradley, Jr. 1981. Natural Buffer Areas: An Annotated Bibliography. Coastal Resources Division, Tidewater Administration, Maryland Department of Natural Resources, Tawes State Office Building, Annapolis, Maryland 21401.

Abstract: **
This annotated bibliography contains and supplements information from a study entitled The Buffer Areas Study, which was conducted during the first half of 1981. The bibliography contains information on scientific studies addressing the utilization of buffer areas in the protection of wetlands, streams, and tidal waters. It summarizes the content and conclusions of the selected documents reviewed to obtain information for The Buffer Areas Study.

Palfrey, R. and E.H. Bradley, Jr. 1981. The Buffer Area Study. Coastal Resources Division, Tidewater Administration, Maryland Department of Natural Resources, Tawes State Office Building, Annapolis, MD 21401.

Abstract: *
Buffer areas are zones of undeveloped vegetated land extending from the banks or high water mark of a water course or water body to some point landward. Their purpose is to protect the water resources, including wetlands, they adjoin from the negative impacts of adjacent land use.

This report reviews these potentially detrimental impacts and notes how buffer areas have been shown to negate or reduce those impacts. Relevant literature documenting these positive functions of buffer areas is cited, and information is presented regarding the environmental factors which determine how effectively buffer areas function. This report concludes with recommendations regarding the establishment of buffer areas in the State of Maryland.

Petersen, R.C., Jr., B.L. Madsen, M.A. Wizlbach, C.H.D. Magadza, A. Paarlberg, A. Kullberg and K.W. Cummins. 1987. Stream Management: Emerging Global Similarities. Ambio 16:166-179.

Abstract: *
Stream management throughout the world requires a holistic, ecosystem approach, that is partly centered on stream riparian zones, but also involves fisheries management and factors exogenous to the stream. The importance of the riparian zone as a buffer between the stream and watershed is illustrated by examples from Denmark and The Netherlands where agricultural use of the watershed threatens surface-water quality. Additional examples from western Jamaica, Zimbabwe and the United States illustrate the ecological value as well as historical mismanagement of streams. The economic value of riparian zones as nutrient filters is discussed with examples from agricultural lands in Sweden. The importance of a holistic approach is illustrated by the oncho (river blindness disease) program in western

Africa where disease control may threaten riparian zones and the worldwide introduction of exotic fishes which threatens indigenous species. The holistic approach is extended to a global perspective where factors wholly outside the watershed may affect streams. Examples are deforestation in western Africa that causes desertification in Zimbabwe and long-range transport of air pollutants that causes acidification of running waters in Scandinavia.

Raleigh, R.F. 1982. Habitat Suitability Index Models: Brook Trout. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.24.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Brook trout were found to be susceptible to even modest amounts of turbidity, which reduces the ability to search for food. Warm water temperatures were found to be the single most limiting factor in the distribution and reproduction of brook trout. The required temperature in the spawning gravel beds ranged from 4.5 to 10 °C (40 to 50 °F). Lethal temperatures for adult brook trout were above 20°C (68°F) with the optimal temperature not exceeding 15.6°C (60°F). A 30 m deep (100 ft) vegetated buffer zone with 50 to 75% midday shade was found to be optimal. 80% of this buffer should be well-vegetated for erosion control, for maintaining the undercut bank areas, and for providing essential cover for the brook trout along the shoreline edge.]

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat Suitability Information: Rainbow Trout. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.60.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Rainbow trout were found to require clear, cold waters, 12 to 18°C optimum (54 to 64°F), in both lakes and rivers. Lethal temperature limits were < 0°C (32°F) and > 25°C (77°F). Rainbow trout require silt-free rocky substrate (gravel) for both spawning and cover. Optimal gravel contains ≤ 5% fines. With fines ≥ 30%, low survival of embryos and emerging yolk sac fry occurs. Also essential for the rainbow trout is cover in the form of overhanging bank cover, overhanging vegetation, submergent vegetation, instream objects (small boulders, upturned roots, logs, and debris piles), pool depth (≥ 15 cm), and surface turbulence (riffles). A buffer strip 30 m (98 ft) wide providing 50 to 75% midday shade was found to be the optimal condition. Of the 30 m, (98 ft) 80% should be either established vegetation or stable rock to provide erosion control for the stream bank.]

Rice, P.D. 1984. Habitat Suitability Index Models: Dabbling Ducks. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Optimal dabbling duck habitat is provided by wetlands with 50% cover and 50% open water. Unsatisfactory nesting conditions result from silt-covered shallows, broad mud flats, and absence of submergent vegetation in open water. Preferred wetland nesting habitat is bulrush and cattail, and preferred upland cover is tall grass and brush.]

Richards, D.L., and L.M. Middleton. 1978. Best Management Practices for Erosion and Sediment Control. Federal Highway Administration Rpt. No. FHWA-HD-15-1.

Abstract: *
Erosion and sediment control are an important consideration in the location, design and construction of a highway. Erosion and sediment control plans should be developed prior to construction and effective control measures utilized during construction.

This manual is a compilation of the erosion and sediment control measures which have been successfully used by Region Fifteen of the Federal Highway Administration. The measures covered include silt fences, brush barriers, diversion channels, sediment traps, check dams, slope drains, and temporary berms. A section on water quality monitoring is also included.

Riparian Habitat Committee, (WDAFS). 1982. The Best Management Practices for the Management and Protection of Western Riparian Stream Ecosystems. Western Div., Amer. Fisheries Society, 574.5263/AMERICA.

Abstract: **
This paper is a follow-up to the Riparian Habitat Committee position paper (1980) entitled "Management and the Protection of Western Riparian Stream Ecosystems." The Best Management Practices (BMP) discussed were written as a guide for agencies, landowners, and individuals in the management, maintenance, and protection of western riparian stream ecosystems. For erosion control adjacent to mine operations, the establishment of vegetative buffer strips is recommended.

Robertson, R.J., and N.J. Flood. 1980. Effects of Recreational Use of Shorelines on Breeding Bird Populations. The Canadian Field-Naturalist 94:131-138.

Abstract: *
Field studies were conducted at six lakes in southern
Ontario to investigate the effects on breeding bird populations of the disturbance caused by recreational use of shorelines. The degree of land development observed created extensive edge habitat but had only moderate effects on other vegetation characteristics. Although the disturbed areas had significantly more birds, they tended to have lower species diversity than more natural areas. Species richness remained fairly constant in both disturbed and isolated study areas whereas species evenness was significantly lower in the former. The species composition of bird populations in study areas was also affected by disturbance. Nesting success of Common Loons (Gavia immer) and Eastern Kingbirds (Tyrannus tyrannus) was lower in disturbed areas.

Rogers, Golden & Halpern, Inc. 1988. Wetland Buffer Delineation Method. Division of Coastal Resources, New Jersey Department of Environmental Protection, CN 401, Trenton, New Jersey 08625. 69 pp.

Abstract: *
A buffer delineation method has been developed to protect tidal and non-tidal wetlands in the coastal zone of New Jersey. This study is based on existing information and identifies appropriate buffer widths to maintain the quality of water entering wetlands. It relies on both field and in-house data that can be objectively evaluated.

The delineation method considers potential water quality impacts and mitigating factors to determine optimum buffer width. Buffering capability is determined based on a combined, case-by-case evaluation of slope, vegetation, and soil characteristics adjacent to the wetland. Impacts of low, moderate, and high intensity development are evaluated based on type of development and impervious coverage. The method also identifies situations in which a buffer width is automatically assigned based on conditions that warrant special

consideration. The method was successfully tested for replicability and reasonableness under a variety of wetland and development scenarios.

In New Jersey, the possible range of buffer width varies depending on the type of wetland: the maximum width of buffers for tidal and non-tidal wetlands, and the minimum buffer width for non-tidal wetlands have been set by law and policy. A User's Guide to the buffer delineation method was developed to ensure that derived buffer widths comply with current state law and policy.

Roman, C.T. and Good, R.E. 1983. Wetlands of the New Jersey Pinelands: Values, Functions and Impacts (Section One). *In*: Wetlands of the New Jersey Pinelands: Values, Functions, Impacts, and a Proposed Buffer Delineation Model. Division of Pinelands Research, Center for Coastal and Environmental Studies, Rutgers - the State University, New Brunswick, NJ. 123 pp.

Abstract: *
(Preface)
This document is a reprint of section one of a June 1983 report entitled "Wetlands of the New Jersey Pinelands: Values, Functions, Impacts, and a Proposed Buffer Delineation Model." 1 This literature review section on Pinelands wetlands values, functions and impacts provided much of the scientific foundation for the development of a wetland upland buffer delineation model. The 1983 proposed model underwent a one year field test, followed by revisions based on the test results. 2 The revised buffer delineation model is presented as a separate document. 3 This model is currently being used as a guideline for evaluating wetland-related applications by the New Jersey Pinelands Commission, the state agency responsible for management and planning in the Pinelands region. Because the proposed buffer model is now obsolete, it seems appropriate to reprint the literature review section as a separate document.

1 Roman, C.T. and R.E. Good. (1983) "Wetlands of the New Jersey Pinelands: Values, Functions, Impacts, and a Proposed Buffer Delineation Model." Division of Pinelands research, Center for Coastal and Environmental Studies, Rutgers - the State University, New Brunswick, NJ. 123 pp.

2 Roman, C.T. and R.E. Good. (1984) "Buffer Delineation Model for New Jersey Pinelands Wetlands: Field Test." Division of Pinelands Research, Center for Coastal and Environmental Studies, Rutgers - the State University, New Brunswick, NJ. 68 pp.

3 Roman, C.T. and R.E. Good. (1985) "Buffer Delineation Model for New Jersey Pinelands Wetlands." Division of Pinelands Research, Center for Coastal and Environmental Studies, Rutgers - the State University, New Brunswick, NJ. 73 pp

Roman, C.T. and Good, R.E. 1986. Delineating Wetland Buffer Protection Areas: The New Jersey Pinelands Model. pp. 224-230. *In*: Jon A. Kusler and Patricia Riexinger (eds.), Proceedings of the National Wetland Assessment Symposium, June 17-20, 1985. Portland, Maine. ASWM Technical Report 1.

Abstract: **
The article synthesizes the authors' previous work on developing a model for the New Jersey Pinelands ("Wetlands of the New Jersey Pinelands: Values, Functions, Impacts, and a Proposed Buffer Delineation Model," 1983; "Buffer Delineation Model for New Jersey Pinelands Wetlands: Field Test," 1984; and "Buffer Delineation Model for New Jersey Pinelands Wetlands," 1985).

The model and standards for assessing buffer widths are based on three general factors: wetland quality, impact assessment, and land use. The New Jersey Comprehensive Management Plan (CMP) requires a 300 foot (91 m) buffer unless an assessment of "non-significant impact" has been determined, at which point the required buffer may be reduced to as low as 50 feet (15 m). The 300 foot (91 m) base width is assumed to ensure protection of the wetland quality from high impact land development. The procedure for implementing the model, the rating system for determining wetland quality, and buffer width ranges are documented. The authors conclude with recommendations for other regions, based a on general conclusion that all wetland protection provisions should strive to include a buffer protection provision.

Schroeder, R.L. 1983. Habitat Suitability Index Models: Pileated Woodpecker. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.39. 15 pp.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[In the results of a Virginia study, most Pileated Woodpeckers rested no farther than 150 m (492 ft) from water, and most nests were within 50 m (164 ft) of water. Average distance between water sources was 600 m (1969 ft). Minimum nesting area was 130 ha (320 acres).]

Schroeder, R.L. 1984. Habitat Suitability Index Models: Black Brant. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.63.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use

Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Preferred black brant winter habitats are large tidal lagoons with openings to the sea, containing eelgrass beds and sea grass (ulva) that are exposed during the tidal cycle or are available by "tip-up" feeding (since black brants do not dive) in 1 foot deep water. Human activity is a major limiting factor for black brant, and significant aquatic and terrestrial buffers are necessary for protection. Buffer zones from human activities are divided into three categories. Highly disruptive activities such as helicopter flights, shellfish harvesting, or sculling require a 183 m (600 ft) buffer zone. Moderately disruptive activities, such as hunting and flights of fixed wing aircraft, require a buffer zone of 137 m (450 ft). Low-level disruption includes general swimming, boating, fishing, and shoreline development and requires a 91 m (300 ft) buffer zone.]

Shisler, J.K., P.E. Waidelich, and H.G. Russell. 1985. Coastal Wetlands: Wetlands Buffer Delineation Study - Task 1. Mosquito Research & Control, New Jersey Agricultural Experiment Station, and Rutgers University, New Brunswick, New Jersey 09803.

Abstract: *
(Intent of Study)
Recently, controversy has arisen over the need for buffer zones between wetlands and developed upland areas. Criteria are needed for the establishment of buffer zones for the protection of specific wetland functions. The intent of Task 1 was to review the literature on wetlands and buffer zones. From this literature search, a definition of a buffer zone was developed. Based on this definition, a rationale for the existence of a buffer was determined. Also included as part of Task 1 are interim guidelines for wetlands regulation, detailed sampling methods, and a listing of study sites.

Shisler, J.K. et. al. 1987. Coastal Wetland Buffer Delineation. New Jersey Dept. of Environmental Protection, Division of Coastal Resources, Trenton, New Jersey. 102 pp.

Abstract: **
Under contract from the New Jersey Department of Environmental Protection, the authors undertook a study to assess the effectiveness of existing buffers in limiting the level of wetland disturbance, and to develop management guidelines for the implementation of buffers in coastal wetlands in developing areas. One hundred study sites were selected in three wetland types (salt marsh, tidal freshwater marsh and hardwood swamp) and in four land use categories (agriculture/recreation, single family/low density residential, high density residential, and commercial/industrial). An index of direct human disturbance (DHD) was

developed from measurements of physical wetland disturbance which allowed for comparison of relative numeric representations of wetland degradation. Levels of disturbance were compared between similar wetland protected by buffers of different widths in different land use categories, while community indices were compared between disturbed and undisturbed wetland of similar type.

With all study sites, disturbance was found to be greater in high density land uses than in low density land uses. The primary salt marsh disturbance occurred during the construction period. Disturbance of tidal freshwater marsh, the most disturbed of the three wetland types, was typically caused by encroachment from adjacent residential uses, e.g., the depositing of refuse on the wetland, and children destroying wetland vegetation. Hardwood swamp disturbance also related to the depositing of refuse; "extension of property" by the adjacent landowners was also a problem. The authors conclude that buffers, in order to be effective at minimizing human disturbance in wetland systems, must be established prior to and during the development of adjacent areas. Wetland contiguous with certain special lands (e.g., endangered species habitat) require particular consideration. Recommended buffer widths for low intensity land uses (<30% impervious cover) were 50 ft (15 m) for salt marshes, 100 ft (31 m) for tidal freshwater marshes, and 50 ft (15 m) for hardwood swamps. Recommended buffer widths from high intensity land uses (> 30% impervious cover) were 100 ft (31 m) for salt marshes, 150 ft (46 m) for tidal freshwater marshes, and 100 ft (31 m) for hardwood swamps. The study further stressed site evaluation on a case-by-case basis, and outlined additional guidelines for establishing buffer zones.

Simberloff, D., and J. Cox. 1987. Consequences and Costs of Conservation Corridors. Conservation Biology 1:63-71.

Abstract: *
There are few controlled data with which to assess the conservation role of corridors connecting refuges. If corridors were used sufficiently, they could alleviate threats from inbreeding depression and demographic stochasticity. For species that require more resources than are available in single refuges, a network of refuges connected by corridors may allow persistence. Finally, a corridor, such as a riparian forest, may constitute an important habitat in its own right. A dearth of information on the degree to which of these potential advantages will be realized in any particular case. Some experimental field studies suggest that certain species will use corridors, although lack of controls usually precludes a firm statement that corridors will prevent extinction.

Corridors may have costs as well as potential benefits. They may transmit contagious diseases, fires, and other catastrophes, and they may increase exposure of animals to predators, domestic animals, and poachers. Corridors also bear economic costs. For example, a bridge that would maintain a riparian corridor costs about 13 times as much per lane-mile as would a road that would sever the corridor. Also, per-unit-area management costs may be larger for corridors than for refuges. It may be cheaper to manage some species by moving individuals between refuges rather than by buying and maintaining corridors.

Each case must be judged on its own merits because species-environment interactions differ. As an example, we used the case of the Florida panther (felis concolor coryi), of which there remain about 30. The Florida panther's inbreeding problems could possibly be stemmed somewhat by a corridor system, but it is far from certain that even an extensive system will save this animal, and costs of such a system would lessen the resources that could be devoted to land acquisition and other means of aiding many other threatened species.

Sinicrope, T.L., P.G. Hine, R.S. Warren, and W.A. Niering. 1990. Restoration of an Impounded Salt Marsh in New England. Estuaries 13:25-30.

Abstract: *
The restoration of a 20 ha tidal marsh, impounded for 32 yr, in Stonington, Connecticut was studied to document vegetation change 10 yr after the reintroduction of tidal flushing. These data were then compared to a 1976 survey of the same marsh when it was in its freshest state and dominated the *Typha angustifolia*. Currently, *T. angustifolia* remains vigorous only along the upland borders and in the upper reaches of the valley marsh. Live coverage of *T. angustifolia* has declined from 74% to 16% and surviving stands are mostly stunted and depauperate. Other brackish species have also been adversely effected, except for *Phragmites australis* which has increased. In contrast, the salt marsh species *Spartina alterniflora* has dramatically expanded, from <1% to 45% cover over the last decade. Locally, high marsh species have also become established, covering another 20% of the marsh.

Smardon, R.C. 1978. Visual-cultural Values of Wetlands. pp. 535-544 *In*: P.E. Greeson, J.R. Clark, and J.E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. American Water Resources Association.

Abstract: *
The paper addresses the visual-cultural values, or the visual, recreational, and educational values, of inland and coastal wetlands in the United States. An "ecological aesthetics" perspective is proposed, based on evidence that information about natural and cultural processes associated with a landscape increases the aesthetic value of that landscape for the perceiver. Single significant visual-cultural values, as well as composite values, of wetlands are reviewed. The critical literature is reviewed and detailed findings are discussed for (1) wetlands in comparison to other landscapes, (2) specific types of wetlands compared to each other, (3) wetlands and their immediate surroundings, (4) wetlands and the micro-landscape within, and (5) dynamic phenomena associated with wetlands. Little substantive research concerning visual-cultural values of wetlands has been done. Existing research is restricted to the central northeastern, southern, and west coast regions of the United States. Priorities and key questions for visual-cultural wetland research are suggested.

Soil Conservation Service. 1982. Filter Strip (acre). Soil Conservation Service (SCS), Filter Strip 393.

Abstract: **
This document contains the Soil Conservation Service guidelines for planning considerations and design criteria for strips of vegetation to remove sediment, organic matter, and farm pollutants and waste water to protect streams, ponds, and lakes, and above conservation practices such as terraces or diversions. Buffer strip widths are recommended for croplands, concentrated livestock runoff, overland flow treatment of liquid wastes, and on forested land, partially based on the slope of the land. Buffer widths are established at 10 ft for slopes < 1% and proportionately greater up to at least 25 ft for 30% slopes.

Sousa, P.J., and A.H. Farmer. 1983. Habitat Suitability Index Models: Wood Duck. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.43. 27 pp.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[A ratio of 50-75% cover to 25-50% open water is recommended for ideal breeding and brood rearing habitat. Wood duck nest in tree cavities and, to reach maximum production, need 20 acres of nesting habitat for each acre of brood habitat. Nest sites near water are preferred. In Massachusetts, nests were located within 183 m (600 ft) from water; in Minnesota, nest trees ranged from 0 to 350 m (0 to 1150 ft) of water. Nest cavities must have an entrance diameter of at least 3.5 inches to allow wood ducks to use them. Isolated wetlands less than 4 ha (10 acres) in size are considered marginal wood duck habitat unless adjacent wetlands are closer than 46 m (150 ft).]

Steinblums, I., H. Froehlich, and J. Lyons. 1982. Designing Stable Buffer Strips for Stream Protection. U.S. Forest Service, 2520 Watershed Protection and Management.

Abstract: *
Survival and effectiveness were evaluated for forty streamside buffer strips in the Cascade Mountains of western Oregon. Stream shading was found to be related to four characteristics of the buffer strip, while survival was a function of seven vegetation and topographic variables. These relationships are expressed in predictive equations that may

be used with on-site evaluation for designing proposed strips. The equations aid assessment of stream protection in the proposed harvest design and make rapid evaluation of design modifications possible. All options can be quantified and the most suitable design chosen. [The authors define buffer strip effectiveness in terms of stream shading, which was quantified by measuring angular canopy density (ACD). The relationship of ACD to buffer strip width was curvilinear, yielding ACD values of 17 and 73% respectively for buffer widths of 20 and 100 ft.]

Stuber, R.J., G. Gilbert, and O.E. Maughan. 1982. Habitat Suitability Index Models: Largemouth Bass. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.16.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Optimum habitat consists of large, slow-moving rivers or pools (≥ 60% of habitat), relatively clear, shallow (≤ 6 m deep), with soft bottoms, some aquatic vegetation, with overwintering areas (40 to 60% of lake at least 15 m deep), and shoreline vegetation (adult largemouth bass typically fed near the vegetation). Additional optimal conditions for adult largemouth bass include cover vegetation, log debris, and brush, with cover ranging from 40 to 60% (> 60% reduced prey). Amount of cover was found to be positively correlated with the number of fry present. Optimal fry habitat contained cover from 40 to 80%. Optimal temperature for fry growth ranged from 27 to 30 °C (80.6 to 86°F).]

Swanston, D.N., and F.J. Swanson. 1976. Timber Harvesting, Mass Erosion, and Steepland Forest Geomorphology in the Pacific Northwest. *In*: D.R. Coates (ed.), Geomorphology and Engineering. Dowden, Hutchinson and Ross, Stroudsberg, PA.

Abstract:
This chapter defines the large-scale movements of material down slopes--creep, slump, debris avalanche, and debris torrent--and reviews research done in the Pacific Northwest on the destabilizing effects of clear-cutting and road-building.

Swift, L.W. and J.B. Messer. 1971. Forest Cuttings Raise Temperatures of Small Streams in the Southern Appalachians. J. Soil Wat. Conserv. 26:111-116.

Abstract: *

Stream temperatures were measured during six forest-cutting treatments on small (23 to 70 acre) [9.3 to 28.3 ha] watersheds in the southern Appalachian Mountains. Where forest trees and all understory vegetation were completely cut, maximum stream temperatures in summer increased from normal 66°F to 73°F (19°C to 23°C)or more. Some extreme treatments raised temperatures more than 12°F (-11°C) above normal. Where streambank vegetation was uncut or had regrown, summer maximums remained unchanged or declined from temperatures measured under uncut mature hardwood forest. Increases in stream temperature were judged to degrade water quality and constitute thermal pollution because, after each clearcut, water temperatures exceeded optimum levels for trout habitat.

Swift, L.W. Jr. and S.E. Baker. 1973. Lower Water Temperatures within a Streamside Buffer Strip. U. S. Department of Agriculture, Forest Service Research Note SE-193. S.E. Forestry Experimental Station, Asheville, NC. 7 pp.

Abstract: *

The removal of streamside vegetation increases the water temperature in mountain streams. Clearcutting and farming have been found to raise temperatures beyond the tolerance level for trout (68°F [20°C]). Within the sale areas of a commercial clearcut in the mountains of North Carolina, a narrow buffer strip of uncut trees and shrubs was left beside a stream. Although water temperatures within the sale area may have exceeded 68°F (20°C), the stream immediately below the sale area was never warmer than 62°F (17°C).

Tollner, E.W., B.J. Barfield, and C.T. Haan. 1975. Vegetation as a Sediment Filter. pp. 61-64. *In*: C.T. Haan and R. W. DeVore (eds.), National Symposium on Urban Hydrology and Sediment Control. Office of Research and Engineering Services, Publ. No. UKY BU109. University of Kentucky, Lexington, KY. 314 pp.

Abstract: **

The authors suggest the use of grass strips as supplements to settling basins to reduce increased sedimentation caused by development. Mathematical modelling was used to examine sediment deposition to determine the appropriate width of grass filter strips. Results indicated that runoff velocity (which is determined by channel slope, flow rate, and vegetation spacing) determines the sediment trapping capacity. Settling velocity (a function of particle size and sediment concentration) and filter length also influence sediment trapping capacity. The trapping equation is included in the report.

Tollner, E.W., B.J. Barfield, C.T. Haan, and T. Y. Kao. 1976. Suspend Sediment Filtration Capacity of Simulated Vegetation. Transaction of the Society of Agriculture Engineering 19:678-682.

Abstract: *

An exponential power function relating the fraction of sediment in a simulated rigid vegetal media to pertinent physical variables was developed using linear regression techniques and various transformations. Homogeneous sediments and non-submerging flows were studied. The mean velocity was found to be the most influential parameter on sediment trapping followed by the flow depth, particle fall velocity, section length, and spacing hydraulic radius.

The spacing hydraulic radius is a combination of the distance between two media elements and depth of flow and is analogous to the hydraulic radius of an open rectangular channel. This term was observed to be a reasonably good predictor of the length scale in shallow flows through the experiment media. An equation utilizing the spacing hydraulic radius was observed to be a good predictor of the mean flow velocity.

Trimble, G.R. Jr. and R.S. Sartz. 1957. How Far from a Stream Should a Logging Road be Located? J. Forestry 55:339-341.

Abstract: **
The authors determined that logging roads were a major cause of sedimentation leading to poor water quality in forested areas. The width of forested filter strips required to improve the water quality was calculated, using data collected on the length of sediment discharge from existing logging roads. The degree of slope and soil condition were the main factors considered. Additional factors such as culvert spacing, road surface condition, steepness of road, sediment trapping, and age of culvert were also found to influence sediment in runoff. Recommendations were given for municipal and general watersheds. In a municipal watershed, the recommended buffer is 50 ft (15 m) with an increase of 4 feet (1.22 m) for every 1% increase in slope. In general watersheds, the recommended buffer is 25 ft (7.6 m) with an increase of 2 feet (.61 m) for every 1% increase in slope.

Walter, M.F., T.S. Steenhuis, and D.A. Haith. 1979. Nonpoint Source Pollution Control by Soil and Water Conservation Practices. Transactions of the American Society of Agricultural Engineers (ASAE), pp. 834-840.

Abstract: *
There has been a tendency to equate best management practices, as defined in water quality legislation, with soil and water conservation practices. The effectiveness of SWCP's at controlling potential pollutants other than sediment depends on the characteristics of pollutants. Pollutants have been categorized in groups having distinctly different soil absorption properties which have been related to the effect of SWCP's on water and soil movement.

Wentz, W.A., R.L. Smith, and J.A. Kadlec. 1974. State-of-the-art Survey and Evaluation of Marsh Plant Establishment Techniques: Induced and Natural, Vol. 2, A Selected Annotated Bibliography on Aquatic and Marsh Plants and Their Management. Prepared for the U.S. Army Engineer Waterways

Experiment Station, Vicksburg, Mississippi by the School of Natural Resources, Univ. of Michigan, Ann Arbor, Michigan.

Abstract: *
The 703 references listed in this volume were collected for the investigation of marsh and aquatic plant establishment which is reported in Volume I, Report of Research, of this report. The purpose of this bibliography is to make available an annotated listing of references which were not cited in Volume I. Although the bibliography does not represent an exhaustive review of the literature, it does provide an extensive survey of the pertinent references on the ecology and management of aquatic and marsh plants. The references selected for this bibliography emphasize studies useful to researchers and managers. In accordance with the focus of Volume I, this volume concentrates on coastal Great Lakes, and riverine marshes.

Whipple, W., Jr., J.M. DiLouie, and T. Pytlar, Jr. 1981. Erosion Potential of Streams in Urbanizing Areas. Water Resources Bulletin (AWRA) 17:36-45.

Abstract: *
In urbanizing areas, the usual increase in flood flows also increases erosional capability of streams. In order to evaluate such tendencies quantitatively, 25 stream reaches were studied, and were classified as to whether erosion of the channel and banks was light, medium, or heavy. Analysis of characteristics indicated that (1) densely developed areas are correlated with greater erosion, (2) wide stream buffers of natural vegetation are correlated with lesser erosion, and (3) there is no definite correlation of erosion to slope or characteristics of soil.

Erosional stream stability can be avoided by retention of storm water runoff, creating additional channel roughness or reducing channel slope during floods by drop structures, such as culverts, which restrict flow. Channel straightening and general bank protection should be minimized in such streams. Design of culverts should take such effects into consideration.

Williams, J.D. and C.K. Dodd, Jr. 1978. Importance of Wetlands to Endangered and Threatened Species. pp. 565-575. *In*: Phillip E. Greeson, J.R. Clark, and J.E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. American Water Resources Association.

Abstract: *
The importance of wetland habitats to certain endangered and threatened plants and animals of the United States is reviewed and examples of endangered and threatened reptiles, amphibians, fishes, and birds dependent on wetlands are discussed. The role of the American alligator in shaping some wetland habitats is greater than its commercial value. The status of wetland habitats in desert areas of the southwestern United States is examined and Ash Meadows, Nevada, is used as an example to illustrate the precarious nature of

these habitats. On a national basis, the percentage of endangered and threatened species dependent on wetlands is presented by major taxonomic groups. Without increased protection of wetland habitats, many of our endangered and threatened species may disappear before the end of the century.

Wilson, L.G. 1967. Sediment Removal from Flood Water by Grass Filtration. Transactions of the American Society of Agricultural Engineers (ASAE), pp. 35-37.

Abstract: **
The authors studied sediment removal from runoff using grass filtration. The development of an economical and efficient method of improving the quality of water required for artificial recharge stimulated the research. Several field experiments were conducted using various lengths of Bermuda grasses. A maximum percentage of sand, silt, and clays were trapped at buffer lengths of 10, 50, and 400 feet, respectively. Bermuda grasses in particular were found to be effective in reducing sediment loads as a result of a higher roughness coefficient. Previous results suggest effective grass filters should meet the following requirements: (1) deep root system to resist scouring if swift currents develop; (2) dense, well ramified top growth; (3) resistance to flooding and drought; (4) ability to recover growth subsequent to inundation with sediment; and (5) yield of economic returns through either the production of seed or hay.

Wolf, R.B., L.C. Lee, and R.R. Shartz. 1986. Wetland Creation and Restoration in the US from 1970 to 1985: An Annotated Bibliography. Wetlands 6:1-88.

Abstract: **
This bibliography deals with the creation of new and the restoration of disturbed salt and freshwater wetlands in the United States since 1970. The authors' aim was to provide wetland scientists and regulatory agencies with an index for identifying and locating publications useful in planning new projects or reviewing old ones. In selecting projects, they emphasized site engineering and plant propagation. Therefore, numerous articles that discuss preparing the site for natural or artificial revegetation, and transplanting and seeding of vegetation, are included in the 304 reports cited. However, articles concerning more minor habitat adjustments and, for example, lake or reservoir management for wildlife or waterfowl, are not included.

Documents are arranged alphabetically by senior author. A full citation and brief description of the problem or topic discussed is included for each one. National Technical Information Service (NTIS, Springfield, VA 22161) order numbers are provided for publications available through that office. Following the citations are indices arranged by plant species, subject, and state.

Reports of wetland restoration and creation projects from more than 30 states are cited. In these articles, all major aspects of wetland construction are described in detail. Such topics as site selection; planning; engineering and design; seeding; plant material selection, harvest,storage, and transplanting; fertilization requirements, cost and labor estimates; and maintenance requirements are included for marsh, riparian, and littoral zone development. Detailed directions for propagating about 150 plant species can be found. Additionally, more basic questions are addressed, such as the value of wetlands, whether artificial or restored wetlands approximate natural, and how wetlands should be regulated. Several bibliographies, project surveys, and literature reviews are included.

Wong, S.L., and R.H. McCuen. 1982. The Design of Vegetative Buffer Strips For Runoff and Sediment Control. A technical paper developed as part of a study of stormwater management in coastal areas funded by Maryland Coastal Zone Management Program. 23 pp.

Abstract: **
This study analyzes the design of vegetative buffer strips to reduce runoff volume and sediment loading was analyzed, an economical alternative to detention basins for the management of stormwater runoff. A mathematical model was developed which includes the variables that reflect important design factors for vegetative buffer strips, including soils characteristics and cover complex characteristics. A graphic representation is provided for the relationship between sediment trapping efficiency, the length and slope of the buffer strip, and the roughness coefficient of the vegetation. The ability of buffer strips to reduce runoff volume is also examined. The reduction in the runoff volume occurs as the vegetation impedes and retards the flow of water, allowing a portion of it to infiltrate into the soil. The rate of infiltration is a function of: 1) the condition of the vegetative cover, 2) the properties of the underlying soil, 3) the rainfall intensity, and 4) antecedent soil conditions. These factors act in an interrelated manner to affect the amount of water that infiltrates into a buffer strip.

Young, R.A. and C.K. Mutchler. 1969. Effect of Slope Shape on Erosion and Runoff. Transactions of the American Society of Agricultural Engineers (ASAE) 9:231-239.

Abstract: *
(conclusion)
Erosion varies significantly from a given slope length with the same average degree of slope but with different slope configurations. Runoff also varies according to slope configuration but to a lesser degree. These variations are essentially independent of the type of surface cover existing on the ground.

There is a characteristic slope segment, the percent slope of which correlates best with soil loss from that entire slope. For topographic and rainfall conditions described in this experiment, that slope segment was the bottom 15 ft (4.6 m) of the slope.

The amount of lapsed time since the last tillage operation before testing was a significant factor affecting soil loss. This is due to the fact that, with the passage of time, erosion and elevation tend to remove the more readily eroded particles, leaving the soil in a less erodible condition.

Antecedent soil moisture, while obviously having a significant role in erosion and runoff, appeared insignificant in this experiment because its effects were interrelated with type of run, slope shape, and year of testing.

Maximum soil displacement on the concave slopes took place in the upper one-third of the 75-ft (23 m) plot, with deposition occurring at the bottom of the plot. On the convex and uniform slopes, the maximum displacement occurred about three-fourths of the way down the slope.

Type of run, initial or wet, and year of testing were the dominant factors affecting runoff from the corn and fallow plots, and amount of vegetative cover was the dominant factor affecting runoff on the oat plots.

Further study is needed to determine the exact pattern of soil movement on these slopes and the changes in slope shape resulting from this movement.

Young, R.A., T. Huntrods, and W. Anderson. 1980. Effectiveness of Vegetated Buffer Strips in Controlling Pollution from Feedlot Runoff. J Environ. Qual. 9:483-497.

Abstract: *
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[Bufferstrips of 36 m (118 ft) for the feedlot study sites were found to be sufficient in reducing the concentration of nutrients and microorganisms to acceptable levels in feed lot runoff from summer storms.]

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The author has reviewed the value of wetland buffers and riparian areas for fish and wildlife. The review includes a summary of information from Habitat Evaluation Procedure (HEP) models for several species of birds, fish, mammals, and amphibians relevant to buffer widths. The selected species include the Wood Duck, Blue-Winged Teal, Lesser Scaup, Gadwall, Dabbling Ducks, Canvasback Duck, Black Brant, Marbled Murrelet, Bald Eagle, Great Blue Heron, Spotted Owl, Yellow-Headed Blackbird, Red-Winged Blackbird, Ruffed Grouse, Downy Woodpecker, Black-Capped Chickadee, Song Sparrow, Black-Tailed Deer, Elk, River Otter, Beaver, Muskrat, Mink, Black Bear, Salamander, Red-Spotted Newt, Western Pond Turtle, Coho Salmon, Cutthroat Trout, Brown Trout, and Chinook Salmon. Minimum buffers of 200 ft (61 m) were recommended in forested areas. In non-forested wetlands, such as eelgrass beds, salt marshes, and palustrine emergent wetlands, a minimum of 300 ft (91 m) was recommended. The report suggested that buffers may need to be more extensive to protect sensitive soils and species. Replacement of vegetation around wetland systems was also recommended.

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