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Effectiveness of Agricultural and Silvicultural Nonpoint Source Controls

Final Report

Final Report

EFFECTIVENESS OF AGRICULTURAL AND SILVICULTURAL NONPOINT SOURCE CONTROLS

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Acknowledgment

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The Workgroup was composed of experts in the areas of water quality monitoring, aquatic biology and nonpoint source controls from the Pacific Northwest. It met several times in Seattle to review draft reports and provide guidance to the consultant. The project staff from Jones & Stokes, Inc. were always in attendance. The Workgroup consisted of the following individuals:

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INTRODUCTION

Background

The nation's efforts to improve water quality conditions in rivers, lakes, estuaries, and territorial seas received a significant boost in 1966 with passage of the Water Pollution Control Act. Major revisions to the law occurred with passage of the Federal Water Pollution Control Act of 1972 (PL 92-500), which was later amended by the Clean Water Act of 1977 (PL 95-217) and the Water Quality Act of 1987 (PL 100-4). This body of law (33 USC 466 et seq.) has been commonly referred to as the Clean Water Act since 1977.

The Clean Water Act classifies sources of pollutants in one of two categories. A "point source" refers to "any discernible, confined and discrete conveyance." The Water Quality Act of 1987 (Section 503) specifies that this "does not include agricultural stormwater discharges and return flows from irrigated agriculture." Nonpoint source is not defined in the Clean Water Act but is usually taken to include all other sources that are typically diffuse. Examples include runoff from agricultural and silvicultural lands, mining operations, and construction sites, and intrusion of saline water into estuaries, rivers, and lakes as a result of reduction in freshwater flow.

Water quality management during the 1970s and early 1980s focused on the reduction of pollution from municipal and industrial point sources. An effort was also made in the 1970s to establish federal programs to collect nationally consistent water quality data in association with state and local monitoring.

The substantial improvement in the nation's water quality has been widely acknowledged (e.g., The 1987 Report of the Association of State and Interstate Water Quality Administrators) but further progress toward achieving national goals depends on a deliberate effort in solving water quality problems associated with nonpoint sources of pollution (Smith et al. 1987). Nonpoint sources of pollution (i.e., pollution from diffuse sources such as agricultural lands, timber lands, and storm runoff from urban areas) are expected to prevent achievement of water quality goals in many rivers, lakes, and estuaries even after completion of all planned point source control programs.

Recognition of the nonpoint source problem led Congress to pass the Water Quality Act of 1987 with new provisions directed at nonpoint sources of pollution. Section 316(b) of the Water Quality Act of 1987 establishes as policy

> "that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this Act to be met through the control of both point and nonpoint sources of pollution."

Section 316(a) of the Water Quality Act of 1987 amends Section 319, to address nonpoint source management programs.

Section 319 of the Clean Water Act, as amended, requires the U. S. Environmental Protection Agency (EPA) to approve Nonpoint Source (NPS) Assessment Reports and NPS Management Programs prepared by the states. The State NPS Assessment Reports will: 1) identify water bodies that cannot meet the water quality standards without NPS controls, 2) identify categories of nonpoint sources that adversely impact these water bodies, 3) outline the processes necessary to identify Best Management Practices (BMPs), and 4) outline existing state and local NPS control programs. The State NPS Management Program must: 1) identify BMPs which will be undertaken to solve priority NPS pollution problems, 2) identify programs to implement the BMPs designated, 3) schedule annual milestones for implementation of both program methods and the BMPs, 4) certify that the laws of the state provide adequate authority to implement the management program, 5) describe the sources of federal and other financial assistance, and 6) identify federal financial assistance programs and federal development projects to be reviewed for consistency.

Problem

Water quality data collected in the Pacific Northwest between 1974 and 1981 as part of nationwide water quality monitoring programs indicate general reductions in levels of fecal streptococcus bacteria and lead in the region's rivers and lakes, but increasing levels of suspended sediment, nitrate, and arsenic (Smith et al. 1987). These data demonstrate that a few of the water chemistry variables commonly used to indicate water quality have not improved despite extensive efforts in point source control.

In addition to the earlier lack of recognition of the NPS pollutant problem, a second major problem in the nation's water quality improvement programs is the failure to directly monitor improvements in fish populations and aquatic habitat from point source control implementation. Although ample evidence of improvement in water quality in the vicinity of point source discharges can be found, most of the evidence is chemical rather than biological. The typical post-implementation water quality monitoring program focuses on changes in physical and chemical characteristics of the receiving water, based on the assumption that fish populations and aquatic habitat benefit from improvements in physical and chemical conditions. Thus, direct evidence of progress toward one of the goals of the Clean Water Act, i.e., "biological integrity of the Nation's waters" (Section 101(a)), is incomplete.

EPA guidance to the states on implementing Section 319 emphasizes the need for states to assess the effectiveness of their NPS programs. In addition, EPA Region 10 has become concerned about potential inadequacies of water quality monitoring programs established as part of the land management plans that EPA reviews under the National Environmental Policy Act (NEPA), particularly when the monitoring program addresses NPS controls. Traditional monitoring of physical and chemical characteristics of receiving water has often been unsatisfactory in evaluating the effectiveness of NPS controls because of the diffuse nature of the pollutant loading.

EPA Region 10 has determined that established NPS monitoring programs must be evaluated to ensure the protection of water quality from nonpoint sources of pollution. The agency recognizes the need to consider a wider range of parameters, in addition to standard water quality indices, to evaluate NPS control programs. EPA Region 10 wishes to assess the potential of using broader ecosystem indicators of aquatic habitat quality and to offer this information to federal, state, tribal, and local resource managers as they prepare NPS assessment and management programs.

Objectives

This document analyzes specific monitoring methods and monitoring programs for NPS controls germane to agricultural and silvicultural practices and provides the necessary information on which to base guidelines for monitoring effectiveness of NPS control programs. The effectiveness of the individual BMPs was not part of the scope of work and is not addressed in this document.

The four main objectives of the report are to:

- inventory selected monitoring programs associated with BMPs implemented by resource management agencies in the agricultural and silvicultural sectors, including programs that use only baseline monitoring;

- summarize the water quality and aquatic habitat parameters that have been monitored and the techniques that have been used;

- evaluate the applicability of monitoring techniques, particularly those assessing aquatic habitat condition; and

- recommend, based on experience of the region, appropriate elements of a monitoring program.

Approach

The consultant team consisted of two main working groups: one focused on agricultural and the other on silvicultural programs in the Pacific Northwest. At the direction of EPA, the team concentrated on programs in Idaho, Oregon, and Washington, with effort in Alaska directed toward only the forestry sector in Southeast Alaska.

The team contacted federal and state land and water management agencies in Idaho, Oregon, and Washington, and forestry agencies in Alaska. Targeted agencies included the U. S. Department of Agriculture (USDA) Soil Conservation Service (SCS), Bureau of Land Management (BLM), U. S. Forest Service (USFS), EPA operations offices, state fish and game departments, state agencies responsible for water quality regulation, and state forestry departments. At the state level, the consultants identified and contacted agency personnel in regional offices who were knowledgeable about local agencies (e.g., local soil conservation districts) that have executed NPS control programs or relevant habitat quality monitoring. These local entities were also contacted in many cases.

A guideline prepared by the team for use during telephone interviews with agency personnel provided consistency in information collection (Appendix A). A majority of the questions focused on the monitoring program objectives, the environmental features being monitored, the techniques used to measure response, the reliability of the data collected, and the duration of the monitoring program. The team members also noted the type of monitoring involved (e.g., whether baseline, implementation, effectiveness, or validation monitoring is underway; whether cumulative effects are being considered; and whether impact on beneficial uses of water has been monitored). In addition to noting information sources (references) germane to the monitoring program, the team members requested names and phone numbers of additional people who should be contacted by the team.

In many cases it was discovered that data had been collected that were used to document adverse effects or that could be used as baseline information, but no post-implementation monitoring had been conducted or was planned. Some of these programs are included in this report because they: 1) serve as models of the kind of effort undertaken by the agency, 2) could include post-implementation monitoring if funds were made available, or 3) help portray the range of parameters and techniques that could be used in monitoring effectiveness of NPS control programs. For these same reasons, a few projects involving NPS investigations are included in the report even though BMPs have not been implemented.

This report catalogs and summarizes many of the data collection activities that are part of NPS control programs in the Pacific Northwest (Chapters 2 and 3, Appendices B and C). The report also presents an inventory of the environmental features and beneficial uses that have been monitored and the techniques that have been used. It evaluates and summarizes the current status of NPS monitoring efforts in the Pacific Northwest (Chapter 4). An approach to monitoring effectiveness of NPS control programs is then recommended along with suggested guidelines for selection of environmental parameters and techniques (Chapter 5). For each technique, the report presents a brief analysis of its applicability, the factors required to ensure reliability of the data collected, and its utility for broader application (Appendix D). Techniques used to measure aspects of living aquatic resources are emphasized.

Chapter 2

REVIEW OF AGRICULTURAL-RELATED MONITORING

Introduction

Information on agricultural NPS monitoring activities in the Pacific Northwest is presented in Chapter 2 by ecoregion as defined by Omernik and Gallant (1986). The information is organized and condensed from published material wherever possible, or compiled from information gathered in telephone interviews. Information for each activity is organized and summarized under the following headings.

Site Description. The site description gives a brief outline of the geography and climate. Enough information is presented to enable readers to determine whether their site conditions are comparable.

Land Use. A brief description is given of the major land uses, especially those contributing to NPS pollution, in the project watershed. Land use types and acreages, and quantities of pollutants are summarized where the information is available to enable readers to determine whether their projects are comparable with others in the region.

Beneficial Use. This section focuses on those beneficial uses that the BMPs are or should be addressing. A complete list of the beneficial uses of a water body is not intended.

Best Management Practices. The kinds of BMPs that have been applied to the watershed, the percent of the watershed that has had BMPs applied, and the length of BMP implementation is discussed in this section to enable readers to cross-reference their projects with others in the region. No attempt is made to discuss the merits of individual BMPs, and there is no attempt to relate individual BMPs to a specific reduction in NPS pollution.

Monitoring. The objectives of a NPS pollution control and monitoring program are essential for judging the success of the program. The objectives of the NPS program are given in the first paragraph of this section whenever possible. Details of the design of the monitoring program (parameters measured, sampling regime, time frame) are given. The data collected by the monitoring program are of little interest since the main concern of this report is the design of monitoring programs; data from monitoring are therefore not reported here.

Discussion. The discussion section highlights the conclusions of the monitoring program, whether the objectives were met, if any of the measured parameters were particularly useful, and if there were any major problems of the program.

Additional Information. The names and addresses of project leaders, and references to selected published reports are given to enable readers to gather additional information on the project. A full bibliography of reports is not intended, rather, key references that can be used as an introduction to the project and its outcome are noted.

PART I: CONFINED ANIMAL AND FEEDLOT OPERATIONS

Coast Range

Tillamook Bay Project, Oregon

Site Description. The Tillamook Bay drainage basin is located in northwestern Oregon bounded on the east by the Pacific Coast Range and on the west by the Pacific Ocean. Annual precipitation averages 230-380 cm (90-150 in) in the drainage basin. Five major river systems (the Miami, Kilchis, Wilson, Trask, and Tillamook) flow into the Tillamook Bay estuary. Soils in the basin are quite varied, ranging from well drained, fine-textured soils in the uplands to poorly drained, extremely acid soils in the tidelands.

Land Use. The basin area is 147,170 ha (363,520 ac), of which 130,790 ha (323,050 ac) are forested and 9,530 ha (23,540 ac) are agricultural. The primary agricultural industry is dairy farming, which involves approximately 4,935 ha (12,190 ac). The livestock produce over 270,000 tonnes (300,000 tons) of manure each year, which resulted in severe instream water quality problems. Additional farmland is used for hay and silage production, and raising other types of livestock.

Beneficial Use. The estuary is Oregon's primary oyster growing area, which has been continually threatened with closure due to excessive fecal coliform levels in the growing waters. Recreational clam digging, fishing, boating, and numerous other activities attracting more than a million tourists a year have also been affected.

Best Management Practices. BMPs are aimed to 1) prevent rain water and clean surface water from coming into contact with manure, and 2) when this is not possible, prevent contaminated surface water from reaching the streams and bays. BMPs have been encouraged since 1981 and so far have been applied to 109 farms of approximately 150 in the basin. The BMPs cover a range of systems, including permanent vegetative cover (51 percent installed: 146 ha [362 ac]), animal waste utilization (36 percent installed: 1,288 ha [3,181 ac]), structural animal waste management systems (waste storage, roofing, guttering), grazing land protection systems, streambank protection, and erosion control structures. Over 50 percent of the planned BMPs have been installed for all the river basins, except for Trask River (31 percent installed).

Monitoring. Monitoring objectives were to identify the sources of fecal coliform contamination, to determine the extent of improvement once BMPs were implemented, and to extend the shellfish harvest season.

From 1979 through 1981, the Oregon Department of Environmental Quality (DEQ) conducted an intensive weather-related survey to determine fecal coliform densities and to identify the major sources of fecal contamination in the basin. The survey included 79 river and stream stations selected for proximity to shellfish growing areas, and the 5 small sewage treatment plants that discharge either to the bay or into the lower reaches of one of the major rivers. Because nonpoint source loading is closely related to precipitation and soil conditions, water quality data were collected during four different weather periods: 1) heavy rain on saturated ground, 2) rain after a period of dry weather, 3) summer low-flow during dry weather, and 4) the first "freshet" storm at summer's end with sampling beginning prior to soil saturation. Since 1981, fourteen monitoring stations, funded by a Section 205(j) grant (Clean Water Act) from EPA, were established in Tillamook Bay. Samples were collected by DEQ on a quarterly basis since 1984, changing in October 1986 to monthly sampling with an intense 12-day sampling period conducted by the Food and Drug Administration (FDA) in early December 1986. Water temperature, salinity, and fecal coliforms were monitored in addition to oyster bacterial content at two stations.

The DEQ and the Soil and Water Conservation District (SWCD) sampled 12 tributary sites at monthly intervals and analyzed for pH, water temperature, turbidity, discharge at stream gage sites, and fecal coliforms. Three of these sites are still being monitored to provide information on BMP effectiveness.

Water samples were collected using approved EPA methods and were analyzed by the DEQ laboratory, the Tillamook City Laboratory, and the Oregon State Health Division Laboratory.

Discussion. A comparison of 1975-1983 data with 1983-1985 data shows that the bacterial levels in the tributary streams have been reduced by between 30 and 78 percent, depending on sampling location, by the implemented BMPs. Fecal coliform counts have also been reduced in the bays by between 16 and 64 percent, depending on sampling location. The improved water quality allows a longer oyster harvest season. Although it is improving, degraded water quality continues to occur low in the watersheds near the bay. The cause of this is not known. The results of the extensive monitoring program will be used to develop a water quality model.

Additional Information.

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Reports: The latest annual report is Oregon Department of Environmental Quality (1986).

Puget Lowland

Johnson Creek Project, Washington

Site Description. The Johnson Creek watershed is located in Whatcom County, Washington. This 5,445 ha (13,450 ac) watershed lies in the north central portion of the county with the southern boundary being the Nooksack River and the northern boundary being the United States/Canadian International Boundary. Johnson Creek, the major stream in the watershed, is a tributary of the Sumas River and comprises about 40 percent of the Sumas River Basin.

The climate of the area is influenced by Puget Sound on the west and the Cascade Mountains on the east. The mean annual precipitation is 120 cm (47 in). The mean annual temperature is $8^{\circ}C$ ($49^{\circ}F$), and the average growing season is about 140 days.

Land Use. The watershed is predominately used for dairy farming. There are 57 family-owned small dairy farms with an average size of 117 acres, producing approximately 150 million liters (40 million gal) of animal wastes per year. The wastes are applied to pasture and cropland when weather conditions permit. The storage of animal waste during the wet season was a major problem.

Beneficial Use. Johnson Creek is no longer used for swimming, and fish populations are greatly reduced due to poor water quality.

Best Management Practices. A detailed conservation planning inventory was completed for all the farms in the watershed in 1979; BMPs were individually applied to each farm from 1980 on. The measures included guttering, animal waste storage facilities, and fencing of streams to limit livestock access. Wastes, organic matter, and canary grass were removed from the natural stream bottom, and the streambanks were revegetated with snowberry and dogwood cuttings. The cost of implementing the BMPs were met by USDA funds and by a self-imposed tax upon the local farmers. The majority of BMPs have been implemented.

Monitoring. The farmers proposed to improve the quality of the watershed, restore the salmon and trout habitat, and lower the water table of pasture and cropland to facilitate waste application.

Baseline water quality data were collected by the SCS, and monitoring was continued by the Washington Department of Ecology (DOE) while the BMPs were implemented. DOE conducted a water quality survey over a 2-day period in August, 1980. They measured fecal coliforms, dissolved oxygen, temperature, turbidity, pH, nitrate, total phosphate, and flow. They also conducted a visual survey of water quality.

Discussion

The effectiveness of the BMPs in improving water quality has been assessed by observation only. The river banks are walked annually by the farmers and a SCS representative. It is observed that the water flow rate is improved and cattle are away from the stream banks, although canary grass encroachment is still a problem. Fish populations are monitored by the Washington Department of Fisheries using counts of spawning adults. There has been no major increase in fish population, although more of the stream channel is now used for spawning. Crayfish are returning to the creek where gravel substrate has been maintained by reduced organic deposition and improved water flow. The local organizations would like the post-implementation water quality monitoring program to include water column measurements.

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Reports: Whatcom County Conservation District et al. (1981).

Newaukum Creek Project, Washington

Site Description. The Newaukum Creek watershed is located in King County, Washington, approximately 60 km (40 mi) southeast of the Seattle Metropolitan area. This 7,530 ha (18,600 ac) watershed is in the southeastern portion of the county. Nearly 75 percent of the watershed lies on the broad Enumclaw Plateau which is 90 m (300 ft) above the Green and White Rivers. The landscape varies from a plateau to steep foothills. The remaining quarter of the watershed is in the steep, forested foothills of the Cascade Mountains. The soils are silty loams, with areas of wetland.

The climate of the area is influenced by Puget Sound on the west and the Cascade Mountains on the east. The mean annual precipitation is 125 cm (49 in) with approximately 80 cm (33 in) occurring during the 6-month period between October and March. The mean annual temperature is 9°C (50°F). The average growing season is 200 days.

Land Use. The watershed is primarily rural. Woodland comprises 40 percent, and pastureland and hayland 48 percent of the land use. Pastureland associated with commercial enterprises, primarily dairy farming, consists of 1,580 ha (3,904 ac). Five thousand animals produce 151 million liters (40 million gal) of waste a year, which is applied to the pasturelands. Small rural ownerships comprise about 360 ha (900 ac) of pastureland. The majority of the woodland is in private ownership, and woodland harvesting is presently at a minimum.

Beneficial Use. Newaukum Creek is used for spawning by coho, chinook, and chum salmon and steelhead trout, and provides rearing habitat for juvenile salmonids and resident fish populations all year long. Recreational activities, such as fishing and hiking, are enjoyed in the watershed.

Best Management Practices. A BMP program was implemented in 1985, and as of 1986, six contracts had been completed. The BMPs are designed to improve water quality, to improve fish habitats, and to enhance pasture conditions. The most important are the correct application of manure to pastures, installing gutters and diversion pipes to separate rainwater from dirty runoff, installing curbs to prevent manure runoff, building manure storage ponds, and fencing along streams.

Monitoring. The Municipality of Metropolitan Seattle (METRO) conducted a preliminary water quality survey in 1971 and a follow-up study in 1972-1974. The studies showed high levels of total coliform counts, nutrient concentrations, and turbidity.

METRO again monitored the creek from August 1977 to June 1979 with the following objectives: 1) to document groundwater levels and quality in the basin; 2) to document storm runoff and basin flow characteristics as related to land uses; and 3) to select a method for estimating the effects of urbanization on stream flow and water quality in the basin. Water levels were measured in 22 wells and samples taken from 15 wells. In addition, stream flow was monitored continuously at four sampling stations: three at the mouths of urban, forested, or agricultural subbasins, and one near the mouth of the creek. Turbidity, alkalinity, specific conductance, 5-day biochemical oxygen demand, flow, temperature, pH, and dissolved oxygen; total and fecal coliform counts, fecal streptococci; suspended, settleable, and non-settleable solids; nitrogen and phosphorus ions; metals; and pesticides were measured. Aquatic invertebrates (species and biomass) and periphyton colonization on artificial substrate were also monitored. At the time of sampling, the riparian vegetation was qualitatively noted and stream bank stability was likewise observed.

Monitoring is to continue at three sites on a monthly basis. The Muckleshoot Indian Tribe, METRO, and SCS have joint responsibility and cost sharing.

Discussion. Data showed that concentrations of suspended solids, nutrients, and bacteria were highest at the agricultural site. Invertebrate samples were taken once in September and were analyzed by proportion of Ephemeroptera, Plecoptera, and Trichoptera (EPT), mass, and species diversity.

The forested subbasin had a low invertebrate biomass due to low nutrient concentrations, shading, and high water velocities. The biomass at the agricultural site was about half that of the forested site, due to fine sediments in the stream substrate. Periphyton biomass was minimal in the three subbasins. Diatoms were prevalent in the shaded, low nutrient water of the forested site, whereas algae were prevalent at the agricultural site. Sedimentation limited algal colonization on the rock. Two stations on the mainstem of Newaukum Creek had high periphyton biomass. High nutrient availability, minimal sedimentation, and moderate stream velocity were cited as reasons. However, excellent exposure to sunlight at one site resulted in a biomass that was six times greater than that of the second site, indicating the importance of localized conditions for periphyton colonization.

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Reports: USDA (1984a).
Prych and Brenner (1983).

Kamm Slough Project, Washington

Site Description. Kamm Slough watershed is located in northwestern Washington in Whatcom County. It drains through an abandoned oxbow of the Nooksack River, entering the Nooksack near Lynden, Washington. The 20 sq km (8 sq mi) watershed ranges in elevation 12-42 m (40-140 ft) above mean sea level.

Mean annual precipitation is about 106 cm (42 in). The watershed has a high water table and numerous springs. Minor flooding occurs in the lower reaches of Kamm Slough watershed during annual peak flows of the Nooksack River. There is a water deficit through the summer months, requiring supplemental irrigation for crops.

Alluvial deposits, outwash sand and gravel, and silt and clay are the major soil materials.

Land Use. Farming is the main industry of the watershed, using 84 percent of the land area. Dairy farms use over 60 percent of the watershed for pasture, hay, and silage crops. Vegetables, berries, beef operations, and small acreage owners account for the remainder. Cattle manure is the main source of NPS pollution.

Beneficial Use. The Kamm Slough watershed is a spawning ground for salmon; the Lummi Tribal Fisheries Department and the Washington Department of Fisheries released fry in 1983, 1984, and 1985.

Best Management Practices. BMPs for the area include the storage of animal waste through the winter, spreading the correct amount of animal waste on the fields in the dry season, excluding livestock from waterways, diverting milkhouse wastewater to the animal waste storage pond, and separating clean rainwater from feedlot runoff.

To date, 65 percent of the farms spread animal waste year-round, 52 percent have less than 1 month storage capacity in their waste holding facilities, 42 percent of the farms allow animal access to waterways, and few farms have well-managed riparian vegetation.

Monitoring. Monitoring was initiated to enable the county conservation district to form a basis for documenting and evaluating the impact of agriculture on water quality and fishery resources.

Three sites were initially sampled in March, 1985; thereafter, two sites were monitored on a monthly basis through February 1986. One sample site was near the Kamm Slough/Nooksack junction; the other was two-thirds up the watershed. The parameters measured were dissolved oxygen, temperature, flow, conductivity, turbidity, total alkalinity, suspended solids (standard methods); phosphate, nitrate, nitrite and ammonia (spectrophotometer); fecal coliform (membrane filter); and pH. These parameters were measured either in the field or at the Lynden Sewage Treatment Laboratory.

A fish survey was conducted by both the Lummi Department of Fisheries and Washington Department of Fisheries, for which the following parameters were measured: fine sediments (one sample in 1984), population studies in 1984 and 1983 (electrofishing), and riparian vegetation survey (observation).

Discussion. Further implementation of BMPs was recommended. There are no current plans for future monitoring.

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Reports: Whatcom County Conservation District (1986a).

Tenmile Creek Project, Washington

Site Description. Tenmile Creek is located in Whatcom County, Washington, joining the Nooksack River at Ferndale. The watershed is almost 9,300 ha (23,000 ac), and ranges in elevation 3-113 m (10-370 ft) above mean sea level.

The watershed is divided into two regions, the King Mountain uplands to the southwest and the Nooksack Lowlands. The lowland soils are alluvial, well drained, and productive, but require irrigation. The upland soils are heavy and poorly drained.

Average annual precipitation ranges from 205 cm (85 in) in the west to 115 cm (45 in) in the east, with 70 percent falling in the winter months. The average annual temperature is 9^{o}C (49^{o}F) with a mean maximum of 20^{o}C (75^{o}F) and a mean minimum of -2^{o}C (29^{o}F). Flooding of the lowlands is a common occurrence in heavy rains.

Land Use. About 4,860 ha (12,000 ac) is used for grazing and forage production for dairy and beef cattle. Twenty-five percent of the watershed is second-growth woodland, although very little is being managed for timber production, and 9 percent is cropland for berries and vegetables.

Beneficial Use. The wetlands serve as a feeding and resting area for migrating waterfowl and the bald eagle. Recreational activities include fishing and birdwatching. Some areas are utilized by salmon.

Best Management Practices. The construction of manure storage lagoons for the winter months is a high priority since over 63 percent of the farms have less than 2 weeks storage. Gutters and pipes to separate rainwater from wastewater are needed on 56 percent of the farms. Riparian vegetation is in fair to poor condition in over 92 percent of the farms with stream access, and fencing and riparian replanting is needed. A cost share BMP program is being considered.

Monitoring. A monitoring program was devised to identify the sources of sediment and dairy waste, monitor physical and biological water parameters with particular reference to fish habitat, and develop watershed rehabilitation strategies.

Water quality parameters were measured on a monthly basis from March 1985 through February 1986 at 15 sites located throughout the watershed. Temperature, conductivity, and flow were measured in the field. Dissolved oxygen (Winkler method), pH, phosphate, nitrate, nitrite, ammonia (spectrophotometer), fecal coliforms, turbidity, total alkalinity, and suspended solids were measured at the City of Lynden Sewage Treatment Laboratory. Macroinvertebrates were assessed qualitatively in

July, fish populations were measured once (electrofishing, five sites), and stream channel and riparian vegetation were assessed qualitatively.

Discussion. The BMPs are being implemented. No post-implementation monitoring has yet been conducted.

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Reports: Whatcom County Conservation District (1986b).

Samish River Project, Washington

Site Description. The Samish River watershed occupies 35,900 ha (88,665 ac) in northern Washington. The Samish River originates near Acme, adjacent to the floodplain of the South Fork of the Nooksack River, and flows southwest to join the Skagit River near Burlington, Washington. The upper watershed consists of narrow- to broad-bottomed valleys used for agriculture, and steep forested slopes managed for timber harvest by the Department of Natural Resources (DNR) and industrial and private owners. The middle watershed has a broad, gently sloping valley floor, and many reaches of the Samish River are braided. The lower watershed is the Samish River floodplain (9,716 ha [24,000 ac]), protected from high tides by levees and dikes.

The soils of the bottom lands range from poorly-drained, clayey gleys to sandy organic soils. The upland soils are thin, derived from glacial and volcanic deposits. The climate is maritime.

Land Use. Croplands total 11,340 ha (28,000 ac), mostly in the lower portions of the watershed. Crops are predominately vegetables and flower bulbs, with hay, corn, and silage grown for livestock feed. There are 24 dairy farms in the valley (total area of 1,740 ha [4,300 ac]) with 8,832 animal units producing 125 million liters (33 million gal) of manure per year.

Beneficial Use. The estuary at the mouth of the Samish River produced over $10 million worth of oysters and crab and over $4 million worth of commercial fishing. Recreational activities of the watershed include sportfishing (worth $4.2 million), boating, and swimming.

Best Management Practices. Twelve dairy farms in the watershed have long-term storage (at least 6 months) for animal waste. About half of the farms confine their animals for the wet season. About 80 percent of the farmers do not allow direct animal access to the waterways; 58 percent separate clean roof water from wastewater; and only four dairies do not store milkhouse waste.

Monitoring. The Conservation District survey aimed to: 1) identify any water quality problems in the Samish River; 2) inventory the dairy farms in the watershed; 3) inventory the dairy waste management practices; and 4) identify the sources of NPS pollution.

Water samples were collected from four sites: one each upstream, midstream, and downstream, and one tributary. Samples were collected in January, April, early and late June, 1987, and analyzed by the Skagit County Health Department for total and fecal coliforms.

Discussion. Results indicate that the level of fecal coliforms exceed DOE water quality standards for Class A waterways. This is particularly true following a rainfall event. BMPs will be encouraged, particularly those minimizing contaminated runoff. Further concerns are the proper application of manure to fields.

No further monitoring is planned, as implementation of BMPs is the current objective.

Additional Information.

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Skagit Conservation District
227 North Fourth Street
Mount Vernon, WA 98273
206/336-2257

Reports: Robert (1987).

Sequim Bay Project, Washington

Site Description. Sequim Bay is located on the Olympic Peninsula to the west of Port Townsend, Washington. The Sequim Bay area has a low annual rainfall because of its presence in the Olympic rainshadow.

Land Use. The land is used predominately by dairy and beef operators ranging from part-time farmers to large commercial operations.

Beneficial Use. The river and bay are used recreationally.

Monitoring. An initial monitoring program was conducted September 1986 through July 1987 to find the sources of pollution within the watershed. Fecal coliforms were measured, with one sample of water and one sample of sediment being analyzed for herbicide pollution in November 1986. Two large dairy and beef farms contribute 95 percent of the pollution as measured by fecal coliform counts.

Discussion. The second phase of the NPS program is to encourage farmers to implement BMPs, which is scheduled to occur through 1988. There is some concern that the lack of financial incentive for the farmers will slow the schedule. A water quality monitoring program and a public education program will also be conducted through 1988.

Additional Information.

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Reports: No published reports are available.

Quilcene and Dabob Bays Project, Washington

Site Description. The Quilcene Bay and Dabob Bay watersheds are on the eastern shore of the Olympic Peninsula, Washington, and include Tarboo and Donovan Creeks, and the Little and Big Quilcene Rivers. The geology of the area consists of basalt ridges, low gradient valley bottoms, and river outwash. A hardpan of soil compacted during the Ice Age is commonly found at a depth of 25-100 cm (10-40 in), impeding water movement. A perched watertable occurs 0-60 cm (0-24 in) below the surface in much of the area. The area experiences a maritime climate with short, dry summers, long, wet winters, and an average annual precipitation of 120 cm (49 in).

Land Use. The majority of the project area (27,570 ha [68,106 ac]) is forested and harvested for timber. Annual production averages 150 million board feet. Farms, often small and run as a hobby or for a second income, cover 610 ha (1,510 ac). Many farms have livestock.

Beneficial Use. Quilcene Bay is a natural spawning ground for oysters and supports 10 commercial shellfish growers, marketing over 320,000 tonnes (350,000 tons) of oyster meat per year. The oyster hatchery run by Coast Oyster Company, the largest hatchery in the world, is located in the bay. Other marine resources include crab, shrimp, and salmon, and a herring spawning ground. The bays and rivers are also recreational resources used by boaters and fishermen.

Best Management Practices. An 18-month BMP program is being introduced to the farmers. There are two main areas of concern: the first is to protect stream banks from animal access and encourage riparian growth; the second is the removal of livestock from a 25-acre pasture that is tidally inundated. So far, about 25-30 percent of the farmers have installed BMPs focusing on protecting the stream banks from animal access. The removal of livestock from the inundated pasture is now complete.

Monitoring. Sampling by the Department of Social and Health Services (DSHS), 1983, showed several of the marine sampling stations failed to meet the FDA standards for fecal coliforms in areas used for commercial shellfish growing/harvesting. The headwaters of the Quilcene Bay were closed, and a study to provide baseline information on fecal coliform densities in the basin through time was initiated.

Sampling was conducted at each of the 9 marine and 18 freshwater ambient monitoring stations at least once per month for 10 months with replicate samples taken at all stations. Samples were taken 1-6 inches from the surface to maintain consistency with historical records and monitoring protocol. No sediment sampling was conducted. Marine samples were analyzed for fecal coliforms (Most Probable Number, MPN). Freshwater samples were analyzed for fecal coliforms using the membrane filter technique. Analytic procedure was as described in Standard Methods for the Examination of Water and Wastewater (American Public Health Association [APHA] 1985).

In addition to analysis of fecal coliform concentration in marine water, salinity and temperature were recorded at each station to the bottom or until readings stabilized. Temperature and stream flow were measured at the lowest station in each stream. The flow data were used in calculating bacterial loading to the receiving waters.

Reconnaissance monitoring, taking up to 100 water samples in a particular drainage over a period of a day or two to further define the existence and location of NPS pollution sources, was conducted twice for most drainages to provide a wet-season, dry-season comparison. Storm event sampling, necessitated by the elevated bacterial counts in marine waters following intense rainfall, was conducted at the freshwater sites once in late winter.

Other aspects of the Dabob and Quilcene Bay study are a septic tank survey, including soils and land use, and a harbor seal survey.

Discussion. Results show that: 1) sampling stations with the highest fecal coliform counts had the greatest variability through time; 2) there was no consistent correlation between fecal coliform levels in the freshwater and the bays; 3) the total loading of fecal coliforms from the streams did not change during the wet season; and 4) bacterial counts were elevated at the start of a storm event, but fell to normal levels within a week. It was suggested that further monitoring should include turbidity or suspended sediment analysis, a study on the contribution of harbor seals to bacterial contamination, and the encouragement of voluntary implementation of BMPs by farmers. Monitoring the implementation of the BMPs has ceased as the Conservation District technician is no longer employed.

Additional Information.

Contact: Janet Welch
Jefferson County Planning and Building Department
Port Townsend, WA 98368
206/385-9140

Reports: Welch and Banks (1987).

Snohomish River Project, Washington

Site Description. The Snohomish River flows into Puget Sound at Everett, Washington. The lower reaches of the river, which comprise the study area, flow through flat farmland. French Creek, a very polluted tributary flowing into the Snohomish River near the town of Snohomish, is an intensive study site.

Land Use. The predominant land use is dairy farms, ranging in size from 50-500 head. Other livestock and poultry farms are also found. Most of the farmers in the French Creek watershed are part-time/hobby farmers.

Beneficial Use. The Snohomish River is used for recreational boating and fishing.

Best Management Practices. A BMP program was initiated in early 1987, and of 160 farms in the watershed, 12-15 have contracts to implement BMPs. BMPs include waste storage lagoons with 9-month capacity, gutters to separate rainwater and manure, and crop rotation to improve soil fertility. In French Creek, the BMPs involve drainage control and reseeding the pastures, fencing and herd rotations, placing a water supply away from the stream, and confining the animals in the wet season.

Monitoring. The Tulalip Tribe is conducting a monitoring program at their own laboratory, with quality control assessed by the DSHS. Thirty-two sampling sites, located on the tributaries and main stem, are being sampled at 18-20 day intervals for 3 years, funded by a DOE grant. The measured parameters are dissolved oxygen, turbidity, suspended sediments, temperature, nitrate, and fecal coliforms. The same parameters are being monitored at French Creek, at one upper and one lower watershed sampling station.

The program is funded by DOE, the State Conservation Commission, and an internal tree-selling program.

Discussion. The project is too new for the impact of the BMPs on water quality to be known. A public involvement program has been an important part in the success of the program.

Additional Information.

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Everett, WA 98205
206/335-5634

Reports: No published reports are available.

Clover, South Prairie, and Muck Creeks Project, Washington

Site Description. The three creeks are located in Pierce County, Washington. The South Prairie Creek drains into the Carbon River; Muck Creek drains into the Nisqually River, close to McKenna; and Clover Creek, an ephemeral stream, drains into Chambers Creek which discharges to Puget Sound near Steilacoom.

Land Use. The South Prairie watershed has a mix of dairy farmers and part-time/hobby farmers. BMPs have been implemented, mainly manure storage ponds. Farmers in the Muck Creek watershed have also applied BMPs which include lagoon storage of manure, tile drainage, separator devices to keep rainwater from manure, and fencing. The Clover Creek watershed is predominately urban with hobby farmers and no BMPs have been applied. The creek bed itself is full of trash and canary grass.

Beneficial Use. The creeks have no direct beneficial use apart from aesthetics.

Monitoring. Since there are no known background data, a monitoring program was initiated in the spring of 1988. There are six sampling stations along Clover Creek, three on South Prairie Creek, and six stations on Muck Creek. Conductivity and dissolved oxygen were measured twice at each site, and duplicate grab samples were analyzed by the Conservation District for fecal coliforms. Sampling was conducted once a week in the wet season for 16 weeks.

Discussion. The first spring rainfall in March and early April resulted in elevated fecal coliform counts, but counts fell through April despite continued rains. The urban Clover Creek has higher conductivity measures and fecal coliform counts than the rural Muck and South Prairie Creeks, which have had BMPs applied.

Additional Information.

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10923 Canyon Road East
Puyallup, WA 98343-4262
206/536-2804

Reports: There are no published reports available.

Totten, Henderson, and Eld Inlets Project, Washington

Site Description. The three tidal inlets are at the southern tip of Puget Sound, Washington. Henderson Inlet is east of Olympia, and the Eld and Totten Inlets are west of Olympia. The soils of the watersheds are developed from glacial and lacustrine deposits. The climate is maritime, with an annual average precipitation of about 100 cm (40 in).

Land Use. The land use of the watersheds includes part-time/hobby farms, a few commercial dairies, forested areas, and residential development.

Beneficial Use. The streams which flow into the marine inlets support significant populations of salmon. The inlets support shellfish populations for commercial and recreational use. The lower portions of Henderson and Eld Inlets have been designated by the DSHS as closed (Henderson Inlet) and conditionally approved (Henderson and Eld Inlets) depending upon rainfall within a 24-hour period. The reason for these designations is nonpoint source pollution.

Best Management Practices. BMPs are being installed in all three inlets; riparian fencing, gutters, and downspouts are most common.

Monitoring. An intensive monitoring survey of the Eld and Henderson Inlets was conducted from August 1983 to August 1984. Monthly and quarterly samples were taken at the head and mouth of the tributaries, streams, and throughout the marine area. In 1985, Totten Inlet was intensively studied. Since 1986, surveillance monitoring of all three inlets has occurred, and since 1987, a wet-dry season monitoring program has been conducted for major streams and marine stations.

Thurston County SCS is monitoring water quality as it concerns BMPs. Samples and flow measurements are taken from creeks at points above and below priority farms (five in Eld and Henderson Inlets, four in Totten Inlet), before and after BMP implementation, three to four times in the wet season, and once or twice in the dry season. Samples are analyzed for fecal coliforms and temperature following Department of Environmental Health (DEH) guidelines. Suspended sediments are about to be monitored for Totten Inlet samples.

Discussion. The early action watersheds (as defined by the Puget Sound Water Quality Authority) of Eld, Henderson, and Totten Inlets are part of Thurston County's overall water quality plan. Their plan includes a Lake Management Program initiated in 1978, and a groundwater monitoring program initiated in 1987, and a stormwater quality survey initiated in 1988. With all these programs in place, monitored parameters may include pH, suspended solids, salinity, conductivity, heavy metals, fecal coliforms, temperature, dissolved oxygen, nutrients, and organics (Hofstad pers. comm.).

Additional Information.

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Olympia, WA 98502
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Reports: Thurston County Health Department (1987).

Burley and Minter Creeks Project, Washington

Site Description. Burley Lagoon and Minter Bay are two small watersheds, 4,178 ha (10,319 ac) and 4,256 ha (10,514 ac) respectively, on the south side of the Kitsap Peninsula, Washington, and flow into Henderson Inlet. These rural areas, part of northern Pierce County and southern Kitsap County, saw a threefold population increase in the 1970s.

Land Use. The watersheds support predominately part-time/hobby farmers, who rear a variety of animals, including horses, llamas, and guinea fowl. There are over 175 farms in the project area, with 66 percent less than 4 ha (10 ac) in size. The agricultural acreage occupies 7 percent of the watersheds, residential occupies 13 percent, and unharvested forestland 68 percent.

Beneficial Use. The streams flow into Burley Lagoon and Minter Bay, which are heavily used for commercial oyster fishing. DSHS found Burley Lagoon oysters contained over 700 times FDA standards for the concentration of fecal coliforms during routine testing in 1978. The bays were closed to commercial shellfish harvesting in 1978, and remain closed to date.

Best Management Practices. The implementation of BMPs was initiated in 1984 and is ongoing with projects such as stream fencing, sediment ponds, streambank protection, culvert installation, gutters and downspouts, livestock crossings, grassed waterways, and riparian plantings. As of June, 1987, 19 of the 33 landowners contacted had agreed to implement BMPs on their property and 13 had already installed a total of 3,150 m (10,300 ft) of fencing.

Monitoring. The DOE conducted an in-depth 12-month study on baseline water quality in 1984. Four marine stations and 16 freshwater sites were sampled every 2 weeks. Flow, temperature, pH, turbidity, conductivity, nitrogen (ammonia, nitrate and nitrite), total and orthophosphate, suspended sediment, and bacteria (fecal coliforms and fecal streptococci) were monitored.

Currently, samples are collected in the spring from 12 sites in the Burley watershed. Turbidity and fecal coliforms are measured. Future work in the area will include monitoring the streams, Burley Lagoon, and Minter Bay under different flow, tide, and weather conditions, and monitoring will be conducted above/below and before/after specific BMP implementation. Similar work will be performed in the Minter watershed.

Discussion. The ratio of fecal coliforms to fecal streptococci varied between 0.7 (indicative of animal waste) and 4.0 (indicative of human waste), and was consequently meaningless. Fecal streptococci measurements were discontinued.

The Burley and Minter watersheds have received substantial attention since 1979 and several reports defining the problem were written between 1979 and 1985. The BMP implementation was initiated in 1984, and between then and July 1987 both failing septic systems correction and agricultural BMP implementation have been addressed. Significant water quality improvements have occurred, apparently coinciding with the number of BMPs applied. For example, Bear Creek had three livestock BMPs implemented and six failing septic systems repaired, resulting in an 80 percent reduction in fecal coliforms. In contrast, Purdy Creek had only one livestock BMP implemented and one failing septic system corrected, resulting in a 33 percent reduction in fecal coliforms. Public education and cooperation are considered the most important components of the project.

Additional Information.

Contact: Francis Naglich
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Port Orchard, WA 98366
206/876-7171

Reports: Several reports are available from the SCS. The DOE report is Determan et al. (1985). An assessment of applicable BMPs was made by Jones & Stokes Associates (1984).

Coweeman and Arkansas River Project, Washington

Site Description. The Coweeman River flows into the Columbia River just east of Kelso, southern Washington. The Arkansas River flows into the Cowlitz River just east of Kelso, southern Washington. A drainage ditch, Ditch 5/10, part of the flood control drainage ditch system for the cities of Longview and Kelso, is also monitored for industrial and urban pollution.

The soils are quite well drained, although the lowlands are only about 6.5 m (20 ft) above mean high tide. The area has a gently rolling topography with a maritime climate, receiving an average of 120 cm (45 in) of rain a year.

Land Use. The Coweeman River watershed is 90 percent third-growth forest. It is privately managed, and will be cut within a few years. Part-time/hobby farmers use the rest of the watershed. The Arkansas River is composed of 50 percent private forestry property and 50 percent rural farming: mostly cattle grazing, some chicken farms, and horses.

Beneficial Use. The Coweeman River is a major recreational area, with fishing and swimming being prime activities.

Best Management Practices. Most of the farmers adjacent to the Coweeman River have fenced off the riparian area. No BMPs have been implemented along the Arkansas to date.

Monitoring. A monitoring program to assess water quality was initiated in autumn 1987. There are four sampling stations on Coweeman River and five on Arkansas River. Water samples will be analyzed for fecal coliforms, pH, conductivity, suspended sediments, temperature, and ammonium-N. Flow will also be measured. Intense storm event sampling is planned with sampling once or twice a day for 3 days following a storm (1.8 cm [0.75 in] rainfall in 24 hr). The sampling program, supported by Centennial Clean Water Act funds, will continue until the funds are exhausted.

Discussion. Much of the watershed is forested, and several of the streams are temperature sensitive, as defined by the State Forest Practices Act (FPA). Agricultural BMPs will be important in contributing to improved and sustained water quality.

Additional Information.

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Cowlitz County
Conservation District
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Kelso, WA 98626
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Reports: No published reports are available.

Lacamas Creek Project, Washington

Site Description. The Lacamas Creek drainage basin is located in southern Washington, Clark County. Lacamas Lake is in the lower reaches of the drainage, close to the Columbia River, into which Lacamas Creek eventually drains. Lacamas Lake has a relatively rapid water exchange; average water residence time is about 3 weeks, yet it is becoming eutrophic through excessive inputs of nutrients. The river basin, 17,410 ha (43,000 ac), is both residential and agricultural, with animal-keeping (llamas, sheep, ponies, cattle) the dominant farming activity.

Land Use. The land use in the watershed is predominately agricultural. A 2-year study (1983-1985) showed Lacamas and Round Lakes were severely over-enriched with nutrients, particularly phosphorus. The sources of phosphorus were identified as failing septic systems and agricultural practices. This lead to the second, and latest, phase of the Lacamas Lake Restoration Project: to identify the specific sources of phosphorus, the major contributors, and any major mitigation actions to be taken.

The agricultural inventory involved 11,740 ha (29,000 ac), concentrating on farms adjacent to streams, farms with 5 animal units or more, and farms 2.5 ha (6 ac) or more in size. The inventory was extensive, surveying farm management practices, the structural condition of the farm, the status of riparian and pasture vegetation, and the amount and quality of farm runoff. A single sample of runoff was tested for fecal coliforms, nitrate, ammonia, Kjeldahl nitrogen, and phosphorus.

The agricultural and septic tank survey showed that 96 percent of the phosphorus entering Lacamas Lake was the result of animal wastes.

Beneficial Use. Lacamas Lake is used for recreational fishing and boating.

Best Management Practices. The identified BMPs include improved waste management (e.g., dry stack, roofed dry stack, roof gutters, outlet pipes), pasture management (reseeding), crop management, and riparian management (fencing, animal crossings, alternative watering sites, revegetation). To date, no BMPs have been installed.

Monitoring. The monitoring program is not yet devised. It is anticipated that measurements will include fecal coliforms, phosphorus, nitrate, ammonia and Kjeldahl nitrogen, with monitoring sites above and below farms. It is hoped that two farms will be monitored to test the efficacy of specific BMPs.

Discussion. The program identified 47 agricultural sites requiring BMPs and about 19 percent of the septic systems as requiring attention with a cleanup cost of $3 million. No post-BMP implementation data are gathered.

Additional Information.

Contact: Thomas Waltz
Intergovernmental Resource Center
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Vancouver, WA
206/699-2361

Reports: Waltz (1987).

PART II: IRRIGATED FARMING

Willamette Valley

Polk County Project, Oregon

Site Description. Several watersheds in the Willamette Valley are being studied by the Department of Soil Science at Oregon State University (OSU). The watersheds are located in southern Polk County, north of Corvallis, on rolling terrain, with gentle slopes and slight elevation. Runoff flows into the Willamette River which drains northward to the Columbia River.

Average January and July temperatures are 3^{o} and $18^{o}C$ respectively (38^{o} and $70^{o}F$). Average annual rainfall is about 120 cm (47 in) most of which falls in the winter as rain. The soils are fine silty clays overlying paleosol or weathered sandstone parent material.

Land Use. The land is devoted almost entirely to production of grass seed, hay, pasture, and orchard crops, with minor areas of forest.

Beneficial Use. The watersheds are managed for experimental purposes.

Best Management Practices. The predominant BMP is the installation of tile drainages, which improves soil water drainage and reduces runoff and soil erosion.

Monitoring. The experimental watersheds are intensively monitored; various erosion plots are installed, and subsurface moisture is measured with wells, piezometers and tensiometers. Runoff is monitored with V-notch weirs, and various experiments have studied the transport of suspended sediment, total and dissolved inorganic phosphorus, nitrate and ammonium, turbidity, conductivity, and the redistribution of ^{137}Cs is measured to assess erosion. The sampling intensity varied. One program was monitored for 24 hrs, 7 days a week for 9 months, from 1976 to 1982.

Discussion. The Oregon State University run project is experimental, studying soil erosion rates and the measurement of erosion on farmed, hilly land. Various BMPs are applied and tested; however, the aim of the research is not to improve water quality in streams, rather to directly measure soil erosion.

Additional Information.

Contact: Gerald Kline
Soil Science Department
Oregon State University
Corvallis, OR
503/754-2441

Reports: OSU Agricultural Extension Station (1980).
Brown et al. (1981).
OSU Agricultural Extension Station (1985).

Sierra Nevada

Bear Creek Project, Oregon

Site Description. Bear Creek watershed is in southern Oregon in the northern part of the Sierra Nevada ecoregion as defined by Omernik and Gallant (1986). Bear Creek flows 40 km (25 mi) south from Emigrant Lake through a wide, flat valley and the town of Medford before joining the Rogue River. The Rogue River system includes two major reservoirs and a wild and scenic river reach between the towns of Grants Pass and Agnes.

Land Use. The land use of the valley is mixed, and includes irrigated cropland, orchards, grazing animals, forestry, and quarrying.

Beneficial Use. A park corridor has been created along the length of Bear Creek, which provides many recreational opportunities, including bicycling, horseback riding, boating, fishing, and bird watching. River water is used for irrigation.

Best Management Practices. Approximately 2,400 ha (6,000 ac) have been converted from flood irrigation to sprinkler irrigation, with an increase in irrigation efficiency from 35 percent to 70 percent, on average.

Permanent crop cover is planted in orchards, and orchardists have removed chemical and heating devices from close proximity of streams and irrigation ditches.

Monitoring. A monitoring program, funded by an EPA grant to the Division of Soil and Water Conservation, was undertaken in 1980. The Rogue Valley Council of Governments has monitored 38 sites along Bear Creek and its tributaries for temperature, fecal coliforms, and suspended sediments. Nutrient measurements will begin in 1988.

Discussion. Since the start of the monitoring program in 1980, fecal coliform counts have dropped from 2,000 colonies/100 ml to 350 colonies/100 ml. Qualitative observations on fish populations show higher populations of anadromous fish and migration further upstream. Suspended sediments, however, are virtually unchanged, probably due to 4 years of drought and reduced overland runoff. The success of the program is attributed to public education and raising the environmental consciousness of individuals in the area.

Additional Information.

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Rogue Valley Council of Governments
155 South Second Street
Central Point, OR 97502
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Reports: Rogue Valley Council of Governments (1987).

Eastern Cascades

Klamath Project, Oregon and California

Site Description. The Tule Lake and Lower Klamath National Wildlife Refuges and the Shoalwater Bay and Squaw Point Wildlife Management Areas, located on the Oregon/California border, is one of several areas in the western states that have been identified by the U. S. Department of Interior (DOI) as areas where irrigation drainage might be causing, or have potential to cause, adverse effects on wildlife and human health. Based on increasing national concern about irrigation drainage and the documented toxicity problems involving selenium in the irrigated western San Joaquin Valley, California, the DOI initiated a screening program to determine whether irrigation drainage waters have caused or have the potential to cause harmful effects on human health, fish and wildlife, or other water uses. The screening program is being executed by the U.S. Geological Survey (USGS) in cooperation with the U.S. Fish and Wildlife Service (USFWS) and the Bureau of Reclamation.

Monitoring. Water samples will be collected at a time that optimizes peak irrigation season and natural use patterns and migratory cycles of fish and wildlife. Flow, pH, specific conductance, temperature, and dissolved oxygen will be measured in the field. Water and sediment samples will be collected and analyzed for selected pesticides, metals, and trace elements. Sampling of aquatic organisms will occur at the peak period of use for migratory species and the peak period of metabolic activity for resident species. Plant and animal tissues will be analyzed for selected metals, trace elements, and pesticides. Bottom sediments will be collected only once after a period of prolonged low to steady flows during or after the irrigation season.

Sampling and field measurements for water and sediments followed standard methods described in the "National Handbook of Recommended Methods for Water Data Acquisition." Analyses followed standardized USGS procedures for water and sediments, and USFWS procedures for biological materials. Quality assurance procedures include splitting samples, testing field blanks, instrument calibrations, analysis of blind standard reference samples, interlab comparisons of split samples, and analysis of spiked samples.

Discussion. The activities carried out under this program at the Klamath Lake Project are not directly related to monitoring the effectiveness of BMPs. They provide, however, preliminary baseline data that would be relevant to any subsequent effort to reduce the impact of pesticides, heavy metals, or trace elements on aquatic biota. Affiliated agencies on the project are USFWS and Bureau of Reclamation.

Additional Information.

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Menlo Park, CA 94025
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Reports: No published reports are available.

Columbia Basin

Moses Lake Clean Lake Project, Washington

Site Description. Moses Lake is a large, shallow, eutrophic lake located in Lincoln and Grant Counties, Washington, to the southeast of Ephrata. The watershed is about 6,345 sq km (2,450 sq mi), drained by Crab Creek (84 percent of the watershed) and Rocky Ford Creek.

The climate is severe, with extremes ranging from 34°C (104°F) to -31°C (-33°F), although the average summer temperature is 18°C (71°F) and the average winter temperature is 1°C (34°F). Precipitation is 23 cm (9 in), 60 percent of which falls in winter. The soils are very gravelly and porous, allowing rapid water percolation to the groundwater. They are young soils, with little structural development, and tend to have a saline horizon at 40-63 cm (15-26 in), particularly near Quincy.

Land Use. Much of the land of the Crab Creek watershed is agricultural: rangeland (255,060 ha, 630,000 ac), dryland agriculture (316,350 ha, 781,400 ac), and irrigated farmland (5,280 ha, 130,520 ac). The latter predominates in the lower watershed and is believed to be the primary source of NPS pollution. The City of Moses Lake, on the east shore, has a population of 27,000.

Beneficial Use. Moses Lake is regulated as part of the Columbia Basin Project which supplies water to over 200,000 ha (500,000 ac) of farmland. The lake is used extensively for recreational purposes, primarily fishing, boating, and swimming.

Best Management Practices. Six BMPs were identified for the project area: irrigation water management, irrigation system improvements, fertilizer management, animal waste control, sediment and water control structures, and stream protection systems. The farmers are reimbursed at a 75 percent cost share, and to date, about 2,164 ha (5,346 ac) are under BMP implementation. Other non-agricultural BMPs, including diluting the lake water with Columbia River water and overhauling existing sewage systems, have greatly contributed to water quality improvements.

Monitoring. Moses Lake has been studied since the early 1960s to determine the cause of noxious algal blooms. Diluting the water with low nutrient Columbia River water was initiated in the 1970s, and in 1982, grants from Washington DOE and EPA allowed an investigation into the nutrient sources.

The Moses Lake Clean Water Project was conducted in three stages. The first stage, focusing on nutrient source identification, was completed in March 1984. The second phase focused on nutrient control demonstrations and the evaluation of the effect of these controls on Moses Lake water quality and was completed in March 1985. This phase included on-farm nutrient controls, detention pond construction, improved septic tank controls, stream dredging, and carp eradication. Stage 3, completed in May 1987, provided for the implementation of control practices on and off farms.

The lake was sampled at 8 sites approximately twice a month from March through September, 1983 through 1985. Major inputs to the lake were sampled on a year-round basis at six sites. The samples were analyzed for pH, temperature, dissolved oxygen, chlorophyll, phytoplankton cell volume, nitrogen (total and nitrite/nitrate), phosphorus (total and orthophosphate), specific conductance, and transparency (Secchi disc).

The watershed was sampled at 80 sites in 1982-1983; 25 stations monitored the watershed behavior, whereas the remainder monitored specific farming practices. Groundwater was monitored at 26 wells and 12 spring locations. The sampling schedule varied with station, ranging from bi-weekly to quarterly. The measured parameters likewise varied, but included flow (current meter, staff gage), suspended solids, specific conductance, nitrogen (total and nitrite/nitrate) and phosphorus (total and orthophosphate). Fifteen of these stations (six surface water sites, four springs, and five wells) were sampled for the same parameters from March 1986 to March 1987. Monitoring of most of the 15 stations is planned for 1989-1990 along Rocky Ford Creek and at the Crab Creek inlet to Moses Lake. Grab samples will be taken and analyzed for suspended solids, total and nitrate nitrogen, total phosphorus, and orthophosphate by a testing laboratory in Seattle following EPA standard methods.

Discussion. There has been noticeable improvement in the water quality of Moses Lake; phosphorus levels have declined by 50 percent, chlorophyll-a levels have dropped 62 percent, and lake water transparency has doubled. It is difficult to attribute the improvement to any one control measure; lake water dilution, septic tank improvements, agricultural BMPs, and fish management all contributed. A Moses Lake management model was written and verified with 1978 and 1979 water quality data.

Additional Information.

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Vashon, WA 98070
206/463-3388

Reports: Publications are numerous. The final stage summary is by Bain and Moses Lake Conservation District (1987).

South Yakima Project, Washington

Site Description. The Yakima is one of the largest rivers in Washington and has a drainage of 1.6 million ha (3.0 million ac). The river is 355 km (220 mi) long, flowing southeasterly from the Cascade Range to meet the Columbia River at the city of Richmond, Washington. The soils of the watershed are developed from basalt parent material or from unconsolidated, glacially deposited material. Annual precipitation is between 330 cm (140 in) in the mountains to 25 cm (10 in).

Land Use. Major land use practices include timber (36 percent of the watershed), pasture grazing (47 percent), irrigated agriculture (16 percent), and urbanization (0.8 percent). Irrigated agriculture and urbanization are of primary importance with respect to water quality effects.

Beneficial Use. The Yakima River is used extensively for irrigation and for the generation of hydroelectric power. At certain times of the year, up to 80 percent of the flow in the Yakima River is comprised of irrigation return water. The river was historically one of the most important fish producers in the Columbia River system. Major efforts are underway to restore habitat and remove migration barriers to improve current fish production.

Best Management Practices. Sediment reduction practices include the conversion from furrow to sprinkler irrigation, installing sediment ponds, and water management to minimize runoff from the fields. These were implemented with the help of cost-share programs. When the project stopped in 1986, nearly 100 percent of the BMPs were implemented.

Monitoring. Water quality data have been collected in the Yakima River Basin since 1910 and many studies have since been conducted. Water quality parameters that have been measured in various studies include discharge, temperature, specific conductance, dissolved oxygen, color, turbidity, pH, suspended sediments, loads and particle size, trace elements, organic compounds, pesticides, bacteria, and fish.

A comparison of the data collected after treatment with the historical data show the forested reaches have retained the background levels of turbidity, bacteria, nutrients, and major ions. Concentrations of turbidity, nutrients, and ions are above background during and after logging. Agricultural drains have the largest concentrations of turbidity, nutrients, major ions, bacteria, and pesticides.

Currently, the Yakima River is one of the seven National Water Quality Pilot Studies. The program's aim is to describe existing water quality conditions and how they vary spatially and temporally, and to address water quality problems limiting the identified beneficial uses of the river and watershed. Six areas are addressed: salinity, trace elements, organics, suspended sediments, sanitary quality, and bioassessment. The bioassessment will include tissue analyses, fish and macro-invertebrate population studies, and aims to describe why and how the species are restricted both spatially and temporally in the river.

Data collection started April 1987 and will continue at an intensive level for 3 years, drop to a low level for 6 years, and intensify again for another 3 years. The intensive program involves comprehensive monthly sampling at 6 sites and synoptic sampling. Synoptic sampling provides a "snapshot" of water quality conditions over a broad geographical area by making single measurements at many sites (over 100) during a week. Each synoptic study is tailored to a specific set of water quality variables. To date, four have been held for nutrients, two for bacteria and suspended sediments, two for ions and elements, and one for trace elements in bottom material. A sample for total recoverable and bottom organics is planned.

Discussion. One study by King et al. (1983) involved an extensive water quality sampling program from 1977 through 1981 in tandem with BMP implementation. The nearly complete implementation of BMPs accompanied by the intensive water quality monitoring program demonstrated water quality improvements. Sediment loadings were reduced by up to 80 percent and total phosphorus was reduced by up to 50 percent. Sediment control

BMPs had little effect on nitrogen loadings. The Imhoff cone was used effectively at the farm level to help the irrigator visualize his soil loss and optimize water management for soil retention. The project contributed greatly to the understanding of how specific BMPs reduced soil erosion, and the data set was used to develop an economic model.

The current study (McKenzie and Rivella 1987) is not directed towards BMP implementation, although extensive interaction with agencies responsible for BMP implementation occurs. A synthesis report of the Yakima River National Water Quality Pilot Study is anticipated in 1992.

Additional Information.

Contact: Stuart McKenzie
USGS
Portland, OR
503/231-2016

Reports: King et al. (1983).
Johnson et al. (1986).
McKenzie and Rivella (1987).

Snake River Basin/High Desert

Harney and Malheur Lakes Project, Oregon

Site Description. Malheur National Wildlife Refuge, located in Harney County in southeastern Oregon, is one of several areas in the western states identified by the DOI as areas where irrigation drainage might be causing, or have potential to cause, adverse effects on wildlife and human health. Based on increasing national concern about irrigation drainage and the documented selenium toxicity problems in the irrigated western San Joaquin Valley, California, the DOI initiated a screening program to determine whether irrigation drainage waters have caused or have the potential to cause harmful effects on human health, fish and wildlife, or other water uses. The screening program is being executed by the USGS in cooperation with the USFWS and the Bureau of Reclamation.

Monitoring. Samples were collected in March, 1988 and will be collected again in May and June to coincide with irrigation. Flow, pH, specific conductivity, temperature, and dissolved oxygen were measured in the field. Water and sediment samples were collected and analyzed for selected pesticides, metals, nutrients, and trace elements. Plant and animal tissues were analyzed for selected metals, trace elements, and pesticides.

Water samples were collected at a time that optimized cycles of fish and wildlife. Sampling of aquatic organisms occurred at the peak period of use for migratory species and the peak period of metabolic activity for resident species. Sediments were collected only once after a period of prolonged low to steady flows.

Sampling and field measurements for water and sediments followed standard methods described in the "National Handbook of Recommended Methods for Water Data Acquisition." Analyses followed standardized USGS procedures for water and sediments and USFWS procedures for biological materials. Quality assurance procedures include splitting samples, testing field blanks, instrument calibrations, analysis of blind standard reference samples, interlab comparisons of split samples, and analysis of spiked samples.

Discussion. A similar project in the Snake River/High Desert ecoregion is underway at American Falls Reservoir, located on the Snake River in southeastern Idaho, near Pocatello. The activities carried out under these programs are not directly related to monitoring the effectiveness of BMPs. They provide, however, preliminary baseline data that would be relevant to any subsequent effort to reduce the impact of pesticides, heavy metals, or trace elements on aquatic biota. Affiliated agencies on the project are USFWS and the Bureau of Reclamation.

Additional Information.

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345 Middlefield Road
Menlo Park, CA 94025
415/329-4415

Reports: No published reports are available.

Rock Creek Rural Clean Water Program, Idaho

Site Description. The Rock Creek watershed is located in south central Idaho, with headwaters in the Sawtooth National Forest in western Cassia County, and draining to the Snake River near Twin Falls, Idaho. Soils in the lower watershed are highly erosive, thin, medium textured surface soils and strongly calcareous silty subsoils. The climate in the lower watershed is semi-arid with moderately cold winters and hot summers. Annual precipitation averages approximately 23 cm (9 in).

Natural hydrology of Rock Creek has been significantly altered by the development of irrigated agriculture in the lower watershed and by hydroelectric projects. Historically, flows were driven by snowmelt, with high flows in the spring and low flows in the summer and fall. Peak flows now occur in September as a result of irrigation drainage and generation of hydroelectric power during the summer months.

Land Use. Approximately 25 percent of the watershed area is in irrigated cropland (21,000 ha of 80,300 ha [51,870 ac of 198,340 ac]). Typical crops are dry beans, dry peas, sugar beets, corn, small grains, and alfalfa. All crops are irrigated by water diverted from the Snake River and delivered through a series of canals. It is estimated that approximately 50 percent of precipitation and delivered water percolates to subsurface drainage and 14 percent returns to surface waters by way of irrigation drainage (Clark 1986).

Beneficial Use. Hydroelectric power generation occurs in the lower watershed, and the river water is used for irrigation. Fishing and swimming are common all along Rock Creek. Recreational floating (tubing) is popular in the Rock Creek Park area.

Best Management Practices. BMPs are individually tailored for each participating farm. Conservation tillage (minimum or no tillage) has been most commonly identified as the best practice. Other conservation practices include emplacement of sediment basins, mini-basins, I-slots, vegetative filter strips, buried pipe runoff control systems, concrete irrigation ditches, and gated pipelines. Cessation of stubble-burning is also encouraged as a non-structural BMP. Improved animal waste management practices are also being implemented for confined animal operations. The project is federally funded. Cost-sharing grants are made to farmers cooperating in the program through the implementation of qualified BMPs. BMP implementation is expected through 1995.

Monitoring. Rock Creek has been identified as a pollution problem for many years. Many water quality investigations have been conducted over the past 25 years, and major efforts have been made to reduce waste loading from point sources.

Rural Clean Water Program (RCWP) funds were obligated for the Rock Creek watershed in 1980; monitoring has been conducted by the Idaho Department of Health and Welfare, Department of Environmental Quality (IDHW-DEQ) since 1981 and is planned to continue through 1990. The objectives of the monitoring program are to identify water quality conditions in irrigation drains and Rock Creek, and to quantify changes in water quality as a function of changes in land management activities in the drainage areas.

Suspended sediment, nutrients, and bacteria are monitored weekly during the irrigation season (April-October) on the subbasin drains. Rock Creek is sampled twice monthly during the irrigation season for flow, dissolved oxygen, pH, temperature, specific conductivity, suspended sediment, nutrients, fecal coliform bacteria, metals, common ions (PO_4, Mg, Na, Ca, K, Cl, F), and monthly during the non-irrigation season. Nutrient measurements include total phosphorus, dissolved orthophosphate, nitrate and nitrite nitrogen, ammonia nitrogen, and Kjeldahl nitrogen. Monitoring of volatile suspended solids was added in 1986. Additional parameters that have been or will be examined less frequently are bank erosion, cobble embeddedness, stream channel sediment characteristics, benthic macroinvertebrate populations, and fish populations (electroshocking). In addition, fish tissue is monitored for metals and pesticides annually. Changes in riparian habitat and aesthetic features are documented qualitatively by color photography.

The list of parameters that have been monitored vary annually and by station. It is anticipated that monitoring for some metals will be discontinued and monitoring for pesticides will increase.

Quality assurance for laboratory and field measurements began with the 1985 field season and includes duplicate (split) samples for water chemistry and bacteria, and percent recovery from field spiked samples. Results indicate variability in the quality of measurement. Water chemistry parameters are assayed using standard protocols approved by EPA or the APHA.

Groundwater contamination by salts and nitrate in the general area has been examined by the U.S. Department of Agriculture (USDA) Agricultural Research Station in Kimberly, Idaho. Additional groundwater monitoring is planned beginning in 1988 by the IDHW-DEQ.

Discussion. The 8-year Rock Creek RCWP has included two drought years and one 100 year flood, representing extreme hydrological conditions. The data are correspondingly quite varied. Suspended sediments, for example, decreased markedly in some subbasins, up to 99 percent for some sample dates, but overall reduction was masked by increased river channel erosion. The fecal coliform and macroinvertebrate data were likewise variable. Nutrients (phosphorus and nitrogen) have declined slightly, but are still considered pollutants. The total fish population increased substantially in three sampling stations and rainbow trout biomass increased at four of the six stations.

Rock Creek RCWP is administered by the USDA Agricultural Stabilization and Conservation Service. Technical assistance is provided by the USDA Soil Conservation Service, and the Snake River and Twin Falls Soil Conservation Districts. The USDA

Agricultural Research Station in Kimberly, ID and the University of Idaho are also involved in researching technical and economic aspects of the Rural Clean Water Program.

Additional Information.

Contact: William Clark
IDHW-DEQ
450 West State Street
Boise, ID 83720
208/334-5860

Reports: Many reports on water quality issues in Rock Creek watershed have been published. A comprehensive water quality monitoring report is available (Clark 1986). The National Water Quality Evaluation Project (1985) has evaluated Rock Creek RCWP data and made comparisons with similar projects.

PART III: DRYLAND FARMING

Idaho State Agricultural Water Quality Program

The IDHW-DEQ and the Soil Conservation Commission jointly administer a state Agricultural Water Quality Program. The program financially assists soil conservation districts (SCD) with control and abatement programs that receive priority ranking during a screening process undertaken by the IDHW and the Idaho Soil Conservation Commission. Applications for assistance are prepared by the local SCDs. Once approval of a project is made, up to 75 percent of implementation costs of BMPs are supported by the state cost-sharing program.

As of 1987, 17 cost-sharing projects have been implemented. Of these, 14 projects involve implementation of BMPs in watersheds in dryland agriculture and three involve watersheds in irrigated land. Three additional projects involving dryland agriculture and one additional project on irrigated land will begin in 1988. A list of ongoing projects, new projects for 1988, and projects still in the planning phase is attached as Appendix B.

Best Management Practices. BMPs are individually designed for each participating farm. The most common BMPs include minimum or no tillage, terracing, subsoiling, emplacement of sediment basins, and strip cropping. Another practice is the use of the Conservation Reserve Program.

Monitoring. IDHW-DEQ conducts the baseline analyses for the cost-sharing projects. Baseline data are collected for 1 year; sampling occurs at least once in the fall during low flows and twice each month from February through July.

The information that is collected is generally consistent for all cost-sharing projects. The data include flow, temperature, suspended sediment, turbidity, specific conductivity, dissolved oxygen, pH, fecal coliform and fecal streptococcus (membrane method), and nutrients (total ammonia, nitrate and nitrite nitrogen, Kjeldahl nitrogen, total phosphorus, and orthophosphate). The IDHW-DEQ Twin Falls Region includes dissolved volatile solids and macroinvertebrate surveys (Shannon-Wiener diversity, functional feeding groups, and biotic condition index) in the baseline.

Discussion. The state program provides baseline data useful for evaluating effectiveness of NPS control programs. No funds are currently available for post-implementation monitoring. The Twin Falls Regional Office has plans to conduct a follow-up water quality survey in approximately 2 years.

Additional Information.

Contact: Contact persons at the IDHW-DEQ regional offices and the local USDA SCS District Conservationists are listed in Appendix B. At IDHW-DEQ in Boise, the main contact is:

Robert Braun
IDHW-DEQ
450 West State Street
Boise, ID 83720
208/334-5860

Reports: Reports for some of the individual projects are available from IDHW-DEQ.

Columbia Basin

Palouse River Basin Project, Washington and Idaho

Site Description. The basin drained by the Palouse River and its tributaries encompasses almost 1 million ha (about 2.4 million ac) in parts of five counties in eastern Washington and two counties in northern Idaho.

The elevation varies from 150-1,600 m (500-5,300 ft) above sea level. Annual precipitation ranges from less than 30 cm (12 in) in the west to over 90 cm (35 in) in the east.

There are 10 sub-watersheds in the basin: South Fork Palouse, North Fork Palouse, Rebel Flat Creek, Cottonwood Creek, Pine Creek, Thorn Creek, Rock Creek, Cow Creek, Union Flat Creek, and the Palouse River main stem.

Land Use. A large part of the basin, 38 percent, is dryland cropland, with wheat being the dominant crop, followed by barley, legumes, and summer-fallow. Twenty-eight percent of the basin is rangeland, with animals overwintered in pens.

Beneficial Use. The Palouse River feeds into the Snake and Columbia Rivers, which have many beneficial uses, including irrigation, hydroelectric power production, and providing municipalities with water. There is limited opportunity for recreational use; hunting, and to a lesser extent, trout fishing, are most common.

Best Management Practices. Sheet and rill erosion, soil slips, and gully and stream channel erosion have degraded the soil and water quality and resulted in considerable economic loss. BMPs to reduce sediment yield, including minimum tillage, stubble mulch tillage, field strips and divided slope farming, terraces, and reseeding, are being implemented and are expected to be completed in the 1990s.

Monitoring. Monitoring was conducted to establish the scope of the problem. Turbidity data were collected by Washington DOE and EPA at bimonthly intervals from a site near the mouth of the Palouse River from August 1970 to September 1971, and October 1973 to August 1976. Nitrate and nitrite analyses were also conducted, and aerial photographs and field checks were used to identify wildlife habitat in the basin.

Discussion. The focus of the project was to determine which sub-watershed was a major contributor to NPS pollution and to develop suitable BMPs to ameliorate the problem. Extensive baseline data were gathered, but monitoring since the BMPs were applied has been limited.

Additional Information.

Contact: Paul Taylor
USDA SCS
360 U. S. Courthouse
West 920 Riverside
Spokane, WA 99201-1080
509/456-3710

Reports: There are many reports on the individual watersheds. A project summary for the Palouse Cooperative River Basin study is given by the USDA (1978).

Southeast Washington Cooperative River Basin Project, Washington

Site Description. The Southeast Washington Cooperative River Basin Project area, located in southeast Washington state, encompasses over 1,000,000 ha (2,785,081 ac). The area is bordered on the south by the State of Oregon and on the east by the State of Idaho and the Snake River. The northern and western boundary of the study area is formed by the northern drainage boundary of the Snake River from Whitman and Franklin Counties.

Mean annual precipitation varies from less than 25 cm (10 in) per year in the west, to about 170 cm (70 in) a year in high mountain areas. The annual temperature range is -29°C to 30°C (-30°F to 95°F). The forest and rangeland is transected with numerous steep canyons. The soils are generally silt loams formed from deposited loess, mixed in the lowlands with alluvial deposits.

Major waterways include the Columbia River and the Snake River. Numerous small tributaries include Alkali Flat Creek in Whitman County; Grande Ronde River and Asotin Creek in Asotin County; Alpowa Creek in Garfield and Asotin Counties; Deadman Creek in Garfield County; Tucannon River and Pataha Creek in Columbia and Garfield Counties; the Touchet River in Columbia and Walla Walla Counties; and Dry Creek and the Walla Walla River in Walla Walla County. The watersheds of these stream systems constitute the 10 major areas used in the study.

Land Use. Forty-three perçent of the area (484,210 ha [1,196,000 ac]) is used for the production of crops, mostly winter wheat. Seven percent of the land is used for irrigated crops, 30 percent for rangelands, and 17 percent is forested.

Beneficial Use. The Wenaha-Tucannon Wilderness area contains streams suitable for recreational fishing of salmon. The Touchet River is a sport-flyfishing stream.

Best Management Practices. Erosion of the topsoil within the study area is estimated to total 9,393,800 tonnes (10,357,000 tons) per year, of which 8,750,700 tonnes (9,648,000 tons) are from cropland. Productivity of crop and rangeland have deteriorated, and there is a significant loss of fish spawning and rearing habitats due to sedimentation and high stream temperatures. BMPs fall into the general categories of minimum tillage and stubble mulching, increasing terraces and strip cropping, increasing the acreage planted to small grain crops, reducing summer-fallow, reducing the acreage of strip slopes under cultivation, pasture reseeding, and herd management. These are being implemented throughout the study area.

Monitoring. Major study objectives included: 1) basin-wide evaluation of erosion and sediment problems, present land management and stream habitat condition; 2) intensive study of the Tucannon River to determine instream effects of erosion and sediment on water quality and stream habitat conditions; and 3) evaluation of impacts of conservation practices and land use changes as applicable to cropland and forested areas, and production practices on rangeland areas in the basin.

The monitoring program to establish baseline information was extensive. Washington State University, USGS, SCS, and DOE have been monitoring water quality parameters on an ongoing basis since 1979. The results of the study are presented in four types of reports: a summary document, ten individual watershed reports, and two separate reports relating directly to the Tucannon River instream investigation.

Discussion. The project aim was to identify which watershed contributed the greatest amount to NPS pollution and to encourage the use of BMPs to reduce pollution input. Public education was a major part of the project.

Additional Information.

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Reports: The summary document is USDA (1984b).

Little Greasewood and West Fork Greasewood Creeks Project, Oregon

Site Description. The North Central Oregon Wheat Growing Region project covers five counties; Umatilla, Morrow, Sherman, Gilliam and Wasco, along the south bank of the Columbia River. The area is characterized by rolling hills and steep slopes, hot dry summers and cold, wet winters. Occasional severe summer storms and freeze-thaw cycles with snowmelt cause extremely severe soil erosion. Little Greasewood watershed, 16 km (10 mi) northeast of Pendleton, Oregon, was selected to demonstrate that BMPs could reduce erosion from dry cropland.

Land Use. Little Greasewood watershed contains 1,814 ha (4,480 ac) of cropland, and the West Fork Greasewood watershed has 1,886 ha (4,660 ac) of cropland.

Best Management Practices. BMPs have been enthusiastically received by the 30 farmers in the watersheds. All are using a wider variety of crops in their rotations with winter wheat. Conservation tillage is being carried out on 1,980 ha (4,900 ac). There are now 6.5 km (4 mi) of grassed waterways and 13 km (8 mi) of creek bank terracing and planting with wheatgrass.

Monitoring. Eight sampling stations were placed at intervals from the head to the mouth of the creeks; grab water samples were taken periodically from November 1981 to March 1983. Field boundary runoff was collected in December 1982, and all water samples were analyzed for suspended solids (Imhoff cones). Precipitation, soil temperature, and rill erosion were also monitored.

Discussion. Two attempts to use mechanical equipment (a stage recorder and a continuous water sampler) resulted in failure due to silting and freezing. A portable turbidity meter was inadequate because the upper range of the meter was exceeded when erosion was occurring.

In 1981, the suspended sediment loading was less than 8 ml sediment per liter at all stream sample sites. In 1983, runoff from farms with BMPs applied had significantly declined, reducing the stream discharge. Soil erosion from two conventionally tilled farms continued to occur. Due to the lower stream discharge, the concentration of sediment increased to 19 ml/l. The result of the water quality monitoring, taken in isolation, appears to imply the implemented BMPs were not working. This, in fact, would be a false conclusion and emphasizes the need for a watershed management approach to controlling NPS pollution.

Additional Information.

Contact: Bob Adelman
USDA SCS Umatilla County
1229 S.E. Third
Pendleton, OR 97801
503/276-3811

Reports: George (1983).

Tammany Creek Project, Idaho

Site Description. Tammany Creek flows into the Snake River at the southern edge of Lewiston, Idaho.

Land Uses. Much of the area is under dryland crop farming. Urban development encroaches on the lower reaches of the watershed. Livestock operations are found in the watershed.

Beneficial Use. Tammany Creek is protected for secondary contact recreation (e.g., wading and floating), and coldwater fisheries, including salmon spawning. The creek enters the Snake River at Hells Gate State Park, a high use recreation area that includes swimming beaches and a marina.

Best Management Practices. Tammany Creek is currently under a PL-566 Small Watershed Program. Currently, six farmers have been contacted and three have applied BMPs to their land. The stream has been proposed by the Nez Perce SCD as a candidate for the Idaho State Agriculture Water Quality Program. If selected, further BMPs would be identified and implemented with state cost-sharing.

Monitoring. Baseline water quality conditions were sampled by IDHW DEQ six times between November 1983 and April 1984. Eleven parameters were measured at the mouth of the creek, and turbidity measurements were recorded for 19 stations upstream. Water quality data were also collected on seven occasions between May 1976 and February 1977. Parameters included temperature, dissolved oxygen, pH, bacteria (fecal coliform and fecal streptococcus), nutrients (total phosphorus, ammonia, nitrate-N, and nitrite-N), turbidity, suspended solids, and flow.

Discussion. BMPs have been implemented under the PL-566 program and further implementation is planned. Baseline data have been gathered and monitoring is continuing to measure the effectiveness of BMPs in reducing NPS pollution. The implementation of BMPs is monitored by SCS under the PL-566 program. Various agencies worked in cooperation, including the Nez Perce Soil Conservation District, USDA SCS, and IDHW-DEQ.

Additional Information.

Contact: Byron Chase
USDA SCS Nez Perce County
3510 - 12th Street
Lewiston, ID 83501
208/746-9886

Reports: Unpublished file reports are retained by USDA, SCS and IDHW-DEQ.

Pine Creek Project, Idaho

Site Description. The Pine Creek Project is a representative example of the Idaho Agricultural Water Quality Program. The watershed is in the northeast corner of Nez Perce County, Idaho, and is a third-order tributary to the Clearwater River. There are 13 first- and second-order streams, 1.6-4.8 km (1-3 mi) long, that drain the 6,820 ha (16,850 ac) in the watershed. The last 8 km (5 mi) are in a canyon where elevation drops 30 m (1,000 ft) to Clearwater River at 21 m (875 ft).

The rolling plateau, at an elevation of 640-850 m (2,200-2,800 ft) has slopes of 4-30 percent of highly erodable silt-loam soils. The canyon has slopes of 30-60 percent.

Land Use. There are 30 operators farming the 5,260 ha (13,000 ac) of dryland crops of peas and winter wheat. Most of the remaining 1,560 ha (3,850 ac) are rangeland and timber.

Beneficial Use. The stream is used as an agricultural water supply and for secondary contact recreation. Salmonid spawning habitat is present, but is limited by water quality.

Best Management Practices. Various farms have started to implement BMP programs. Some BMPs, such as sediment basins, grassed waterways, and tile drains, are in use.

Monitoring. The objectives of the planning study were to: 1) determine water quality in various reaches and sub-watersheds; 2) determine baseline water quality; and 3) document the effects of storm event runoff on water quality in Pine Creek.

Three monitoring stations were chosen on Pine Creek to divide the watershed. This method allowed the separate watersheds to be evaluated for their contributions to the sediment and nutrient loads. One station was 1.6 km (1 mi) above the community of Leland, another station characterized the east fork of Pine Creek, and the third station was at the mouth, portraying the whole watershed.

Methods of sample collection, preservation and analysis followed Standard Methods (APHA 1985) or EPA guidelines (EPA 1979). Samples were taken every 2 weeks for 1 year beginning February 1985 through February 1986, with a concentration of effort in spring 1985 and during storm events. Flow, water temperature, conductivity, and pH were measured in the field. Turbidity, suspended sediment, total Kjeldahl nitrogen, total ammonia, total nitrite plus nitrate, total phosphorus, total hydrolyzable phosphorus, orthophosphate, and fecal coliform were analyzed in the laboratory.

This project served as part of a series of quality assurance checks by IDHW-DEQ on precision and accuracy of sampling procedures. Duplicate and spiked samples were collected from various stations and on different dates. The data were pooled for several projects and results were compiled.

Discussion. Substantial quantities of suspended sediment, total phosphorus, and nitrogen were lost from the watershed. A BMP implementation plan submitted by the Nez Perce SWCD emphasized: soil erosion reduction from critical acreages; riparian enhancement in the upper watershed, including bank stabilization on the lower end of the east fork of Pine Creek; reduction of nutrient losses from cultivated fields, specifically inorganic nitrogen in the early spring; and control of animal wastes from feedlots, barnyards, and pastures.

The quality assurance checks for IDHW-DEQ gave variable results. Precision estimates for suspended sediment, total phosphorus, total nitrite plus nitrate, total Kjeldahl nitrogen, and turbidity were good to excellent. Orthophosphate, total hydrolyzable phosphate, and total ammonia exhibited poorer precision.

Additional Information.

Contact: Byron Chase
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3510 - 12th Street
Lewiston, ID 83501
208/746-9886

Reports: Latham (1986).

Little Canyon and Big Canyon Creeks Project, Idaho

Site Description. Little Canyon and Big Canyon Creeks drain into the Clearwater River in Lewis County, Idaho.

Land Use. Approximately 90 percent of the combined watersheds are in dryland farming.

Beneficial Use. The Clearwater River provides significant anadromous fish spawning habitat. It also supports a significant recreational and subsistence fishery.

Best Management Practices. No BMPs have been formally initiated on the watersheds.

Monitoring. The Lewis County Soil Conservation District has been collecting water quality data in Big Canyon Creek, Little Canyon Creek, and tributaries to Little Canyon Creek during low flows. Data collected over the past 18 months include flow, temperature, pH, Kjeldahl nitrogen, nitrate and nitrite, ammonia, orthophosphate, fecal coliform, fecal streptococcus, and riparian cover.

Discussion. Monitoring effectiveness of BMPs has not taken place. The existing data can be used as baseline for further monitoring projects.

Additional Information.

Contact: Biff Burley
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019 West Main Street
Craigmont, ID 83523
208/924-5561

Reports: Published reports are not available.

Northern Basin and Range

Rock Creek Project, Idaho

Site Description. Rock Creek in Power County drains into the Snake River below American Falls, Idaho. The majority of the watershed lies in the Northern Basin and Range ecoregion. Lower reaches of the watershed lie in the Snake River Basin/High Desert ecoregion. The valley floor slopes gently from south to north, with rolling foothills on the valley flanks giving way to steep mountain slopes. The surface soils in cropland areas are predominately deep silt loams formed from loess. In grazing areas, the surface soils are stony, gravelly, and cobbly loams.

The climate is characterized by cold, moist winters and hot, dry summers. Wind erosion is particularly severe because of strong winds from the southwest during the spring when the cultivated ground is bare. Most of the upper tributaries to Rock Creek are ephemeral, flowing only during heavy summer storm events or during snowmelt (February and March). Mean annual precipitation is 33 cm (13 in).

Land Use. The majority of the 830 sq km (320 sq mi) basin is used for dryland agriculture and livestock grazing. A small amount of irrigation occurs in the watershed. Hard red winter wheat and barley are the principal dryland crops, while row crops, pasture, and hay are irrigated. Rangeland is predominately in small holdings. In the Sublett subbasin, 1,972 ha (2,400 ac) are in irrigated cropland, and 5,300 ha (13,100 ac) are in rangeland.

Beneficial Use. The primary use of water is downstream in the Snake River. Some recreational use occurs, as well as use by fish and wildlife species. In-basin use for irrigation also occurs.

Best Management Practices. A cooperative agreement in 1981 between the Power County Soil Conservation District, USDA SCS, and USFS has resulted in implementation of BMPs in 9,350 ha (23,100 of 36,200 ac) in the Sublett subbasin in southern Power County. Terracing and conservation tillage practices are the primary BMPs, with approximately 160 ha (400 ac) placed in permanent vegetation.

Monitoring. Baseline data were collected from October 1977 through June 1979. Data collected included flow, pH, temperature, dissolved oxygen, suspended solids, turbidity, volatile suspended solids, nutrients (ammonia nitrogen, Kjeldahl nitrogen, nitrate and nitrite nitrogen, total phosphorus, orthophosphate), conductivity, selected ions (Ca, Mg, Fe, Na, K, Cl, SO_4, F), total and fecal coliforms, and selected metals (As, Ba, Cd, Cr, Cu, Hg, Pb, Mn, Se, Ag, Zn). Benthic macroinvertebrate communities were also characterized.

Discussion. The water sampling program was designed to provide background information on sediment inputs and problem areas, and there has been minimal post-BMP implementation monitoring. Data showed bacterial concentrations were variable, and were inversely correlated with river discharge. Aquatic invertebrate results were similarly variable, and there were no statistical trends in either species diversity or evenness. Ephemeral streams were found to contribute large pulses of water and sediment during relatively short periods of time.

Additional Information.

Contact: James Stalnaker
USDA SCS Power County
American Falls, ID 83211
208/226-2177

Reports: Power County Soil Conservation District (1981).

PART IV: GRAZING

Forest Rangeland: Eastern Cascades Slopes and Foothills

Freemont National Forest, Oregon

Site Description. The Freemont National Forest comprises almost half a million hectares (1.2 million ac) and is located in Lake and Klamath Counties of south central Oregon, beginning at the Oregon-California border. The topography is dominated by northwest trending fault-block mountains and valleys, and various volcanic landforms such as cinder cones and basalt flows. The elevation ranges between 1,219-2,438 m (4,000-8,000 ft) above sea level, and slope gradients are generally 40 percent or less.

The soils are young, developed from volcanic debris, and have a low to moderate fertility. The forest lies in the high desert country, the rain shadow of the Cascade Mountains. Average precipitation varies from 40-100 cm (16-40 in) a year, with intense (50 cm/week) summer storms. Annual temperature extremes range from $-30^{o}C$ to $33^{o}C$ ($-22^{o}F$ and $91^{o}F$).

The vegetation is diverse. There are 42 forested communities, with the dominant trees being juniper, Ponderosa pine, white fir, and lodgepole pine. The 15 non-forested communities include sage brush-bunchgrass prairies, wet meadows, and fire-adapted shrub flats.

Land Use. The 281,780 ha (696,000 ac) of forest rangeland is divided into 73 grazing allotments, and permits about 71,000 animal unit months of grazing yearly. Beef cattle are the predominant livestock. About 20 percent of the allotments show some degree of resource damage, primarily to riparian areas and below optimum growth of forage species. Logging is managed on a non-declining flow basis with harvest of only those lands capable of producing 1.4 cu m/ha/yr (20 cu ft/ac/yr).

Currently, forest management is undergoing revision. The area is to be managed to preserve the economic activities and to preserve or enhance recreation, wildlife habitat, range management, and fisheries habitat.

Beneficial Use. Major rivers of the forest are the Chewaucah, Sycan, and Sprague Rivers, which are important sources of water for agricultural lands and the municipalities in the surrounding valleys. Reservoirs, stockponds, and wetlands are located in the forest, and the lakes and streams provide areas for recreational fishing, boating, and camping.

Best Management Practices. BMPs already implemented in the rangeland include riparian fencing (both permanent for exclosure studies and temporary to allow regrowth) and regulation of the grazing season. BMPs for logged areas are designed for each harvested unit, with the aim that 80 percent of the activity area be left in a condition of acceptable productivity potential for trees. Tractors and skidders are avoided on wet soils and slopes. Skyline yarding is preferred on slopes exceeding these recommendations. Reseeding is conducted, with a minimum stocking of 100 trees per acre.

Monitoring. There are eight baseline water quality monitoring stations distributed throughout the forest, and a variable number of project stations located before/after and above/below the worked area. Dissolved oxygen, temperature, flow, and suspended sediments (grab samples) are measured. It is planned to establish 10 paired watersheds: six pairs on large streams and four on tributaries in the rangeland. One of each pair will be a grazing exclosure.

Riparian monitoring along high priority streams has been planned to include bank walks. Photographs and aerial photographs will be taken. It is hoped that a limited aquatic macroinvertebrate sampling program and population surveys will be expanded. Monitoring will be conducted in cooperation with the Oregon Department of Fish and Wildlife.

Discussion. To date, the monitoring program has characterized baseline water quality conditions; there has been insufficient monitoring to accurately identify the most significant cause of NPS pollution. The monitoring program will be expanded if further funds become available. It appears that road construction and logging have the greatest cumulative impact on water quality, but grazing has a concentrated impact on riparian vegetation and channel morphology.

Additional Information.

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Reports: There are several publications and reports. A synthesis is provided by USFS (1987a).

Forest Rangeland: Northern Rockies

East Fork Salmon River Project, Idaho

Site Description. The East Fork Salmon River is located in Custer County, Idaho, and empties into the Salmon River downstream of Clayton, Idaho. The upper half of the watershed is located in Challis National Forest and the Sawtooth National Recreation Area. The system displays a low to medium gradient and flows through wide valleys of lodgepole pine forest, meadow ranchland, or sagebrush/grass habitat. Surface soils are primarily highly erosive sandy and clay-loam soils.

Land Use. Most of the watershed is associated with ranching activities.

Beneficial Use. The East Fork Salmon River and its tributaries were important spawning streams for wild spring and summer chinook salmon and wild steelhead trout. The system is a treaty-guaranteed fishing area for members of the Shoshone-Bannock Tribes.

Best Management Practices. Land use BMPs have not been implemented or planned. Effort will be directed to enhancing fish habitat directly through instream activities and enhancement of riparian habitat.

Monitoring. Idaho Department of Fish and Game and the Shoshone-Bannock Tribes conducted a fish and aquatic habitat inventory in 1986 in preparation for a habitat enhancement effort funded through Bonneville Power Administration. Data collected include flow, temperature, stream morphology, riparian cover, stream substrate (cobble embeddedness), and fish populations (observations during snorkeling and electroshocking).

Streambed characteristics are being evaluated with three different methods: Leopold transects across the stream, Wentworth scale, and analyses of sediments collected with a McNeil corer.

Discussion. The study currently provides baseline data necessary to evaluate effectiveness of instream and riparian habitat enhancement activities. Affiliated agencies on the project are Bonneville Power Administration, USFS, and Bureau of Land Management.

Additional Information.

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Reports: Richards and Cernera (1987).

Forest Rangeland: Blue Mountains

Meadow Creek Project, Oregon

Site Description. Meadow Creek is located in the Starkey Experimental Forest and Range, about 56 km (35 mi) southwest of La Grande, Oregon. It flows east to eventually join the Grande Ronde River near La Grande, Oregon. The area was logged in the early 1900s, and was heavily grazed. Grazing was regulated by the USFS in 1940, and in 1975 the USFS Pacific Northwest Forest and Range Experimental Station initiated a multidisciplinary case study on Meadow Creek.

The study area included about 8 km (5 mi) of stream flowing through Ponderosa pine and Douglas-fir forests, and small meadows. The creek drains approximately 98 sq km (35 sq mi). Annual precipitation is 50 cm (19 in), falling primarily as winter snow and as fall and spring rain. The soils are predominately well-drained sandy loams.

Land Use. The land use is pasture grazing.

Beneficial Use. Meadow Creek is a steelhead and rainbow trout breeding ground.

Best Management Practices. Small contiguous pastures were fenced along Meadow Creek and stocked with 2-20 heifers, depending on pasture size and grazing system. For 5 years, the pastures were stocked to represent the following management options: 4-yr pasture, 1-yr rest-rotation; deferred rotation; season-long; and no grazing. Big game had access to all treatments in one area and were excluded from these same treatments in another area.

Monitoring. The monitoring objectives were several-fold: 1) to compare infiltration rates, sediment production and compaction under different grazing regimes; 2) to study bank movement generated by different grazing systems; and 3) to compare levels of fecal contamination associated with different systems of grazing cattle.

Water samples were collected above and below each pasture every 3-4 weeks and analyzed for fecal coliforms (membrane filtration). Samples were collected June-October in 1980 and 1981, and intensively during September 1982.

Infiltration rates were estimated on paired treatment-exclosure plots in each grazing system. The plots were sampled early in the grazing season each year during 1975, 1976, 1980, and 1981. Sixteen metal stakes were used as reference points on the edge of cutbanks on straight sections of the stream in each treatment. Bank erosion was measured after each winter period.

Discussion. It was found that monitoring only the rate of bank retreat was of limited value; other features such as bank shape or channel form may have more ecological meaning. Large numerical differences in fecal coliform estimates were observed, although due to background variability, there were no statistically significant differences between grazing treatments. It appears that large populations of indicator bacterial species, testing positive as fecal coliforms, are present in creek sediments, and that these may or may not track the pathogenic organisms of concern to human health.

Additional Information.

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Reports: Buckhouse et al. (1981).
Buckhouse and Bohn (1983).

Burnt River Project, Oregon

Site Description. The Burnt River flows generally southeast from Unity Reservoir to join the Snake River near Huntington, Oregon, near the Idaho-Oregon border. The river valley is initially wide (37 km [23 mi]), then narrows into a canyon before widening again. The canyon is the site of a BLM study. Since the valley runs east-west, temperatures in the canyon are extreme and the river often freezes in the winter. Hot summer temperatures are common, although regular river flows are maintained by the reservoir. The bedrock is basalt, and the elevation ranges from 850-1,765 m (2,800-5,800 ft).

Land Use. The wide valleys above and below the canyon are used for irrigated agriculture. The BLM land includes two grazing allotments.

Beneficial Use. The canyon supports recreational gold miners; four to six prospectors are operational at any one time. Fishing is currently limited since trout are uncommon.

Best Management Practices. One grazing allotment has had partial fencing along the stream for 15 years. Fencing is being planned for the unprotected 8 km (5 mi) of bank, and is to be located about 0.4 km (0.25 mi) from the stream. The SCS is actively encouraging BMPs on the agricultural land.

Monitoring. Sampling was conducted in 1982 and 1983. Grab samples of water were taken at two stations and analyzed at the regional BLM Soil and Water Laboratory, Boise, Idaho for suspended solids, turbidity, dissolved oxygen, pH, temperature, ortho- and total phosphorus, nitrate, nitrite, total bicarbonate, calcium bicarbonate, alkalinity, and sulfates. Three sediment samples were taken from each station in July for macroinvertebrate analysis. The samples were analyzed by the Forest Service Macroinvertebrate Laboratory, Provo, Utah.

Discussion. Fencing and controlled riparian grazing are very effective BMPs. The current riparian vegetation was compared to infrared photographs taken in 1983. Stream shade is 20-30 percent greater in the less intensely grazed allotments due to the well-developed tree and shrub vegetation. The fenced reaches of streams are too short to see an impact on water chemistry. To date, there have been no observable changes in macroinvertebrate or fish populations. Macroinvertebrates have been measured for only 3 years and there has been no significant change in diversity and abundance, and there are too few stream reaches with fish to observe an improvement in fish populations.

The Soil Conservation Service has received a grant for a year-long water quality monitoring program, starting in spring 1988.

Additional Information.

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Reports: There are no published reports available.

Open Rangeland: Columbia Basin

Douglas Creek Project, Washington

Site Description. The Douglas Creek grazing allotment lies approximately 6 km (4 mi) north of Palisades, Washington. The allotment ranges in elevation from 512-1,050 m (1,680-3,460 ft). Topography varies from gentle to steep. Average total annual precipitation is approximately 25 cm (10 in). The total area of the allotment is 1,300 ha (3,200 ac).

Land Use. The allotment has historically been grazed in the spring and early summer. In 1974, a Habitat Management Plan (HMP) was prepared for the area, implementing BMPs. The HMP was revised in 1982, but the following year the grazing lease for the allotment was cancelled. The allotment was rested for 2 years (1983 and 1984). In 1985, the allotment was leased with the stipulation that an allotment management plan would be implemented in the future. Interim management prior to implementation of the grazing plan is 2 years of spring grazing followed by 2 years of fall grazing.

Beneficial Use. The exclosure of 400 ha (1,000 ac) around Douglas Creek has resulted in a public recreational area for camping, hunting and fishing, and provides important habitat for mule deer, upland game birds, and many other wildlife species.

Best Management Practices. Douglas Creek was fenced to exclude cattle, and gap fences and watering devices were installed in 1974. In 1982, an additional 3.2 ha (8 ac) of riparian area was fenced and further fencing, planting, and alternative watering devices are planned for 1988.

Monitoring. The objectives of a 1979 riparian inventory were as follows: 1) to characterize current riparian vegetation composition and structure; and 2) to establish a series of fixed and located photo plots to monitor future riparian development.

Riparian vegetation inventory sheets formed the basis for the vegetative composition and structural portion of the inventory. Initial visual estimates of species and structural composition were used to establish stream sites, and an inventory sheet was completed for each site.

Discussion. The results showed that the riparian vegetation was recovering, although the stream channel was periodically damaged by winter storms. The observed beaver activity was encouraging, since beaver ponds trap stream sediments.

A monitoring program was re-established in 1987 to assess the impact of grazing and to achieve the following objectives: 1) maintain the ecological condition of all riparian areas in the allotment; 2) improve the ecological condition of the riparian areas in certain sections; 3) collect baseline data for riparian key areas and establish measurable objectives for the riparian key areas; 4) provide additional cover and feed for wildlife; and 5) increase livestock carrying capacity.

Baseline cover and ecological condition data are to be collected at riparian key areas, and photopoints will be established at riparian key areas.

Additional Information.

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Reports: Peterson (1987).
Hedges and Yamasaki (1979).

Open Rangeland: Blue Mountains

John Day River Project, Oregon

Site Description. The John Day River system includes the upper reaches of the John Day River (the Middle Fork, the main stem, and the South Fork) encompassing an area of 5,200 sq km (2,000 sq mi) reaching north to Kimberly, Oregon. Part of the 140,480 ha (347,000 ac) area was used in the Oregon Range Evaluation Project (EVAL) established in 1976.

Watersheds range in size from 1.2-18.1 sq km (0.5-7.0 sq mi) and in mean elevation from 1,450-1,992 m (4,750-6,534 ft). Predominant vegetation is mountain meadow, western larch, fir-spruce, Ponderosa pine, and lodgepole pine. Geologic formations of the watersheds are dominated by volcanic material (primarily basalt), meta volcanics, and igneous intrusives.

Climatic data indicate that 70 percent of the 49 cm (20 in) annual precipitation is received as snow between the months of November and April. Average annual temperature is 2^{o}C (36^{o}F) with maximum of 32^{o}C (90^{o}F) in the summer, and minimum -18^{o}C (-5^{o}F) in winter.

Land Use. The land is grazed by both sheep and cattle, predominantly cattle.

Beneficial Use. The beneficial uses of the waterways include irrigation and drinking water. Resident and anadromous fish populations occur in the streams.

Best Management Practices. The effect of grazing systems and intensities was studied from 1967-1984 as part of the EVAL studies. The grazing rotations were deferred rotation, continuous grazing, and no grazing. The BMPs implemented since 1984 by the SCS have embraced the entire project area. Practices include the development of off-stream water supply, prescribed burning, rotational grazing at high density, riparian fencing, and reseeding. Farmers are being contracted at a rate of 6-10 per year to apply BMPs .

Monitoring. The EVAL study looked at the impact of range management strategies upon water quality. Grab samples of stream water were collected at 3- to 6-week intervals from 1978-1984. Parameters measured include nitrate (cadmium reduction), orthophosphate (ascorbic acid), calcium, magnesium, potassium and sodium (atomic absorption spectroscopy), pH, fecal coliforms (membrane filtration), and water flow.

The 7-year monitoring program, initiated in 1984, concentrates on stream morphology for fish habitats, riparian vegetation (fixed photo-points and transects), canopy closure (radiometer), temperature, stream channel morphology (intensive transects at 1-ft intervals), and along-stream inventories (looking at the number of redds per mile, vegetation condition, stream overhang and bank condition) are included in the monitoring program.

Discussion. The EVAL study found elevated levels of nitrogen when alder was among the riparian vegetation, and that pastures grazed only in the summer had high fecal coliform levels in the winter flows. One result of the current BMP program is the establishment of riparian vegetation. Salmonid redds have also increased two- to threefold, but this cannot be attributed to BMPs at this point.

Additional Information.

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Reports: Tiedeman et al. (1987a, 1987b).

Crooked River Project, Oregon

Site Description. Crook County is located in central Oregon, in the Blue Mountains. The relief is varied, and rainfall averages 20 cm (20 in) a year. Much of the rangeland has been invaded by juniper trees, which reduce forage quality. About 670 km (400 mi) of stream are under study, including the following watersheds: Camp, Bear, Sanford, Deer, Birch, Wolf, Committee, Bronco, Beaver, Roba, Indian, Eagle Rock, and Twelve Mile Creeks; and Crooked, John Day, and Deschutes Rivers. Most of the creeks flow into Crooked River, which drains to the Deschutes and eventually the Columbia River.

Land Use. Rangeland grazing by cattle is the dominant land use.

Beneficial Use. The beneficial uses include resident and anadromous fish populations, recreation and fishing, and irrigation.

Best Management Practices. Experiments conducted in the 1960s showed that herd management had little impact on forage, but that the removal of juniper trees greatly improved forage quality. The BMPs implemented in the region focus on increasing grass production and reducing the water sediment load. BMPs include: riparian fencing; placing salt, water, rubbing posts and supplemental feeds away from the stream; prescribed burning; and various grazing rotations. A unique 10-year management plan is devised for each creek, based on consideration of creek bed geology, average flow, velocity, sediment loading, and watershed topography.

Monitoring. Monitoring techniques that have been most successful include a photographic inventory of stream bank vegetation, benthic macroinvertebrate analysis, and infrared photographs of the stream and vegetation. Other monitoring parameters include fish habitat, the riparian community, channel stability, water quality (flow, pH, temperature, conductivity, dissolved oxygen, and phosphorus), and groundwater levels (160 piezometers).

Discussion. There has been a noticeable improvement in riparian vegetation, pasture growth, and stocking density. Bear Creek, for example, no longer dries out and now supports trout.

Additional Information.

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Reports: No published reports are available.

Open Rangeland: Middle Rockies

Upper Teton River Valley Project, Idaho

Site Description. The Upper Teton River Valley is a high mountain valley surrounded on three sides by mountain ranges in Teton County, eastern Idaho. South of State Highway 33, near Tetonia, Idaho, the river begins to drop in a series of canyons to the north and then west.

The climate in the Upper Teton River Valley is characterized by cold winters and cool summers. Precipitation in the Driggs, Idaho area averages approximately 40 cm/yr (16 in/yr) mostly falling as snow. On the east side of the Upper Teton River, the soils consist of a thin layer of silt loam with gravelly subsurface material. A deeper layer of windblown silt loam (loess) is found on the west side of the valley. Extensive wetland meadows occur in the Upper Teton River Valley. Higher elevations are timbered, although logging occurs to a limited extent only in the Big Hole Mountains to the west.

Land Use. The Upper Teton River Valley encompasses approximately 115,380 ha (285,000 ac), of which 66,400 ha (164,000 ac) are in public lands. Approximately 20,000 ha (50,000 ac) of privately owned land are used for hay, pasture, or rangeland. Half of this occurs on wetland meadows. Another 23,000 ha (57,000 ac) of private land are irrigated cropland. Irrigated cropland is predominately in seed potato production, with some barley and hay. Irrigation is generally accomplished through gravity-fed sprinkler systems. Barley and wheat are grown on approximately 5,260 ha (13,000 ac) in dryland. The public land is used for grazing.

Beneficial Use. Recreational use of the Teton River is common. Fishery habitat was severely affected in the lower Teton River and the South Fork Snake River when the U.S. Bureau of Reclamation's Teton Dam failed in 1976. The Teton River at one time was considered a high quality trout stream. The presence of the Teton Range and Grand Teton National Park on the east side of the valley offers potential for recreational development in the upper watershed of the Teton River.

Best Management Practices. Erosion is most severe in the spring. Typically, snowmelt occurs rapidly with high surface flows over frozen soils. Grazing land, dryland crop areas, and seed potato fields are particularly susceptible to erosion. Current survey work conducted by Idaho Department of Fish and Game (IDFG) indicates impacts on fisheries habitat are most severe from grazing practices (Gamblin, pers. comm.). Preliminary data collected by USDA SCS also indicate that suspended sediment loading is higher in tributaries draining publicly owned grazing land (Smart, pers. comm.).

Wetland meadow areas are all privately owned and are generally used all summer as pasture or as natural hayfields. Grazing also occurs on public lands. BMPs have not yet been implemented on grazing land. Based on inventory data collected by IDFG, proposed BMPs are expected to include fencing stream banks to restrict access by livestock and revegetation of stream banks with woody riparian vegetation. In-channel enhancement is also planned by IDFG. Activities are currently in the planning phase, with a stream enhancement plan expected in early 1988.

On irrigated land, BMPs include crop residue management, irrigation water management, and rotation of crops with extensive periods in hay production. On non-irrigated land, fallow rotation is the most common BMP.

Monitoring. Baseline inventory data have been collected by IDFG on grazing use and intensity, bank erosion, stream channel profile, percent riparian cover, and fish population estimates. USDA SCS has collected preliminary data on suspended sediment. The objective of the aquatic habitat baseline inventory is to provide information necessary to develop recommendations for remedial actions. There are no plans for long-term monitoring.

Discussion. This project could be classified under dryland agriculture or irrigated farmland as well as grazing management on forested rangeland and high elevation meadowlands. It is classified in the grazing section of this chapter because personal communications with USDA SCS and IDFG personnel working on the project suggest that grazing practices have greater adverse effects on aquatic habitat.

The Upper Teton River Valley has high potential for post-implementation monitoring of effectiveness of BMPs for grazing management. IDFG has collected detailed baseline data on aquatic habitat and fisheries. There are also excellent opportunities for comparing the relative effects of imposing BMPs on grazing activities, dryland agriculture, and irrigated agriculture.

Additional Information.

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Reports: No published information is available.

Open Rangeland: Snake River Basin/High Desert

BLM Pilot Riparian Program, Idaho

Project Description. The Bureau of Land Management has initiated a program to improve riparian habitat in grazing allotments throughout the western United States. Each BLM district office in Idaho has developed a plan to conduct a pilot riparian project. A list of project sites is included as Appendix C. Most of these are centered on perennial streams.

The Warm Springs Creek project in the BLM Salmon District is atypical because it focuses on wetland meadows with very small perennial flows.

Best Management Practices. A variety of BMPs have been or are expected to be implemented as part of the pilot riparian projects. These include practices such as fencing, deferred or rotational grazing, and alteration of distribution of livestock (e.g., placing salt licks away from streams, providing water tanks, or creating upland shade).

Monitoring. The program calls for monitoring over a 5-year period. In addition to monitoring change in riparian habitat, the proposed protocols for projects in Idaho include analyses of flows, suspended sediments, turbidity, pH, dissolved oxygen, temperature, conductivity, stream channel morphology, bank erosivity, and aquatic macroinvertebrates. Riparian vegetation and bank erosivity are generally being monitored with photographic records. On the Big Elk Creek project in the

Cottonwood Resource area, fish density (electroshocking or snorkeling observations) and habitat quality are also being investigated. Habitat quality is being measured with techniques developed by Binns and Eisermann (1979).

Discussion. The program is relatively new. Although riparian vegetation composition is subject to site-specific edaphic conditions, personal communications with BLM District personnel indicated satisfaction with the program, especially the analysis of aquatic macroinvertebrate communities. Aquatic invertebrates were monitored at selected sites before BMPs were implemented, and community analyses indicated the water quality was fair to good.

Additional Information. A list of project sites is included in Appendix C.

Reynolds Creek Project, Idaho

Site Description. The 233 sq km (90 sq mi) Reynolds Creek watershed is located in Owyhee County about 80 km (50 mi) to the southwest of Boise, Idaho. Reynolds Creek drains north into the Snake River in a rural area south of Nampa, Idaho. Elevation of the watershed ranges from 1,097 m (3,600 ft) at the outlet to 2,252 m (7,390 ft) at the summit. The climate in the area is semiarid. Annual precipitation at lower elevations averages 25 cm (10 in), occurring mostly as rain, and increases to over 102 cm (40 in) at the watershed summit. Annual sediment yield averages 0.68 tonnes/ha (0.25 ton/ac) of which 7 percent originates from snowmelt or rain-on-snow events.

Soils range from shallow desertic at the lower elevations to deep organic soils in the forested areas. An impressive diversity of plant communities typical of the Great Basin Desert are found at the lower and middle elevations, while mountain brush and forest vegetation is typical at the higher elevations.

Land Use. Seventy-seven percent of the watershed is under federal and state government ownership with the remaining 23 percent in private ownership. The primary land use is livestock grazing with about 800 ha (2,000 ac) or 3 percent of the watershed irrigated from Reynolds Creek for hay production.

Beneficial Use. Water from Reynolds Creek is diverted by structures for flood irrigation of hay fields and pasture land.

Best Management Practices. Grazing management treatments include fencing, water development, deferred rotation grazing, and herding.

Monitoring. The watershed research mission is to quantitatively describe the hydrologic processes and interactive influences of climate, soils, vegetation, topography, and management on rangeland watersheds, and to develop information inventories, simulation models, and expert systems that can be used by action agencies and producers to assist in determining optimum management strategies. Hydrologic data have been collected in the Reynolds Creek Experimental Watershed by USDA-Agricultural Research Service (ARS) since 1961. Available data include precipitation, streamflow, and suspended and bedload sediments.

Nutrient levels and bacterial contamination of surface runoff have also been studied at different times by research scientists at ARS and affiliated institutions; however, no current water quality studies are being conducted. The frequency of samples collected and the list of parameters investigated varied by study. Collected data typically included streamflow, temperature, turbidity, suspended sediments, dissolved oxygen, conductivity, pH, total and fecal coliform, fecal streptococci, ammonia nitrogen, nitrate nitrogen, Kjeldahl nitrogen, orthophosphate, total phosphorus, and selected ions (Na, K, Ca, Mg, Cl, carbonate, sulfate). Bacterial counts normally were obtained with the membrane filter technique. A groundwater study that focuses on the water budget of a 16 ha (40 ac) basin has been collecting data from 1983, with a groundwater quality study in the planning stages.

Affiliated agencies in the project are the University of Idaho, Utah State University, Boise State University, USDA SCS, and BLM.

Additional Information.

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Reports: Many reports have been prepared as a result of research on the watershed. The majority of these reports have been prepared by or with the participation of researchers at USDA ARS.

Chapter 3

REVIEW OF SILVICULTURE-RELATED MONITORING

Introduction

Silvicultural projects are organized in the same manner as the agriculture-related projects (Chapter 2), under the following headings.

Site Description. The site description gives a brief outline of the geography and climate. Enough information is presented to enable readers to determine whether their site conditions are comparable.

Beneficial Use. This section focuses on those beneficial uses that the BMPs are or should be addressing. A complete list of the beneficial uses of a water body is not intended.

Best Management Practices. Forestry BMPs generally follow state guidelines; percent of cut, harvest rotation, and road construction are briefly discussed to enable readers to cross-reference their projects with others in the region. No attempt is made to discuss the merits of individual BMPs, and there is no attempt to relate individual BMPs to specific reduction in NPS pollution.

Monitoring. The objectives of an NPS pollution control and monitoring program are essential for judging the success of the program. The objectives of the NPS program are given in the first paragraph of this section whenever possible. Details of the design of the monitoring program (parameters measured, sampling regime, time frame) are given. The data collected by the monitoring program are of little interest, since the main concern of this report is the design of monitoring programs. The data collected are therefore not reported here.

Discussion. The discussion section highlights the conclusions of the monitoring program, whether the objectives were met, if any of the measured parameters were particularly useful, and if there were any major problems of the program.

Additional Information. The names and addresses of project leaders, and references to published reports are given to enable readers to gather additional information on the project. A full bibliography of reports is not intended, rather, key references that can be used as an introduction to the project and its outcome are noted.

Southeast Alaska

Indian River Project, Alaska

Site Description. The Indian River watershed is located on the north side of Tenakee Inlet, on northeast Chichagof Island, Alaska. The study area is a 2,849 ha (7,040 ac) sub-watershed of a 5,439 ha (13,440 ac) watershed that drains into saltwater. Elevations range from 91 m (300 ft) near the stream gage to 910 m (3,000 ft) at the ridge crest.

Climate is typical of coastal Alaska: cool and wet. Major peak flows generally occur in the fall rainy season with secondary peaks occurring during April and May snow melt. Winter snowpack is generally intermittent below 305 m (1,000 ft) in elevation. Approximately 40 percent of the annual 269 cm (106 in) of valley precipitation occurs in September and October.

A wide range of soil types exists in the Indian River watershed. Poorly drained organic soils are found in the alpine and valley bottom muskegs. Well-drained alluvial soils are widely distributed along the valley bottom. Sub-alpine brush slopes have deep, well-drained, gravelly loam soils.

Vegetation in alpine areas are heaths, grasses, and forbs. Muskeg species are predominantly western hemlock and Sitka spruce. Alaska cedar and lodgepole pine are common on poorly drained sites, and mountain hemlock is predominant in higher elevation timber stands.

Beneficial Use. Anadromous fish distribution in the Indian River is restricted to the lower 1.5 km (1 mi), several kilometers below the monitoring site. The major species include pink and chum salmon, with smaller numbers of coho and sockeye salmon. Resident fish species in the upper watershed (study area) are Dolly Varden char and cutthroat trout.

Best Management Practices. Logging and road development began in the upper Indian River watershed during the summer of 1979 and was completed by the fall of 1980. A total of 101 ha (250 ac), or about 8 percent of the watershed was harvested by high lead cable yarding during the study period.

BMPs were prescribed in the study area in order to reduce potential nonpoint source sediment inputs from logging and road construction activities. Log suspension was required for yarding over most ephemeral channels. Timber harvesting was not allowed on sensitive flood plain soils and highly braided channel areas. Trees were left along stream banks as needed to provide stream bank stabilization and to provide fish habitat diversity. Trees are generally not yarded across perennial streams. Road designs utilized a rolling road grade, thus minimizing the amount of road cut and fill, and reducing the potential for concentrating surface water runoff on road surfaces and ditches. Slash from road clearing right-of-way was generally piled in windrows downslope of the road fill to act as a sediment filter. Road drainage culverts were bedded at natural channel grade with rocks placed at the culvert outlets as energy dissipaters. Grass seed and fertilizer were applied to road cutslopes and ditches immediately after construction was complete. A good ground cover was established in most disturbed areas within one year.

Monitoring. The objective was to study sediment production regime of a large fourth-order stream and its response to logging and road building. The base measurement period for this study was water year 1978-1979. Monitoring continued through the period of logging and for 2 additional years. Monitoring, which occurred some distance from the logging and road construction, focused on flow, suspended sediment, turbidity, and bedload transport.

Discussion. The highest monthly suspended sediment discharge in the 6-year monitoring period for Indian River occurred in conjunction with unusually high runoff prior to significant logging disturbance. No apparent changes in the relative magnitude of distribution of monthly discharge were otherwise indicated by the data. Values for post-logging annual suspended sediment yields were within the range of suspended sediment yields measured during the pre-logging baseline period. Results revealed no detectable changes in suspended sediment delivery during the first 2 years of logging activities in the watershed.

The lack of detectable sediment yield changes could be attributed to a number of factors: high natural variability in sediment yields during baseline monitoring, successful implementation of BMPs, relatively light treatment in the watershed (only 8 percent of the watershed harvested), and monitoring well below the watershed treatment. In addition, researchers concluded that traditional sediment measurement procedures for determining BMP effectiveness in relation to sediment impacts in a large watershed may not be the most appropriate approach. Researchers recommended that the effectiveness of BMPs was best evaluated at the sub-watershed level, near the watershed treatment.

Additional Information.

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Reports: Paustian (1987)

Kadashan River Project, Alaska

Site Description. The Kadashan River is located on the south side of Tenakee Inlet on Chichagof Island in Alaska. The study area consists of three first- and second-order streams which drain into the Kadashan River near its mouth. These small streams originate from snowmelt and springs, and range in size from 12 ha (30 ac) to 32 ha (80 ac). The majority of precipitation occurs in the fall, with May, June, and July normally being the driest months. Streams rise and fall rapidly in response to precipitation and snowmelt, with highest flows observed in the fall and in response to rain-on-snow events in the winter and spring.

Soils in the upper part of the study area are comprised of thin glacially derived materials and organics. Valley bottom soils consist of unconsolidated alluvium, colluvium, and glacial sediments. Vegetation is dominated by old-growth stands of hemlock and spruce. In the alpine areas, grasses, forbs, and heaths are common.

Beneficial Use. Coho salmon and Dolly Varden char can be found in streams in the area.

Best Management Practices. Road building began in the Kadashan watersheds in the summer of 1984 and was completed within 1 week. Roads traverse side slopes of between 20 and 30 percent, and are comprised of both cut and fill sections. Road clearing slash was generally placed on fill slopes to act as a sediment filter and cross culverts were placed at the natural elevation of the streambed. Exposed slopes were seeded and fertilized immediately, and a good vegetative cover was established within 1 year. No timber harvest has taken place and the roads have not been utilized by heavy trucks.

Monitoring. The objective was to study sediment production in response to road building and logging. All three watersheds were equipped with sediment settling basins and continuous streamflow recording devices located 30-60 m (100-200 ft) downstream from road crossings. During high flow periods, automatic pumping samplers collected suspended sediments. Grab samples were also taken to determine the accuracy of the automated samplers. Total sediment load (suspended and bedload) was accounted for at each monitoring station. Analyses of settling basin deposits (partial size fractions) were also performed. Monitoring began 2 years before the start of road construction and is continuing.

Discussion. As expected, short-term increases in suspended sediment concentrations were noted immediately below road crossings during road construction. Sediment deposition rates remained above control levels for at least 2 years following road construction. It was estimated that it took a period of 1 to 2 years for the pulse of construction-related sediment to travel less than 100 m (300 ft). Researchers concluded that small, relatively steep streams have a considerable storage capacity to buffer downstream movement of fine sediments between 0.5 and 4 mm (0.02-0.16 in). Sediments smaller than this are flushed quickly downstream. Total sediment yields increased between 20 and 66 percent following road construction, but the relatively short monitoring period and natural variation in sediment production prevented the researchers from estimating what portion of this increase was due to road construction. It was concluded that monitoring near the pollutant source provides the most effective quantitative assessment of BMPs on small watersheds.

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Reports: Paustian (1987).

Auke Bay Laboratory Project, Alaska

Site Description. The Auke Bay Laboratory, operated by the National Marine Fisheries Service, has conducted extensive research on 18 streams in six locations in southeast Alaska. The study streams were small, with a low flow discharge of between 0.01-0.38 cu m (0.3-13.4 cfs) and channel gradients between 0.1-3.0 percent. Peak stream flows occur in late fall in response to heavy rains. Ice cover was absent or minimal from the streams.

In general, streams are similar to many in southeast Alaska. Steep valley walls are vegetated with a dense forest dominated by western hemlock and Sitka spruce.

Beneficial Use. Streams in the area are populated with coho salmon, steelhead and cutthroat trout, and Dolly Varden char. Chum and pink salmon are also present, but were not the focus of the studies.

Best Management Practices. The study was based on extensive comparisons of three silvicultural treatments: old-growth with no disturbance, clearcuts with buffer strips, and clearcuts with no buffer strips. Buffer strips ranged from 10-130 m (30-390 ft) in width, and harvest occurred between 1 and 12 years prior to sampling.

Monitoring. The overall objective of the various studies taking place since the mid-1970s has been to assess the impact of different harvesting practices on salmonid populations and their habitat. A wide range of variables have been monitored, including fish densities, distribution and age structure, benthic invertebrate densities, algae, water temperature, organic debris, fish habitat type, channel stability, and stream sedimentation.

Discussion. The studies concluded that buffer strip width affected fish habitat quality, particularly pool area. These pools were found to be critical winter habitat for steelhead, and units with no buffer strips had significantly less pool habitat than buffered or old-growth units. Pool quality was also higher on buffered reaches due to an abundance of cover. Reaches with no buffer strips tended to have higher summer water temperatures, more algae and more benthos, and tended to produce larger fry. Researchers questioned whether this advantage would be lost as the fish grew and required the high quality pool areas which the buffered reaches possessed in greater numbers.

Additional Information.

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Reports: Numerous articles have been published by the Auke Bay Laboratory. Examples are Heifetz et al. (1986), and Murphy et al. (1986).

Washington State Timber, Fish, and Wildlife Agreement

Introduction. The Timber, Fish, and Wildlife (TFW) Agreement provides the framework, procedures, and requirements for managing state and private forests to meet the needs of the timber industry and to provide protection for fish, wildlife, and water resources, and the cultural/archeological resources of Indian tribes within Washington state.

Participants in the agreement included representatives of a number of Indian tribes, the Northwest Indian Fisheries Commission, the Columbia River Inter-Tribal Fish Commission, Washington Environmental Council, Audubon Society, Washington Forest Protection Association, Washington Farm Forestry

Association, the Northwest Renewable Resources Center of Seattle; Weyerhaeuser, Georgia Pacific, Plum Creek, and Simpson Timber Companies; and the State Departments of Natural Resources, Ecology, and Fish and Game.

The goals sought by all parties are to ensure that the activities of the timber industry are compatible with the conservation of fish, wildlife, water, and cultural and archeological resources. The wildlife resource goal is to provide the greatest diversity of habitats (particularly riparian, wetlands, and old-growth forest), and to assure the greatest diversity of species to maintain the native wildlife of Washington forest lands. The fishery resource goals are long-term habitat productivity for wild fish, and the protection of hatchery water supplies. The water resource goals are for protection of water needs of people, fish, and wildlife. The archeological and cultural goals are to develop a process to inventory, evaluate, preserve and protect traditional cultural and archeological areas in managed forests and assure tribal access. The timber resource goal is the continued growth and development of the state's forest products industry.

Current forest practices rules and regulations provide a management framework for forest practices on state and private lands in the state of Washington. The TFW participants have identified several areas wherein this current system is not meeting the needs of one or more of the parties involved. A critical element of the proposed management system is the inter-disciplinary team (ID Team) concept. The ID Team, assembled by the Department of Natural Resources, will have technical expertise in soils, geomorphology, geology, hydrology, fisheries and wildlife biology, and forest engineering.

Monitoring. The objective of TFW is to provide a basis for understanding resource management interactions and the impacts of forest practices on public resources. The results of these efforts will be used to improve future forest practices, to identify where rules and regulations need to be modified, and to identify cooperative (non-regulatory) efforts that can be implemented. A unique aspect of the proposed management system is the opportunity for the participants to meet both before and after timber harvests have occurred. Discussion of harvest plans will provide all parties an opportunity to voice their concerns and needs well in advance of the actual timber operations.

Among the topics covered in the agreement are forest roads, riparian management zones, unstable slopes, and silvicultural activities. Additional topics include upland management areas, archeological/cultural, old growth, cumulative effects, corrective action, and incentives/compensation.

Discussion. The general principle for future silvicultural practices is to modify the site only to the degree necessary to achieve the desired biological results in the most cost effective manner, while protecting the public resources. Management is guided by the following goal statements:

1. Site-specific watershed prescriptions for timber management should aim at reducing ecosystem disturbances.

2. All decisions, whether silvicultural or non-timber in nature, should be made from an ecosystem perspective that recognizes the interaction of biology, physical sciences and economics.

3. Adaptive management should be introduced and used.

Implementation of the agreement began January 1, 1988. Technical committees have been formed for each of the topics covered in the agreement, and monitoring programs are being decided upon. To date, no monitoring program has been implemented.

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Reports: On file at Northwest Renewable Resources Center

Coast Range

Carnation Creek Project, British Columbia

Site Description. The Carnation Creek basin is a 1,000 ha (2,471 ac) drainage located in a western hemlock-western red cedar forest on the south side of Barkely Sound on Vancouver Island, British Columbia. Elevations in this research watershed are below 800 m (2,640 ft), with the creek flowing directly into saltwater. The watershed contains steep slopes which border a wide valley bottom through which the stream meanders. Soils consist of an organic layer underlain by loamy sands, gravel, and bedrock.

The climate is mild and wet, with an average annual precipitation ranging from 120-480 cm (83-198 in). Approximately 5 percent of this occurs as snow. Streamflows in Carnation Creek range from a low of about 0.02 cu m (0.7 cfs) in August to a winter maximum of about 48 cu m (1,694 cfs).

Beneficial Use. The stream contains small but viable populations of chum and coho salmon, and steelhead and cutthroat trout. Some pink salmon have been known to use the estuary.

Best Management Practices. The Carnation Creek study was designed as a research project. Between 1976 and 1981, approximately 40 percent of the watershed was logged, primarily in the winter. A full range of buffer strip practices were utilized, ranging from logging to the stream channel to leaving considerable strips of native vegetation. Treatments can be summarized in three groups: 1) a strip of trees varying in width from 1 to 70 m (3-230 ft) was left along the stream margin; 2) all but five trees were felled away from the stream, debris was kept from the stream, and stream-side alder was removed; and 3) logging occurred simultaneously on both sides of the creek, some trees were felled across the creek and yarded from it, rotten windfalls in or across the creek were broken by felling and yarding, merchantable windfalls were yarded from the creek, streamside alder were individually sprayed with Tordon 22 K One year before logging occurred, and broadcast burning and replanting occurred on each cutblock.

Monitoring. The Carnation Creek study was designed to determine the impacts of typical logging practices on fisheries resources. Monitoring at Carnation Creek has been carried out in three phases: 1) 1971-1975, pre-logging baseline monitoring; 2) 1976-1981, monitoring of road construction and logging; and 3) 1981-present, post-logging monitoring. Parameters measured included flow, ions (calcium, magnesium, sodium, nitrate, chloride, sulphate, sodium bicarbonate), temperature, gravel quality, organic debris distribution, and channel morphology. In addition, a number of biologic indices were monitored, including macroinvertebrate; periphyton biomass and species composition; population trends, ages, growth, and habitat utilization of coho salmon; and sculpin population trends and interaction with salmonids. Conditions were monitored in the upper reaches of the creek as well as near the mouth.

Discussion. Data indicate that, in general, concentrations of dissolved ions increased after logging, but began to decline within 3 years after disturbance. Five years after logging, concentrations of some ions had not yet returned to prelogging levels. Moderate increases in maximum temperature and temperature fluctuation were recorded where the canopy was removed. The magnitude of changes was roughly proportional to the extent of streamside vegetation removal. Insignificant changes to debris characteristics and channel morphology were observed before and after logging when buffer strips were maintained. When minimal or no buffer strip was left intact, the number and mobility of instream debris pieces increased as did channel erosion. The amount of large, stable debris decreased in the case where no buffer strip was retained.

Biologic sampling revealed a variety of results. Riparian vegetation removal seemed to have minimal impact on algal biomass, although available light was increased. Differences in drift invertebrate biomass and species composition were not discernible between logged and unlogged regions. Studies imply that within unlogged sites, fluctuations due to natural conditions may be large enough to encompass differences observed between logged and unlogged sites. In channels where the overstory was removed, the short-term temperature increases were accompanied by enhanced coho smolt production. Longer-term changes, such as alteration of gravel quality and debris movement appear to have reduced coho smolt production about 5 years after logging.

<u>Additional Information</u>.

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Reports: Hartman (1982).

<u>Olympic National Forest, Washington</u>

<u>Site Description</u>. The Olympic National Forest is located on the Olympic Peninsula in the northwestern corner of Washington state. The narrow, low altitude coastal strip on the west side of the Olympics has an annual rainfall of 183 cm (72 in); on the east side, the annual precipitation drops to as low as 61 cm (24 in). This mild, maritime climate supports a dense coniferous forest dominated by Douglas-fir and western hemlock at low elevations, and western hemlock and Pacific silver fir on higher ridges. Red cedar and Sitka spruce are abundant in moist areas. Riparian vegetation consists of red alder and black cottonwood. The large streams in the region drain areas greater than 775 sq km (300 sq mi).

Soils are developed mainly from sandstone, siltstone, shale and basalt rock sources, and exhibit a wide range of characteristics.

Beneficial Use. The wood products industry is the mainstay of the forest. Anadromous fish populate many of the region's streams. The Wishkah, and the Big and Little Quilcene Rivers serve as municipal watersheds. Boating, fishing, and swimming are common throughout the forest's streams.

Best Management Practices. Acceptance of the BMP concept for timber harvest activities has placed emphasis on establishing a desired ground or vegetative condition after completion of timber harvest activities. Directional felling, selective tree removal, and clearcutting with buffer strips are examples of Olympic National Forest BMPs.

Monitoring. In the past year, the Olympic National Forest has started a process of visually monitoring two timber sale activities per Ranger District per year, after completion of the sale. The objectives are to: 1) determine if the concerns addressed in the Environmental Assessment Report (EAR) were carried through to the timber sale contract; 2) determine if the terms of the timber sale contract were met; 3) assess whether the BMPs which were prescribed in the timber sale contract accomplished what was intended (e.g., were enough trees left after a partial cut); and 4) assess feasibility of implementing BMPs (e.g., was directional felling with jacks possible on slopes over 65 percent).

Monitoring projects are prioritized. High priority watersheds include those sprayed with herbicide or fertilizer. Monitoring BMP implementation is second priority, and sensitive areas, such as municipal watersheds, are third priority.

Discussion. Water quality monitoring emphasized turbidity and water temperature data collection. Other parameters commonly monitored were streambed, streambank, and vegetative and soil conditions. Meaningful interpretation of data was usually difficult due to natural variation. Water temperature data was easier to interpret, and meaningful information has resulted (Burns 1986).

The Olympic Monitoring Plan, fiscal years 1981-1985, provided $29,000 in funding (in 1981) for 85 water monitoring stations and $10,500 for 179 soil monitoring stations (Carlson 1981).

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Reports: Burns (1986).
Carlson (1981).

Clearwater River Project, Washington

Site Description. The Clearwater River, a tributary to the Queets River, drains a 375 sq km (145 sq mi) basin on the western slope of the Olympic Mountains in western Washington. Slopes are steep and covered with Douglas-fir, western hemlock, western red cedar, Sitka spruce, and white fir. Soils are classified as silt clays and silt loams overlying silt and sandstones. The climate is typical low elevation maritime, with annual precipitation averaging about 250 cm (138 in). Rainfall is strongly seasonal, falling mostly between November and March and snow remains on the ground only briefly at the higher elevations. River discharge roughly parallels precipitation, with a maximum recorded high flow of about 1,076 cu m/sec (38,000 cfs) occurring in mid-winter, and low flows of about 1 cu m/sec (35 cfs) occurring in August or September. Average annual streamflow for water year 1974-1975 was about 28 cu m/sec (1,000 cfs).

Beneficial Use. The Clearwater River and its tributaries support a wide variety of fish species. Coho and chinook salmon as well as steelhead and cutthroat trout can be found in the basin. Minor runs of sockeye and chum salmon also exist.

Best Management Practices. The Clearwater basin is under intensive timber management by state, federal, and private land owners. About 60 percent of the basin has been logged at least once, primarily by high-lead techniques. Clearcuts average about 32 ha (79 ac) in size, with 10-100 m (33-330 ft) buffer strips left along larger streams on state lands. Streams on private lands, however, are generally cut over, and smaller streams often have no buffer strip retained. Roads are constructed on full benches to minimize sidecast.

Monitoring. The study was initiated to determine the impact of silvicultural activities on salmonid populations and habitat. Following two large landslides on a small creek in the upper portion of the basin, monitoring of gravel composition, channel morphology, benthic insect abundance, and fish population parameters began in 1972. Although monitoring began near the slides, it has been expanded to encompass the entire Clearwater River basin. The scope of parameters monitored has also been expanded to include riparian vegetation composition and shading, water quality, benthic community composition, and fish escapement.

Discussion. Studies on the Clearwater suggest that the most useful measured parameter has been streambed gravel, whereas, aquatic macroinvertebrates have shown no significant change over the course of the study (Cederholm pers. comm.). The intrusion of fine-grained sediment into spawning gravels is the most significant forestry-related impact in the watershed. On a basin-wide scale, it has been estimated that survival-to-emergence of coho salmon has been lowered by 20 percent. Sediment generated by road-related landslides and road surface erosion are the most important sources for fines affecting spawning habitat; future landslides could be nearly eliminated by road designs which avoid unstable slopes.

Winter refuge habitat is being lost due to disruption or blockage of small floodplain channels, and channel stability has decreased due to removal of large woody debris. Aggradation of coarse sediment has reduced available summer habitat. Study conclusions emphasize that although many parameters have been monitored for nearly 15 years, the processes studied occur with varying frequency over long time periods.

In addition, researchers consider the basin's population of coho salmon to be depressed due to heavy fishing harvests. They conclude that this depression predisposes the salmon population to perturbation associated with silviculturally-related habitat degradation.

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Reports: Numerous reports have been generated by the Fisheries Research Institute, University of Washington, Seattle, WA. Summary information can be found in Cederholm and Reid (1987).

Alsea River Project, Oregon

Site Description. The Alsea River watershed is in Oregon's Coast Ranges, between Newport and Waldport, 11 km (7 mi) south of the town of Toledo. The study was conducted on three small watersheds: Deer Creek (304 ha [750 ac]), Needle Branch (71 ha [175 ac]), and Flynn Creek (203 ha [500 ac]). The Alsea Watershed Study (1958-73) was one of the first long-term watershed studies to consider the impact of timber harvest practices on the biological characteristics of streams, including their anadromous fish populations.

Beneficial Use. The Alsea watershed was used as a research area to determine the impact of timber harvesting on biological characteristics of streams. Fish populations present on the watershed include coho salmon and cutthroat trout.

Best Management Practices. The study was designed with two experimental watersheds and one control watershed. Needle Branch watershed was completely clearcut without stream protection using harvesting methods that were common prior to forest practice regulations. Deer Creek watershed was patch-cut in three cuts, 25 ha (62 ac) each, with a buffer strip left along the main stream channel. The Flynn Creek watershed remained unmodified as a control area.

Monitoring. Stream gaging weirs and two-way fish traps were constructed on all three watersheds in 1958-59, and monitoring began in mid-1959. Roads were constructed in 1965 and logging took place from March through October, 1966. Post-logging monitoring continued until the fall of 1973.

Measurement of change in streamflow, dissolved solids, water temperature, dissolved oxygen, and suspended sediment were important components of the Alsea study. These physical characteristics were monitored to measure changes caused by harvesting and road construction on the water resources and to aid in interpreting changes in the biological communities. Riparian canopy, substrate composition, and fish populations were the biological and habitat characteristics measured.

Discussion. Dramatic changes in water temperature were recorded on the clearcut watershed although no changes were observed where the riparian vegetation remained intact. Dissolved oxygen was greatly reduced in streams receiving fresh logging slash; the levels returned to normal once the slash was removed. There was an increase in the percentage of fine sediments in spawning gravels which coincided with a reduced number of emergent fry per spawning female salmon. Suspended sediment increased fivefold over the baseline values in the first winter after slash burning on the clearcut watershed. Yields declined to near baseline levels 4 years after the harvest. The single most important measure of response of the fish populations in the watersheds was expected to be seen in the numbers of outmigrating smolts. However, the variability in numbers of returning adults confounded the interpretation of smolt data, and no conclusion could be drawn.

An important result of the Alsea study was the base it provided for future research. Also, the study brought managers and researchers from several disciplines together on a long-term basis to work on problems and seek solutions. As a result, the findings from the Alsea study have been used to help develop forest practice regulations (requirements for the use of buffer strips along fish-bearing streams, to protect streambanks during yarding, to provide shade, and to keep slash out of streams) in the Pacific Northwest.

Additional Information.

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Reports: Numerous reports were prepared based on research conducted in the Alsea watershed. A retrospective review of the project is presented in Hall et al. (1987).

Siuslaw River Project, Oregon

Site Description. The land managed by the BLM on either side of the Willamette Valley, the Siuslaw area in the Coastal Range ecoregion, and the McKenzie region in the Cascades ecoregion totals 130,000 ha (320,000 ac) and is managed as a unit. About 1,600 ha (4,000 ac) of Douglas-fir are harvested per year.

The BLM land to the west of Eugene, Oregon within the Coast Range ecoregion has a heavily dissected landscape and the steep-sided valleys have a high landslide potential. The soils are deep, developed on a sandstone bedrock, and annual precipitation ranges from 200 to 250 cm (80 to 100 in). The McKenzie Valley BLM land to the east of Eugene, within the Cascades ecoregion, has a moderately dissected landscape with a maximum ridge height of 910 m (3,000 ft). The soils, developed from igneous parent material, are moderately deep. Precipitation is 100 to 150 cm (40 to 50 in) a year. Landslides are infrequent, but large.

Beneficial Use. Beneficial uses of water resources include fishing and water supply for municipal areas.

Best Management Practices. Riparian zones are left along third-order streams and larger. The width of the zone is decided in the field, but in general is 15 m (60 ft) for third-order streams, 30 m (100 ft) for fourth-order and 60 m (200 ft) for fifth-order streams. First- and second-order streams are treated individually. If stream slopes are steeper than 80 percent, the vegetation is left standing to the brow of the hill. Roads are not built on slopes greater than 60 percent and skyline yarding is used on steeper terrain. Head walls, which are landslide areas, are not cut.

Monitoring. The area is prone to landslides which are exacerbated by logging, and past management practices resulted in a lawsuit. Monitoring is being conducted by both BLM and USFS to gather baseline data and to evaluate changes in water quality due to management practices.

Baseline and long-term monitoring of water quality is being conducted at eight stations. Flow (automated stage and gage), suspended solids, temperature (continuous), turbidity and conductance (once a week in winter, once a month in summer) are monitored. Temperature will be correlated with stream shade. Currently, the baseline stations are positioned above logging sites, although all the forest will eventually be cut.

Stations established to study special monitoring projects and individual timber sales are sampled once a week in the winter and once a month in the summer. Streams are analyzed for suspended solids, flow, and turbidity for 1 year before and after management activity. Bank stability and fecal coliform are monitored (twice in high flow, twice in low flow) at selected stations.

Additional Information.

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Reports: Administrative reports are available for study areas, for example, Swanson and Roach (1987).

Coos Bay Project, Oregon

Site Description. The Coos Bay District in southwestern Oregon covers 124,023 ha (306,230 ac) of commercial forest land. Douglas-fir, western hemlock, and western red cedar are the most common tree species, while white cedar and grand fir are found occasionally. The understory consists of salmonberry, huckleberry, sword fern, vine maple, and rhododendron. The riparian vegetation consists of primarily red alder, with myrtle and big leaf maple as the climax species. Much of the riparian vegetation is relatively new due to the past logging practice of splash dams, used from 1880 to 1956.

The soils in the northern Coos Bay area are of uplifted sandstone. A clay base and vegetation removal have made the steep slopes quite erodible. In the southern end, the soils are of the Klamath Mountain Formation, consisting of a variety of rocks, predominantly granite and serpentine.

Timber harvest in 1972 was managed at 1 million cubic meters (234 mbf) a year. The current proposed management plan allows for a slight increase in harvest.

Beneficial Use. Elk hunting, trout and steelhead fishing are popular sports in the district's forests. Many small streams of the forest feed reservoirs that supply the water to the Cities of Coos Bay and North Bend. A potential 5 million dollar oyster farming industry is pending agreement with the City of Coos Bay to reduce sewage outfall into the bay.

Best Management Practices. The BMPs proposed in the new plan include leaving 4 percent of the commercial forest land (CFL) as riparian vegetation (4,372 ha; 10,800 ac). Seven percent of the CFL is designated as fragile and incapable of supporting sustained timber yields.

The Coos Bay District BLM adheres to the requirements of the Oregon FPA. Broadcast burning of slash leaving down timber, flagging snags for wildlife habitat, installing gabions in streams, and creating pools for salmon spawning are additional practices of the district.

Monitoring. In 1982, the BLM Oregon State drew up the manual "Monitoring Western Oregon Records of Decision," which details the monitoring plans for fisheries and water quality.

Baseline data are collected on temperature and flow from eight streams in the district. Prioli Creek's watershed (130 ha; 320 ac) is all BLM owned with a fish hatchery below and logging above. Sampling of sediment, temperature, conductivity, and precipitation has been done since 1984. At Cherry Creek, which is 80 percent BLM land and 20 percent private land, suspended sediment, turbidity, and conductivity data are collected. Sampling is done above and below the harvest site, during the sale, and for 3 to 7 years after the timber cut.

The new management plan calls for a monthly monitoring of stream flow profiles, temperature profiles, dissolved oxygen, pH, and bedload. These parameters will also be monitored after major storm events. A thorough stream habitat monitoring is to be done periodically (once in a 10-year period for major streams) including channel structure, riparian vegetation, bedload composition, fish, and aquatic populations.

Additional Information.

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Reports: USDI, Bureau of Land Management (1982).
USDI, Bureau of Land Management (1986).

Elk River Project, Oregon

Site Description. The Elk River basin is located 10 km (6 mi) northwest of Port Orford on the southern Oregon coast. Douglas-fir, Port Orford cedar, western hemlock, tanoak, and Pacific Madrone are the main tree species in the forest; big leaf maple and alder are the dominant vegetation in the riparian zones. Annual precipitation is approximately 254 cm (100 in), most of which falls between September and May. The basin is characterized by high relief and steep slopes that are susceptible to mass wasting.

Beneficial Use. The Elk River basin is an important producer of wild chinook salmon, cutthroat and winter steelhead trout for sport and commercial fisheries. A fish hatchery is located within the boundary of the National Forest and is operated by the Oregon State Department of Fish and Wildlife. The basin is also used for commercial timber. The BMPs prescribed focus on protecting the fisheries resource.

Best Management Practices. The BMPs of the Siskiyou National Forest are dictated by the FPA. Water quality criteria follow the forestwide standards and guidelines, a collaborative agreement between the Forest Service and the State of Oregon.

The hydrogeology of the basin is such that few pools are formed for critical spawning beds. Five reaches of stream, primarily in tributaries, were identified as exceptionally productive habitats and are referred to as "flats" because of their low gradient (generally less than 2 percent) and wide valley floor. Harvesting practices near these sites is modified to prevent sediment loading in the spawning beds.

Riparian zones are widened at the request of the staff geologist if it is determined that timber harvesting is occurring on unstable slopes.

Monitoring. The objectives of the study were to: 1) determine where and when (within the past 25 years) mass movement events initiated and terminated in selected areas of the Elk River basins; 2) determine what historical trends, if any, have occurred in stream water temperature and analyze observed trends to determine possible influences of changes in climate, riparian vegetation cover, and channel morphology; 3) inventory fish habitats to determine where salmonid fish are most productive and where they are most sensitive to management activities within selected subbasins of Elk River; and 4) prepare a risk assessment map showing effects of mass erosion on fish habitat on a basin-wide scale. All research for this study was conducted from 1984 through 1986 in the spring and summer months.

Monitoring began in 1986 to check the maintenance of riparian zones after timber harvest and to determine whether the forestwide standards and guidelines were met.

Discussion. The study revealed that there was an increase of landslide occurrences, as determined from aerial photographs, in sites of timber harvesting and associated road building compared to areas of natural forest cover. Most failures (65 percent) occurred within 5 years of harvest. Approximately 40 percent of all debris produced from mass wasting was delivered directly to streams of third-order or greater.

Summer water temperatures in mainstem Elk River at the hatchery generally decreased from 1965 to 1970, increased between 1971 and 1974, and decreased from 1974 to 1985. Temperature increases tended to follow the occurrence of large winter runoff events when riparian vegetation may have been damaged from a landslide that delivered sediment to the channel system.

The salmon and trout production potential of the Forest Service portion of Elk River basin was high but varied with species and year. The variability was attributed to differences in escapement of adults between years and reduced survival of redds and eggs from a storm in February 1986.

Additional Information.

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Reports: Reeves et al. (1987).

Siskiyou National Forest, Oregon

Site Description. The Siskiyou National Forest (469,000 ha [1,092,000 ac]) is located in the extreme southwest corner of Oregon, with a small extension into California. The area is characterized by a rugged, youthful topography with 600-1,500 m (2,000-5,000 ft) of relief. Average annual precipitation ranges from 102 cm (40 in) on the east side to more than 406 cm (160 in) on the west side. As a result, the forest annually yields about 10 billion cubic meters (8.2 million af) of water, 70 to 80 percent between December and March. Nearly half of the forest streamflow drains into the Rogue River basin. Drainage densities average 3 km/sq km (3.7 mi/sq mi) of perennial stream per land surface.

Most of the soil types have developed from weathered metamorphosed volcanic and sedimentary rock. Much of the forest is underlain by relatively impervious rock which results in low infiltration rates and high runoff. Current sediment production for the forest is estimated to be about 565,000 metric tons (623,000 tons) per year. Douglas-fir, western hemlock, western red cedar, Port Orford cedar, Ponderosa pine, white fir, redwood, madrone, and tanoak are the main tree species found in the forest.

Beneficial Use. The major resources of the forest are timber, fish, water, recreation, wildlife, and minerals. The Rogue River is nationally known for its excellent salmon and steelhead fishing. The fisheries in the forest are valued at several million dollars annually. The streams of this area boast one of the largest remaining wild stocks of chinook and coho salmon and steelhead and cutthroat trout in the continental United States.

Best Management Practices. High drainage densities result in 757,000 ha (187,000 ac) of near-stream riparian habitats. Slightly less than 40,500 ha (100,000 ac) are within the land base suitable for the production of timber. The remainder is either in wilderness or in areas unavailable or unsuitable for timber production.

Prior to the 1970's, many riparian areas were clearcut and roaded, particularly along perennial streams that were not used by fish for spawning. Today riparian areas are managed more objectively, taking or leaving trees based on their contribution to the stated objectives and the ecosystem as a whole. Riparian areas are between 46 m (150 ft) and 30 m (100 ft), depending on the stream class. Other requirements for riparian area management on perennial streams include directional felling; no-burn areas within the riparian area; a silvicultural prescription and individual site-specific analysis; full suspension of logs across a stream; stream quality monitoring before, during, and after logging; and ensuring that five to eight potential and existing snags per ha (two to three per acre) will remain on cutover areas.

Monitoring. The monitoring objectives are to determine whether a timber sale results in any adverse effects to flow rates, turbidity, or temperature. The primary water quality problems within the forest are above-optimum water temperature in the summer (due to natural conditions, low summer flows, and past logging practices) and high turbidity during major winter storms. Temperature is considered the forest's critical water quality factor as it has a major effect on the highly valued anadromous fisheries.

Turbidity samples are taken during periods of high flow before any road building or timber harvesting activity, as well as during and after the harvest. Samples for turbidity are taken above and below the unit or on paired watersheds.

Selected riparian areas are monitored to determine the extent of conifer removal and any physical impacts to the residual vegetation or the stream. Stream water temperature warmed by direct solar radiation after impacting shade canopy is a common concern in the forest.

Additional Information.

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Reports: Anderson (1985).
Amaranthus (1981).

Puget Lowland

Lake Whatcom Project, Washington

Site Description. Lake Whatcom is a multiple use forested watershed located in the western foothills of the Cascade Mountain Range approximately 29 km (18 mi) south of the Canadian border. The watershed is 145 sq km (56 sq mi), of which 8 sq km (3 sq mi) are within Bellingham city limits. There are seven continuously flowing creeks that flow into the lake. The lake is also fed by a diversion from the Middle Fork Nooksack River, which adds an additional 150 sq km (58 sq mi) to the watershed.

The maritime climate gives an annual average rainfall of 130 cm (51 in), of which 70 percent falls in winter. The soils of the watershed are derived from glacial parent material and are immature. The area is dominated by western hemlock, western red cedar, and Douglas-fir.

Forestry constitutes over 80 percent of the land use of the watershed. The largest owners are Georgia Pacific, the State of Washington, and Scott Paper. The entire area had been logged by the 1920's, and now second and third growth is harvested.

Beneficial Use. Lake Whatcom is a municipal water supplier for the City of Bellingham and Whatcom County Water District 10. Households and industry withdraw water directly, and the lake is a storage basin to prevent flooding along Whatcom Creek. Additionally, Lake Whatcom supplies a salmon hatchery and is an important habitat for fish and wildlife. Water skiing, swimming, and boating are popular recreational uses of the lake.

Best Management Practices. The Washington State FPA is the primary regulatory control on logging in the watershed. However, a TFW agreement has been enacted which supersedes some guidelines in the state FPA. Additional BMPs have been proposed for consideration, including further restrictions on the use of pesticides; appropriate use of riparian buffer zones; stream stabilization projects; designing roads, drainage, yardage designs and cut layouts to minimize sediment yield and impacts upon the scenic values of Lake Whatcom.

Monitoring. A monitoring program has been in place in Lake Whatcom since 1962. The program is designed to detect major changes in the water quality in the lake.

Currently, the monitoring program consists of monthly (June-October) or bimonthly (November-May) sampling at five lake sites and twice annual sampling at selected creek sites. The water samples are analyzed to measure temperature, pH, dissolved oxygen, conductivity, Secchi depth, nutrients (total phosphorus, soluble phosphorus, total nitrogen, nitrate/nitrite, and ammonia), alkalinity, turbidity, dissolved inorganic carbon, total organic carbon, cations and anions, chlorophyll, phytoplankton, zooplankton, and coliforms. In addition, in 1986, the program included analyses for EPA Priority Pollutants.

Discussion. It is recommended that the water quality monitoring program continue as long as the lake is being used as a source of drinking water. The continued program will collect baseline data on nutrients, inorganic constituents, synthetic organics, algae, physical properties, and coliform bacteria; and identify the sources of future water problems by monitoring incoming creeks and storm drains. The goal is to make the results as useful as possible, and accessible to all agencies concerned with overall lake management.

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Reports: Many reports on Lake Whatcom have been published. A synthesis is given in Institute for Watershed Studies (1986).

Capitol Forest Project, Washington

Site Description. Capitol Forest, managed by DNR, is located in Olympia, Washington. The average annual precipitation is between 75 to 125 cm (35 to 50 in). The mild, quasi-mediterranean climate supports the predominantly Douglas-fir forest. The soils are derived from igneous and sedimentary parent materials. A forest plan was written in the late 1970's and harvesting is nearing completion.

Beneficial Use. In addition to logging, the forest has popular campgrounds and trails because of its close proximity to the City of Olympia.

Best Management Practices. The DNR is managed to bring the highest revenue for the school endowment trust fund that is compatible with the state FPA. The BMPs are detailed in the Washington Forest Practices Rules and Regulations of January 1988. Capitol Forest, being state-owned, is also under the Timber, Fish, and Wildlife Agreement.

Monitoring. Monitoring is being done on five river drainages that drain most of the land in the forest, with sampling sites as close to the forest as possible. During storm events, samples are taken every 2 hours; once the storm subsides, sample frequency decreases to every 4 hours. The parameters measured are stream flow, temperature, suspended sediment, rainfall, air temperature, and relative humidity.

Discussion. Riparian management, as dictated by Washington FPA, is considered important.

Additional Information.

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Cascades

Entiat Experimental Forest Project, Washington

Site Description. The experimental forest is located on the east side of the Cascade Range in north central Washington, a few miles north of Wenatchee. The area consists of four watersheds: Fox (473 ha [1,169 ac]), Burns (564 ha [1,394 ac]), McCall (514 ha [1,270 ac]) and Lake (4,000 ha [9,884 ac]), with the streams draining southeast to the Entiat River which joins the Columbia River. The maximum elevation range is 603 m (1,978 ft) to 2,165 m (7,103 ft), and mean channel gradient is 28 percent. Slopes average 50 percent, but 90 percent is common. Winters are moderately cold and wet with 70 percent of the 203 cm (80 in) annual precipitation falling as snow. Summers are hot and dry. The bed rock is a batholith which weathers deeply when exposed. A 6 m (19 ft) layer of popcorn pumice is common below the sandy loam soil.

The area had never been logged prior to a major fire in 1970, and the climax forest was Ponderosa pine and Douglas-fir with lodgepole pine in the unburned Lake Creek watershed. The Fox, Burns, and McCall watersheds were severely and uniformly burned in a few hours, with a virtual destruction of surface litter. Following the fire, Fox Creek watershed remained untouched as the burnt control. Burns and McCall Creek Watersheds were reseeded with grass and fertilized with ammonium sulfate and urea respectively. Lake Creek Watershed was the unburnt control.

Beneficial Use. The Entiat Experimental Forest is a research facility maintained by the Pacific Northwest Forest and Range Experiment Station since 1959.

Best Management Practices. Two roads were constructed to log burned timber in the watersheds. Logging by tractors was allowed on slopes less than 30 percent, or 40 percent if snow covered; otherwise helicopters were used.

Monitoring. Water yield and precipitation has been measured on these watersheds since 1959. Water temperature and stream chemistry have been measured since 1968 and 1970, respectively. Three of the watersheds of the experimental forest were severely and uniformly burned in the 22,000-ha (55,000-ac) Entiat fire. The pre-fire data provided a unique opportunity to assess the impact of a large wildfire and follow-up fertilization on water quality. Samples of stream flow for chemical analyses were collected from the mouth of each stream at monthly or biweekly intervals from fall to late winter, and twice weekly or biweekly during spring run-off (March to June) from 1970 to 1975. Precipitation and snowpack samples were collected and analyzed also.

Laboratory measurements included pH, total alkalinity, conductivity, nitrate, urea, ammonium, Kjeldahl nitrogen, calcium, magnesium, potassium, and sodium. Streamflow was measured with V-notch weirs and associated stilling ponds, from which sediment was periodically removed and measured. Suspended sediment, turbidity, and total phosphorus were measured in the laboratory using standard methods (APHA 1985).

Discussion. In comparison with the low levels of stream chemical constituents prior to the fire and in the control stream, wildfire has exerted striking and prolonged effects on nitrogen levels of these streams. Effects of fertilization on water quality, however, appear to be negligible. This is explained by the watersheds' capacities to exhibit a high degree of chemical retention. Increases in nitrate were up to 50 times greater than the undisturbed conditions, but were not of sufficient magnitude to degrade water quality when compared to EPA water quality criteria. Solution losses of N, P, Ca, Mg, K, and Na, although small, were sufficient to restrict vegetation growth. Annual sediment yield increased as much as 180 times above the pre-fire levels and were well correlated with turbidity.

Additional Information.

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Reports: Helvay et al. (1985).
Tiedemann et al. (1978).

Goat Creek Project, Washington

Site Description. Goat Creek is located 1 km (0.6 mi) west of the southwest corner of Mt. Rainier National Park in Gifford Pinchot National Forest. The typical tree species are Douglas-fir, western hemlock, western red cedar, and Pacific silver fir at higher elevation. The elevation ranges for the watershed are from 550 m (1,800 ft) to 1,700 m (5,600 ft) at Mt. Adams. Annual precipitation ranges from 180 cm to 300 cm (70 in to 120 in), most of which is snow.

The soils are developed primarily from volcanic rock with some deep glacial deposits. Heavy periods of rainfall and rapid snowmelt are common in the area. The weather and soil conditions, coupled with the removal of forest vegetation and road construction for timber harvest, have lead to increased slumping, landslides, and soil erosion.

Beneficial Use. Goat Creek is used for domestic and commercial water supply. Timber harvest is the major industry of this area. Wildlife habitat and recreation are other important uses.

Best Management Practices. The area was logged in the summer of 1983. BMPs utilized included skyline logging with full suspension over Goat Creek required. Prior to logging, the timber sale officer and hydrologist marked trees within the creek for removal or retention. All embedded logs were left in the creek. Stream cleanout of material resulting from logging and handpiling of slash was also required. Willow and cottonwood cuttings were planted along the streambanks in June 1984.

Monitoring. During the summer of 1983, water quality monitoring was conducted on Goat Creek. Objectives of monitoring were: 1) to test for compliance with Washington State water quality standards for Class AA streams; and 2) to determine if forest service standards for Class I streams were met.

A timber sale was designed to salvage windthrown timber along Goat Creek. There are heavy debris accumulations in Goat Creek and several mass failures resulting from bank undercutting and loss of root stability.

Sampling locations were established above and below the cut area (Unit #6). No change in the parameters monitored below Unit #6 was assumed to mean no impact at the domestic water intake downstream. Stage readings and grab turbidity samples were taken at the site approximately twice weekly. An ISCO Model 1680 automatic sampler was set on a two-hour sampling interval below the site to analyze turbidity and suspended sediment.

Discussion. The photo points are expected to be valuable in assessing the long-term impact of management activities on Goat Creek channel morphology and riparian vegetation.

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Reports: Metzler (1984).

North Fork Willame Creek Project, Washington

Site Description. The North Fork of the Willame Creek is located 25 km (40 mi) south of Mt. Rainier in Gifford Pinchot National Forest. The creek's elevation ranges from 1,250-300 m (4,100-1,000 ft) where it flows into the Cowlitz River. The average annual precipitation is 140 cm (55 in) most of which occurs as snow. Typical tree and target harvest species are Douglas-fir, western hemlock, and western red cedar. The forest understory consists of salal, salmonberry, huckleberry, devils club and alder. Soils are derived from volcanic, pyroclastic rocks.

Best Management Practices. BMPs include leaving 20-25 live trees and 5-10 snags per acre within a 50-foot strip of a Class III, fish-bearing stream. Approximately 95 trees were marked to meet riparian and wildlife goals. Hand firelines are constructed to protect riparian vegetation during slash disposal. Highlead yarding is also used.

Monitoring. The three objectives stated in the monitoring plan are: 1) assess cumulative impact of shade removal on temperature; 2) check compliance with Washington state temperature standards; and 3) test applicability of Brown's temperature model, as described in "An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources" (EPA 1980). Water quality monitoring on the North Fork Willame Creek began in 1983 and was completed December 1987. Monitoring was done above and below a clearcut harvested n 1970, and above and below Unit 6 of the Skate Creek timber sale downstream from the clearcut.

Baseline temperature and suspended sediment data were gathered from June through September for 1983, 1984, and 1985. Post-harvest monitoring was performed from June to September 1987, channel morphology and riparian cover were assessed.

Discussion. Shade removal due to the 1970 clearcut has resulted in a significant difference in temperatures above and below the unit. The maximum temperature increase of 2.5^{o}C (4.5^{o}F) occurred in July, August, and September. The temperature increase was predicted by Brown's model which was validated.

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Reports: Metzler (1986).
EPA (1980).

Wind River Project, Washington

Site Description. The project site is located in the Wind River watershed, Gifford Pinchot National Forest, in southwest Washington. The lower Wind River is characterized by volcanic soils and forests of Douglas-fir and western hemlock. Precipitation averages about 203 cm (80 in). Two sites received herbicide application. One site is located on the Cedar Creek, 12 km (7.5 mi) upstream from the confluence with Wind River, 7 km

(4.3 mi) from the Columbia River. The other site is located on Brush Creek, 5 km (3 mi) upstream from the confluence with Wind River, 4.7 km (2.9 mi) from the Columbia River.

Beneficial Use. Lower Cedar Creek is used as a domestic water supply. Brush Creek has a resident trout population.

Best Management Practices. BMPs used to protect the stream water and aquatic community in this project were: 1) a prioritization of monitoring sites (i.e., priority given to domestic watersheds); 2) buffer strip widths along streams of 30 m (100 ft); 3) timing of application; 4) adequate flight paths avoiding crossing streams as much as possible; 5) flying in winds of less than 10 kph (6 mph) to minimize drift to non-target areas; and 6) following herbicide label directions for application. "Roundup" was applied to a total of 31 ha (76 ac) at an active ingredient rate of about 1.8 kg/ha (2 lb/ac).

Monitoring. The specific objectives of this monitoring project were to: 1) ensure compliance with all applicable state and federal water quality standards; 2) determine if any offsite movement of herbicide was occurring; and 3) determine if correct buffer strip widths, flying procedures, etc., were used, and make recommendations for future projects of this type. Monitoring in both creeks occurred approximately 152 m (500 ft) below the application site.

One control water sample was taken at each creek before the project started. Four project samples were taken during and after spraying the units, at times indicated by the travel times of the stream and sampling station location below the unit. They were cooled to 4°C (39°F), and sent immediately to the laboratory (Oregon State Department of Agriculture). The control sample was analyzed individually and the four project samples were composited as one sample for each creek.

Discussion. Results showed that no residue was detected either in the control or composite samples, therefore, compliance with state and federal water quality standards was ensured. Generous buffer strip widths (30 m [100 ft] for both Cedar and Brush Creeks) and timing (i.e., the low stream flow season in late August), seem to be the main contributing factors in finding insignificant levels of "Roundup" in the stream water.

Additional herbicide spray projects were conducted within Gifford Pinchot National Forest. In 1978, the St. Helens Ranger District sprayed two units (totalling 43 ha; 106 ac) with 2,4,5-T. Three of the six sample sites showed residual 2,4,5-T that exceeded the EPA maximum contaminant level for 2,4,5-T in drinking water. Other projects were conducted by the Mt. Adams Ranger District using "Roundup", 2,4-D and 2,4,5-T.

A careful and well-planned spraying job, observing all control procedures relating to wind, speed, temperature, humidity and precipitation, and the provision of buffers proved to be relatively effective in keeping herbicide from entering the stream.

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Reports: On file at Wind River/Mt. Adams Ranger Districts, and Mount St. Helens National Volcanic Monument.

Bull Run Watershed Project, Oregon

Site Description. The 24,300 ha (60,000 ac) Bull Run Watershed is located on the west side of the Cascade mountains close to the northern Oregon border. The Bull River flows east through Portland before joining the Columbia River. The topography is gently rolling, with a few steep incised draws and a maximum elevation in the watershed of about 1,350 m (4,500 ft). The site has experienced major fires at about 400-year intervals. The last burn was in the early 1900s.

The rainfall ranges from 230 to 480 cm (90 to 190 in) a year. The geology is dominated by Columbia River Basalts, which have given rise to well-drained, deep and stable soils.

The climax species, Douglas-fir, silver fir and hemlock, are harvested. There are no programmed harvests, and cutting is variable. A 2,430 ha (6,000 ac) blowdown is the current harvest site. Strong east winds, up to 145 km/hr (90 mph), funnel through the Columbia Gorge, causing severe blowdowns on about a 10-year cycle.

Beneficial Use. The Bull River is a major source of drinking water for the City of Portland. Turbidity and bacteria are primary water quality concerns.

Best Management Practices. BMPs are designed to reduce sediment and erosion. Road construction is minimal, designed to follow a low grade and reduce erosion. Trees are yarded by helicopter as much as possible, and tractors are not used. The riparian buffer is generally the immediate stream valley, and can be 61 m (200 ft) wide.

Monitoring. The monitoring program is very complete and is designed to determine compliance with the Revised Bull Run Water Quality Standards. The monitoring program includes measurements of physical riparian characteristics and water quality characteristics. The water quality program is run by the USFS and Water Bureau, which take samples above and below harvest and control sites.

The physical riparian monitoring program includes stream shading, bank stability, vegetation coverage, and in-channel debris conditions over time. This inventory monitoring consists of three stages: 1) conducting detailed stream/riparian surveys along selected streams within timber sale units; 2) stratifying stream/riparian areas into separate reach areas and establishing photo points and measurement plots/transects within the reaches; and 3) measuring the condition of physical riparian characteristics before and for several years after timber sale activities. Photo points and solar sample points were established to assess stream shade, riparian vegetation, present and future woody debris input to the streams. The photo points were re-evaluated following felling, helicopter yarding, stream cleanout, fuels treatment, and once a year for 5 years following the completion of post-sales activities.

The water quality monitoring program involves sampling at five key stations located at major tributary junctions, and at least 10 tributary and four reservoir stations on a regular basis. The key stations are sampled daily for turbidity, temperature, pH, conductance, color, suspended sediment, dissolved oxygen, flow, bacteria (total, total coliform, fecal coliform, fecal streptococci); weekly for algae, chlorophyll-a, alkalinity; at 14-day intervals for nitrate, total nitrogen, total orthophosphate, dissolved orthophosphate, total phosphorus, silica; and 28-day intervals for total organic carbon, tannin, and lignins. The following parameters are analyzed annually: ammonium nitrogen, arsenic, barium, cadmium, total chromium, copper, fluoride, iron, lead manganese, mercury, selenium, silver, sodium, zinc, endrin, lindane, methoxychor, toxaphene, 2,4-D and 2,4,5-TP. Transparency (Secchi disc) is measured weekly at the reservoir stations.

Discussion. The data collection at the Bull Run Watershed is extensive; 39 parameters are measured and over 15,000 datum points are generated a year. The most informative parameters are turbidity, which is very responsive to logging and correct BMP implementation; pH, which has been increasing over the past 8 years in logged and control watersheds for as yet no apparent reason; and nitrate-nitrogen. Nitrate-nitrogen responds to burning BMPs. If the watershed is burned there is an immediate release of nitrate that is substantial for 4-5 years. With no burn the release is delayed for about 3 years, but continues for a much longer time.

A previous 7-year USGS survey showed no significant difference in macroinvertebrates, turbidity, and suspended sediments between logged and unlogged watersheds. These results are substantiated by current USFS monitoring, indicating BMPs are properly and adequately implemented.

The monitoring program at Bull Run Watershed costs about $300,000 a year for water quality sampling alone and is too expensive to implement at all national forests and logging operations. Communication of the results is thought to be an important but as yet undeveloped aspect of the research program (McCammon pers. comm.).

Additional Information.

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Reports: USDA Forest Service (1987b).

Middle Santiam River Project, Oregon

Site Description. The study area includes 8,000 ha (19,768 ac) of the Middle Fork of the Santiam River watershed located on the western slopes of the Cascade Range in Oregon. The Middle Santiam River flows to Green Peter Reservoir 30 km (19 mi) downstream, encompassing a total watershed area of approximately 28,000 ha (69,160 ac). The watershed rises in elevation from 335 m (1,100 ft) to 1,465 m (4,807 ft).

Slopes in excess of 60 percent occur on 58 percent of the area. The soils found on these slopes are shallow to moderately deep and medium textured. The climate of the region is maritime with cool, wet winters and warm, dry summers. Annual precipitation ranges from 150 cm (59 in) at the lower elevations to 330 cm (130 in) at the higher elevations.

Overstory vegetation on forested slopes is predominantly 350-year-old Douglas-fir. Ridgetops have a mixture of western hemlock, Pacific silver fir, and subalpine fir. Alluvial valley bottoms and undrained depressions support mixed stands of bigleaf maple, red alder, and western red cedar.

Best Management Practices. Road construction and timber harvesting of old growth forests began in 1972. Care was taken to minimize erosion during harvesting. Roads were carefully designed, and the main roadways were surfaced with crushed rock. Logging of old-growth Douglas-fir was accomplished almost exclusively with highlead cable systems which lifted logs uphill to midslope or ridgetop landing. The few gently sloping sites, such as the benches above the valley bottom, were logged with tractors. Trees were harvested in units averaging about 20 ha (49.4 ac) in area, although as cutting progressed, area of contiguous plantation increased. Clearcut units generally were handplanted with Douglas-fir seedlings within 1 year following harvest.

Monitoring. The purpose of the monitoring was to measure the integrated effects of timber harvesting and road construction on the export of suspended sediments from a medium-sized watershed over time. Water samples were collected every 6 hours from two locations just upstream and 11 km (7 mi) downstream from the study site in the mainstream of the Middle Santiam River and analyzed for suspended sediment and turbidity. Since 1963, stream discharge has been measured at the USGS gaging station located within 30 m (98 ft) of the downstream station. Precipitation was monitored continuously with a tipping bucket rain gage at a weather station located near the downstream sampling location.

Discussion. The site of the sampling station was critical to monitoring water quality changes. Over the 9-year period that turbidity and suspended sediment were measured, seven road-related slope failures occurred. Although increases in turbidity and suspended sediment were measured in association with nearly all of the mass failures, the scale and duration of increases varied. Small failures (less than 1,000 metric tons) appeared to increase turbidity and suspended sediment for a period of 1 to 2 days but did not alter monthly or yearly averages. Large failures which altered annual turbidity patterns in small tributaries for up to 1 year produced detectable changes in the main channel for only 1 month.

Additional Information.

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Reports: Sullivan (1985).

H. J. Andrews Experimental Forest, Oregon

Site Description. The Andrews Forest consists of 6,404 ha (15,813 ac) 80 km east of Eugene, Oregon on the western slope of the Cascades. Douglas-fir, western hemlock, red cedar, true fir and mountain hemlock are the predominant tree species that grow in the mild climate of the region. The average mean temperature during the wet, warm winters is 2°C (36°F) (January), and 20°C (69°F) during the dry summer (July).

The H. J. Andrews Experimental Forest was established in 1948 by the USFS to examine the effects of different logging methods on reforestation, erosion, and water quality. It has become an active site for research on coniferous forest and stream ecosystems. In 1969, the Andrews Forest was selected as an intensive study site by the Coniferous Forest Biome (International Biological Program) because of the existing long-term data base.

Beneficial Use. The gauged watersheds are managed strictly as research basins.

Best Management Practices. Three sets of gauged watersheds have been sites for nonpoint source stations. Watersheds 1, 2, and 3 were established in 1954 and remained undisturbed until 1959 when road construction began. Since that time, various combinations of road building and harvesting have occurred on the watersheds. Roads were constructed to standard USFS specifications, and cut and fill slopes were mulched and seeded. Watershed 1 was clearcut in 1966 and broadcast burned in 1967; Watershed 2 remains unlogged; Watershed 3 had 25 percent of its land clearcut from 1964-1966 in patches and 8 percent in roads. Watersheds 6, 7, and 8 were established in 1965. Watershed 6 was completely clearcut in 1974 and broadcast burned; Watershed 7 had 67 percent of the volume removed in a shelterwood cut in 1974 and 10 years later the overstory cut, the residual was piled and burned; Watershed 8 remains uncut. Watersheds 9 and 10 were established in 1965. Watershed 9 remains uncut; Watershed 10 was clearcut in 1975 and remains unburned. Cable logging was utilized for harvesting.

Monitoring. The objective of the monitoring is to determine the effects of logging on stream quantity and quality. Watersheds 1, 2, 3, 9 and 10 contain large bedload basins which enable measurement of mass sediment movement rates. Grab sampling during storm events on Watersheds 1, 2, and 3 is done to measure sediment yields in manipulated conditions. Watersheds 2, 6, 7, 8, 9 and 10 have automatic proportional pumping samplers that increase their rate of sampling during a storm event. Data for the pumping samplers dates back to 1967 for Watersheds 9 and 10, and 1965 for 6, 7, and 8.

Sampling is done at the mouth of the watersheds. The water from Watersheds 2, 6, 7, 8, 9, and 10 is tested for ions, alkalinity, conductivity, nitrogen, phosphorus, and other constituents. Suspended sediments are analyzed for organic and inorganic components. Water chemistry has been tested in both stream and rainwater for 15 years in some watersheds. Quality assurance is checked against the USGS Water Quality Survey.

The Mack Creek gauge was established in 1978, and is being monitored for nutrient losses and suspended sediments. It, too, has a proportional pumping sampler. Lookout Creek, the major stream draining H. J. Andrews, has been gauged since 1950 by the USGS. Lookout Creek has revealed a varied history of sediment storing and routing conditions. Stream cross-sectional profiles have been measured since 1970.

Discussion. Watershed 3 experienced massive road failures and sediment production associated with the December 1964 storm. Following the road failures, the stream did not return to normalcy for over 10 years.

Runoff from undisturbed watersheds in this area remains clear during the summer low-flow months. Suspended sediment reaches concentrations of 100 ppm during winter storm peaks. Runoff from the first rainstorms after road construction carried 250 times the concentration carried in an adjacent undisturbed watershed. Two months after construction, sediment had diminished to levels slightly above those measured before construction. Sediment concentrations for the subsequent 2-year period were significantly different from preroad levels. In about 10 percent of the samples, sediment concentrations were far in excess of predicted values, indicating a stream-bank failure or mass soil movement. Annual bedload volume the first year after construction was significantly greater than the expected yield, but the actual increase was small. A trend toward normalcy was evident the second year.

Since 1977, the National Science Foundation has supported a baseline monitoring program that includes climatic variables, streamflow, stream water chemistry, atmospheric deposition, litterfall, and successional changes in the composition and structure of the vegetation. Oregon State University, the Pacific Northwest Research Station, and the Willamette National Forest have shared administrative responsibility for the Andrews Forest since 1977. Current management is directed toward maintaining the research value of the site and enhancing it wherever possible. More than 85 separately funded research projects are now using the Andrews Forest. Topics of study include succession and decomposition patterns, fluvial geomorphology, forest-stream interactions, fish population biology, entomology, tree mortality, and soil invertebrates.

Additional Information.

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Reports: Many reports are available. Brenneman & Blinn (1987) summarizes some of the current projects at H. J. Andrews.

Umpqua National Forest, Oregon

Site Description. The Umpqua National Forest is about 32 km (20 mi) east of Roseburg, Oregon, in the western Cascade Range. The 4,000 sq km (1,544 sq mi) National Forest has an extensively dissected topography, with steep slopes and an elevation range of 370 to 1,500 m (1,214-4,922 ft). Annual precipitation averages 127 cm (50 in), most of which occurs in the winter. Since the freezing level fluctuates, winter runoff is supplied by both rainfall and snowmelt.

The dominant tree species are Douglas-fir, western hemlock, incense cedar, Ponderosa pine, and Jeffery pine. The understory consists of salal, rhododendron, and Oregon grape.

Beneficial Use. Water is withdrawn from various creeks for municipal uses. Water turbidity during winter months is a major concern. The Forest Service and private logging companies manage the area around the watershed.

Best Management Practices. Forest plan activities are designed to meet or exceed water quality standards for the state through application of BMPs.

Monitoring. An extensive network of 41 water quality baseline monitoring stations was developed in 1969, with the purpose of characterizing the major watersheds and to rank them by water quality measurements. Currently, 25 stations are being monitored.

Monitoring is conducted in accordance with the National Forest Management Act of 1976. Temperatures are recorded daily, turbidity and/or suspended sediment samples are taken through the winter or after heavy rains. Stream flow is recorded at USGS gauging stations. The Safe Drinking Water Act (1979) parameters, total coliform and turbidity, are measured monthly; inorganics yearly; and organics every 5 years on surface drinking water sources. Biotic parameters (fish populations, macroinvertebrates, and bacteria) have been monitored.

Discussion. Analysis of the turbidity data shows decreasing turbidity on one creek and stable turbidity on a second. Summer temperatures in a third creek are decreasing, due to cooler summers and riparian vegetation regrowth.

Monitoring of the implemented BMPs is being planned under the forest plan.

Additional Information.

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Reports: Smith (1986).

Sierra Nevada

Evans Creek Project, Oregon

Site Description. The Evans Creek watershed is about 540 ha (209 sq mi). The creek flows southwest to join the Rogue River near Grants Pass. The basin is located in the Klamath Mountains, which is characterized by rugged terrain. Elevations vary from 30 m (1,000 ft) to 1,555 m (5,103 ft). Annual precipitation averages 80 m (32 in), and the mean annual temperature is 10^{o}C (54^{o}F).

Over 90 percent of the basin is forested and is actively harvested by the USFS, BLM, and private owners. Small agricultural areas are confined to the valley bottoms.

Beneficial Use. Anadromous fish populate the Evans Creek drainage.

Best Management Practices. A large percentage of the Evans Creek basin has been harvested by tractor and highlead methods.

Monitoring. The monitoring project was designed to develop a procedure in response to the Oregon 208 Assessment of Nonpoint Source Problems. Intensive water quality sampling was conducted by the USGS at three sites in August, 1977. Water samples were taken at hourly intervals and analyzed for nutrients, temperature, pH, dissolved oxygen, conductivity, chlorophyll-a, algal growth potential, fecal coliforms, suspended sediments, turbidity, and flow.

The creek was walked, and bank stability, riparian vegetation, stream condition, fish and macroinvertebrate habitat and populations were inventoried and described using "Stream Reach Inventory and Channel Stability Evaluation" (USFS 1975) and a slightly modified version of this technique.

Discussion. The qualitative approach to monitoring the physical and biological conditions of the stream revealed the following trends. Channel stability varied between moderately unstable to unstable, while fish habitat conditions ranged from poor to good. Slumps, debris torrents, and small slides contributed debris of varying size to the channel which resulted in poor habitat conditions and channel instability. Field channel surveys and aerial photo interpretation were able to identify and rank habitat conditions associated with differing land use procedures.

Water quality parameters measured during low flow failed to adequately define water quality impacts (including suspended sediment) resulting from land management activities on sensitive terrain. Violation of water quality standards for dissolved oxygen and pH did occur, but were linked to low flow conditions rather than land management activities. It was recommended that sampling during high flow events would be a more useful indicator of stream quality. The study also recognized the extreme variability of water quality parameters and suggested that, unless an intensive water quality monitoring effort could be undertaken, limited resources would be more efficiently utilized by focusing on stream and fish habitat conditions.

Additional Information.

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Reports: Oregon Department of Environmental Quality (1978).

Idaho State Nonpoint Source Impacts on Water Quality

Introduction. In 1980, the Idaho Water Quality Standards were revised to include specific language for control of nonpoint source pollution. The Forest Practices Act Rules and Regulations (1979) administered by the Idaho Department of Lands were identified as BMPs for silviculture. An interdisciplinary task force was established in 1982 to study the problems of NPS pollution from forest practices. The task force would provide technically sound answers to the following questions:

1. Do BMPs provide adequate water quality protection for protected uses as defined in the Water Quality Standards?

2. Are current forest practices affecting water quality, and if so, to what extent?

3. Are the existing regulatory controls for silvicultural operations adequate to prevent water quality impacts?

Twenty-five forest operations were inspected by the Task Force in 1984 for compliance with the Idaho FPA and for their potential for impacting salmonid fish habitat. Seven of the 25 operations were considered a major impact or hazard to salmon habitat due to direct delivery of sediment associated with roads or skid trails. At the remaining sites, impacts on protected uses were prevented either by site conditions (low geologic hazard, streams with no protected uses) or by good practices.

Monitoring. Eight task force members, representing major agencies and interest groups involved in the issue of NPS pollution on forested lands, tested specific monitoring techniques and provided technical expertise in the following fields: silviculture, hydrology, geology/soil science, forest road construction, fishery biology, and water quality. Sampling design incorporated consideration of geographic location, geologic land type, logging methods, proximity to streams, and the need to examine forest operations after the first runoff season.

Analysis of water quality impacts was based primarily on the effects of sedimentation on fisheries habitat. A site was rated by observation of direct sediment delivery to streams and the potential for continuing impacts from the site. Observation of cobble embeddedness estimated the existing status of sediment impacts in the drainage.

Site selection was stratified based on land ownership categories: 10 in private operations, 10 in national forests, and 5 in state operations. Sites were selected randomly from a list of candidate operations. Although 25 sites do not comprise a statistically valid sample of forest operations in Idaho, observed trends of compliance with practices, of impacts on streams, and of administrative procedures used by land management agencies are considered to be representative.

Discussion. Compliance with the FPA varied by land ownership category. Forest Service-administered lands had a high compliance rate. Only 5 percent of the individual ratings (n=371) were judged as a minor departure from the intent of the rules. Noncompliance ratings were higher on state and private lands. On state lands, 21 percent of the individual ratings were considered a minor departure, and 12 percent a major departure. On private lands, 10 percent were judged a minor departure, and 8 percent a major departure.

Cobble embeddedness was used as an indicator of the existing substrate condition with respect to cumulative effects of watershed activities. Of the 25 sites inspected, 14 were near a Class I stream, that is, a stream that could be used by resident or anadromous salmonids. Of these 14 streams, obvious cobble embeddedness was observed in 9. At these nine sites (60 percent of Class I streams), sediment delivery from past or ongoing activities may have already caused sustained damage to the fishery habitat.

Most of the task force's work has yet to be done. Current testing is focusing on a probe which determines intergravel dissolved oxygen.

The following agencies are involved in the program: Idaho Department of Health and Welfare Division of Environment, Idaho Department of Lands, Idaho Fish and Game Department, Idaho Conservation League, American Fisheries Society, Idaho Forest Industry Council, and USFS.

Additional Information.

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Reports: Bauer (1985).
Bauer et al. (1987).
Levinski (1986).

Northern Rockies

Boise National Forest, Idaho

Site Description. Boise National Forest is located in the west central portion of the state on the western edges of the Idaho Batholith. The forest covers 1.3 million ha (3.2 million ac) with elevations ranging from 900 to 3,200 m (2,700 ft to 10,500 ft). The mountains have sharply-crested ridges and steep cut slopes. Peak river flows occur in May and June during the snowmelt.

Soils developed from granitic rock generally lack cohesion because of their low silt and clay content causing them to be extremely erodible. The soils are generally shallow and overlie weathered bedrock that disintegrates rapidly upon exposure.

At elevations above 2,000 m (6,500 ft), lodgepole pine is the dominant tree species. Douglas-fir is found at moderate elevations and Ponderosa pine at elevations between 900 and 1,500 m (3,000 and 5,000 ft). The timber harvest target species are Ponderosa pine and Douglas-fir.

Beneficial Use. The forest resources are fish, wildlife, timber, and recreation. Historically, large runs of summer chinook salmon populated many streams in the area.

Best Management Practices. The basic premise of the watershed monitoring program is that NPS pollution can be controlled through the application of BMPs or soil and water conservation practices carefully designed to protect not only designated instream beneficial uses, but also on-site soil productivity.

Monitoring. The goal of the watershed monitoring program is to monitor and evaluate resources and activities to determine if the projects and practices implemented on the Boise National Forest are meeting management objectives. Watershed monitoring includes both monitoring of the soil resource to assure adequate protection of long-term soil productivity, and monitoring of the water resource to assure adequate protection of water quality. Mandates for this monitoring come from the National Forest Management Act, the Clean Water Act, and State of Idaho water quality laws and regulations.

To secure water quality and soil productivity protection, monitoring must address the following questions:

1. Are BMPs implemented as designed?

2. Are BMPs effective in meeting management objectives?

3. Are instream beneficial uses and/or soil productivity protected?

Thirty baseline monitoring sites scattered throughout the forest have been selected to represent sample conditions of the forest. These stations will serve as indicators of long-term trend and to characterize the water quality resource. The most extensive monitoring will be documenting whether project plans and prescribed BMPs are implemented both as designed and in accordance with existing standards. Monitoring to determine if mitigation measures and BMPs were effective in controlling pollutants, will be done mainly where there are issues or concerns relating to unknown effectiveness of practices, and as a demonstration of BMP effectiveness. Information obtained will be used to refine mitigation measures and BMPs for improved application to future projects. Some monitoring will be conducted to answer whether Forest Plan assumptions are appropriate to meet regulations, policy, and objectives. The validation of a sediment yield model and the relationship between sediment yield and fish habitat are of particular interest.

Discussion. The monitoring program is still in draft form which has yet to be implemented.

Additional Information.

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Reports: On file at district office.

Sawtooth National Forest, Idaho

Site Description. The majority of land (600,000 ha [1.5 million ac]) for the Sawtooth National Forest is located in the Northern Rockies ecoregion around Ketchum, Idaho. The southern portion of the Sawtooth National Forest on the Utah border near Twin Falls (245,000 ha [604,000 ac]) is within the Northern Basin and Range ecoregion. The mountains of the northern forest have sharply crested ridges and steep slopes cut by steep walled, narrow stream valleys. Coniferous stands of lodgepole and Ponderosa pine, Douglas-fir and subalpine fir are common at higher elevations. At lower elevations Utah juniper, aspen and mountain mahogany are found. Cottonwood and willow are the primary source of streamside cover within riparian zones.

The average annual precipitation for the forest is 64 cm (25 in), ranging from 114 cm (45 in) near Ketchum to 25 cm (10 in) near Twin Falls. Most precipitation is in the form of snow.

Beneficial Use. The Sawtooths are a popular recreational area for fishing, hunting, boating, hiking, and skiing. Timber harvest and livestock grazing contribute significantly to local economies. Mining is also an important, localized land use. Some stream disturbance has resulted from placer, shaft, and open pit metal mining.

Best Management Practices. In addition to complying with the Idaho FPA, the Sawtooth National Forest has stratified riparian areas to facilitate establishing management goals. The Riparian Area Inventory provides a description of the status of the riparian area as it relates to its potential and management goals.

Monitoring. The various riparian areas of the Sawtooth National Forest have been divided into five value categories, each with a set of minimum standards for management. The goal is to tailor the management guidelines to the type of riparian area. Each riparian designation category has a specific requirement for management of fish, wildlife, recreational opportunities, and water quality.

Riparian complexes, described using dominant vegetation species and land form descriptions, are identified first on aerial photos and then field verified.

Where situations warrant it, intensive site data will be collected with riparian complexes. Community type compositions will be determined using long line transects. Foliage height/volume measurements will be taken for wildlife habitat diversity. Some areas will be intensively mapped for soil types. Streambank transects will be used to characterize streamside communities, streambank stability, and reproductive success of woody species. Data on aquatic habitat components, including spawning habitat conditions, fish populations, bank cover, and macroinvertebrate populations will be collected. Hydrologic conditions of the stream will be examined for width/depth ratio, channel cross-section, gradient, sinuosity, bed material composition (pebble counts), and stream bank material composition. Water quality data (temperature, dissolved oxygen, and fecal coliforms) will be collected.

The data collected will be used to monitor riparian areas. Permanent end points for the transects will be established and the sites will be remeasured at 3-year intervals. Permanent monitoring locations will be used to evaluate effects of multiple use management activities on riparian areas.

Discussion. The inventorying and monitoring of riparian areas provide an interdisciplinary approach to management of soils, landform, water, wildlife, recreation, fishery and livestock. The inventory also serves as a tool to help others (ranchers, other agency personnel, etc.) to understand the ecological relationships and possibilities for riparian areas.

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Reports: On file at office.

Coeur d'Alene Unit Project, Idaho

Site Description. Plum Creek Timber Company initiated a monitoring program which evaluated and documented the effects of forest management operations on the aquatic ecosystem in 1985. Two drainages have been selected for monitoring. These are Prospector Creek (a tributary to the St. Joe River near Avery, Idaho) and the Middle Fork of Calispell Creek (a tributary to the Pend Oreille River near Newport, Washington). These streams were selected because they are representative of the Coeur d'Alene unit and have had relatively little past lumbering activity.

Calispell Creek, running through the Kaniksu National Forest, joins the Pend Oreille River in the northeastern corner of Washington. The topography is gentle, with a maximum elevation in the watershed of 1,600 m (5,256 ft). Precipitation is moderate, 75 to 100 cm (30 to 40 in) a year. Deep glacial deposits overlay granitic bedrock. Features of Prospect Creek are similar.

Beneficial Use. The primary beneficial use for both creeks is fishing.

Monitoring. The goal of the monitoring program is to document and evaluate water quality or aquatic ecosystem changes which may occur as the result of forest management activities. Sampling of each site included aquatic insects (Surber Sampler), waterflow (staff gage), water chemistry (alkalinity, dissolved oxygen, conductivity), channel substrate (modified McNeil sampler), water temperature, weather conditions, and water velocity. Each stream was sampled four times in 1987 (April, June, August, and October). Samples were collected at the Prospect Creek site for analysis of water chemistry by the Idaho Department of Health and Welfare.

Analysis of data will be done by using indices to evaluate invertebrate populations. Tolerance quotient (TQA), species diversity, density, functional groups, and species composition represent the different quantitative and qualitative techniques for data analysis.

Discussion. The use of aquatic insects to monitor water quality is a relatively new technique that is being assessed in this project. Similar projects currently operating are the Gallatin Project near Bozeman, Montana (since 1982) and the Naches Project near Yakima, Washington (since 1986).

Additional Information.

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Reports: Hess (1987).

Three Mile Creek Project, Washington

Site Description. Three Mile Creek is a small tributary of the Pend Oreille River, Colville National Forest, in northeast Washington. The sampling site is located on Three Mile Creek at the forest boundary. A timber sale was scheduled to occur in the watershed during 1987, but has been temporarily postponed.

Summers are warm or hot, with the average daily temperature around 27°C (81°F); while winters tend to be cold, averaging -1°C (30°F). Precipitation occurs in the mountains throughout the year, with an average seasonal snowfall of 75 cm [30 in], and usually supplies sufficient water for the agriculture in the area. The annual precipitation is about 75 cm (30 in). Coniferous stands are Ponderosa pine, lodgepole pine, white pine, grand fir, Douglas-fir, western larch, western red cedar, and western hemlock.

Beneficial Use. Timber is the primary product of the area.

Best Management Practices. Timber management will use BMPs to protect water quality and site productivity.

Monitoring. The objective is to determine if the conduct of the Three Mile timber sale will cause any noticeable change in water quality in Three Mile Creek and, if so, what specific activity caused the change.

The parameters measured are stream temperature, specific conductivity, total dissolved solids, and turbidity. Other parameters will be measured for fisheries needs if significant changes are noticed in the above four parameters.

Precipitation data are collected at Boundary Dam. These data are used to relate changes in water quality to precipitation events. An activity log of road building and timber harvesting will be kept to help identify any sources of accelerated sedimentation.

Stream temperature is recorded continuously with a submersible thermograph during July, August, and September. This allows analysis of daily maximums and diurnal fluctuations. Water samples taken every 6 hours are composited daily using an ISCO automatic sampler and analyzed for turbidity, suspended sediment, pH, and dissolved oxygen.

Discussion. The Three Mile Timber Sale is scheduled to sell in 1991 and baseline data are currently being gathered.

Additional Information.

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Reports: On file at Forest Supervisor's Office, Colville, WA.

Horse Creek Project, Idaho

Site Description. The project area is located in the Selway Ranger District, Nez Perce National Forest. Horse Creek flows east into Meadow Creek, part of the Selway and Clearwater River system. The Horse Creek watershed is approximately 3,100 ha (7,700 ac) in size, with instrumented subdrainages ranging in size from 24-148 ha (58-365 ac). Elevations range from 1,253 m (4,110 ft) to 1,836 m (6,025 ft). Grand fir is the predominate tree species; other species include Douglas-fir, western red cedar, Engelmann spruce, and Pacific yew. Climate and topography are typical of much of northern Idaho, eastern Washington, and western Montana. Steep slopes and erodible soils present a challenge to land managers concerned with protecting streams, spawning beds, and the total forest ecosystem.

Beneficial Use. The project area is reserved for studies designed to develop and test practices that can be implemented to reduce the impacts of road construction and timber harvesting on sensitive areas.

Best Management Practices. To minimize road mileage and ground disturbance, steeper subdrainages were logged with skyline equipment. Differences in sediment production and streamflow were recorded and compared to other methods, such as ground skidding and helicopter logging.

The information gathered from studies being conducted in Horse Creek will be used in developing land management plans in other areas. Topics of investigation are transportation systems, sedimentation, hydrology, logging engineering, water chemistry, and aquatic biology.

Monitoring. The Horse Creek watershed is part of a larger area that was designated a "barometer watershed" in 1964. Since that time, climate, vegetation, streamflow, and water quality have been measured to provide an extensive base of information about natural processes on the site. Additional attention is given to monitoring water quality, streamflow and sedimentation before, during, and after each phase of the job.

The project's objectives are to: 1) measure the effects of forest road construction and timber harvest on water quality, streamflow, and sediment production; 2) evaluate the physical and economic feasibility, and associated environmental effects of alternative road designs and harvesting systems; and 3) develop improved capabilities to predict the physical and environmental consequences of alternative practices.

Monitoring of climate, streamflow, and sediment began in 1965. Roads were built in 1978 and timber harvest began in 1981. Monitoring will continue through 1988. One subdrainage remained undisturbed as a control, while timber was harvested from the nine remaining subdrainages. Roads were constructed across six subdrainages. A network of instruments continuously record climatic variables and streamflow throughout the study area. Eight climatic stations record precipitation, air temperature, humidity, and other meteorological information. Snow depth and water content are measured during winter months. Streamflow and sediment monitoring installations are located in ten subdrainages with the Main Fork of Horse Creek.

Discussion. Hydrologic responses to road building in six small headwater watersheds were highly variable. Actual changes in flow could not be detected on four watersheds after road construction. Similar results occurred on two other watersheds which were significantly altered after road construction.

Additional Information.

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Reports: King and Tennyson (1984).

Silver Creek Project, Idaho

Site Description. The Silver Creek Experimental Area is located within the Emmett Ranger District of the Boise National Forest in the headwaters of the Silver Creek drainage, a tributary to the Middle Fork of the Payette River. Approximately 932 ha (2,300 ac) are included in the study area. Field studies are being conducted on eight small, unlogged watersheds ranging in size from 26-202 ha (64-500 ac).

The site is representative of much of the range in conditions found in the Idaho batholith. Soils range in depth from about 127 cm (50 in) in the lower portions of the watersheds to less than 25 cm (10 in) in the drainage heads. Elevations range from 1,370-1,830 m (4,500-6,000 ft). Ponderosa pine, Douglas-fir, and grand fir are the dominant tree species in the existing timber stands.

Covering about 41,400 sq km (16,000 sq mi) in central Idaho, the Idaho batholith spans large portions of eight National Forests. Much of the area is steep, with coarse granitic soil that tends to slide or wash away when the native vegetation is disturbed or removed. The climate can be desert-like in summer and arctic in winter.

Beneficial Use. The batholith contains a wealth of natural resources, and supports logging, grazing, tourism, wildlife, and fisheries. About 50 percent of the total water yield for the State of Idaho originates from the Idaho batholith.

Best Management Practices. Selected silvicultural alternatives have been used on individual watersheds. Alternatives were to clearcut all merchantable trees in units up to 10 ha, 2 ha, or 0.4 ha (25 ac, 5 ac, or 1 ac), or select cutting. One watershed was left undisturbed as a control.

The four alternatives cover the full range in opening sizes usually encountered in timber harvest operations in the batholith, and are representative of clearcutting, large and small grouped selection cuttings, and tree selection cutting. Slash was burned, or lopped and scattered.

Monitoring. The monitoring objectives of the study program were fourfold: 1) to evaluate the environmental impacts of logging methods, silvicultural systems, and associated road construction, both at harvest sites and downstream locations; 2) to evaluate the effectiveness of a variety of road designs and soil stabilization practices under various site conditions; 3) to compare costs and efficiencies of different logging and road construction practices; and 4) to provide basic data for development of models for predicting environmental, economic, and sociological effects of alternative management programs.

The Silver Creek Study began in 1961 and two of the watersheds were logged in 1976. The logging was completed in the autumn of 1987 and the site will continue to be monitored for 5 years.

The major areas of investigation are forest road design, construction and revegetation, harvesting systems and techniques, size of cut opening, site preparation, regeneration, productivity and residual stand responses. Biological parameters measured are wildlife responses to changes in habitat, aquatic insect activity, and plant succession and biomass. Streamflow, water quality, and sediment yields, stream channel characteristics, nutrients, and soil surface conditions are observed as well.

Discussion. Many studies have been conducted in the Silver Creek Experimental Area. One such study observed the erosional and chemical denudation rates over 11 years (Clayton and Megahan 1986). For three of the four watersheds studied, erosional denudation rates exceeded chemical denudation rates. On the fourth watershed, the rates were approximately equal. The relationship between annual water yield, erosional, and chemical denudation were explored. Chemical denudation is highly correlated with annual water yield. Erosional denudation rates are also related to increasing water yield, but are not as strongly correlated as chemical denudation.

Erosion rates on the study watershed were minimal because of the well developed forest cover. This condition is expected to change, due to man-caused accelerated erosion and natural disasters.

Additional Information.

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Reports: USDA Forest Service, Intermountain Forest and Range Experiment Station (no date).
Clayton and Megahan (1986).

South Fork Salmon River Project, Idaho

Site Description. The South Fork of the Salmon River drainage, part of the Columbia River Basin, comprises an area of 33,500 ha (826,700 ac). The watershed is almost entirely within the Idaho batholith. Approximately one-third of the land in the drainage lies within the Boise National Forest and about two-thirds is within the Payette National Forest.

Elevations range from 825 to 2,830 m (2,700 to 9,280 ft), with about half of the drainage in the 1,500-2,300 m (5,000-7,500 ft) class. The area is characterized by steep slopes with overstory vegetation dominated by Ponderosa pine and Douglas-fir at the lower elevations, and lodgepole pine, grand fir, Engelmann spruce, and subalpine fir at the higher elevations. The granitic bedrock of the batholith produces shallow, coarse-textured soils that exhibit high erosion rates, especially when exposed or disturbed.

Summers are typically hot and dry, with warm season precipitation occurring primarily during high-intensity thunderstorms. Winters are characterized by heavy snows and cold temperatures. Long-duration, low-intensity storms are common in fall, winter, and spring. Most of the annual precipitation falls as snow.

Beneficial Use. The South Fork basin has a wealth of resources involving minerals, recreation, timber, water, forage, wildlife, and fish. Annual water yields for the basin average 2 billion cubic meters (1,661,000 af). Several permit applications have been filed for hydroelectric development. The South Fork system supports fish populations of resident species, such as trout and char, and anadromous species including salmon and steelhead. Historically, the South Fork supported Idaho's largest population of summer chinook salmon, although populations have declined dramatically. The South Fork is considered particularly crucial as a source of spawning and rearing habitat for anadromous fish populations.

Monitoring. The South Fork of the Salmon River is one of the most intensively studied forested river basins in the United States. A comprehensive monitoring program was implemented to evaluate the effects of management activities through studies conducted at project sites, in tributary streams, and in the main stem of the South Fork. Timely feedback to land managers regarding existing or potential problems was an integral part of the monitoring process. In addition, the South Fork Salmon River Monitoring Committee, consisting of soil, water, and aquatic specialists from various concerned agencies and organizations, was established to review monitoring results and make recommendations. Parameters monitored are stream discharge, turbidity, bedload, suspended sediment, fish populations, macroinvertebrates, bacteria, temperature, pH, dissolved oxygen, conductivity, alkalinity, nitrogen, phosphorus, ions, and metals.

Discussion. The early monitoring efforts showed few major impacts from new land-use activities and evidences of habitat improvement. Land disturbances producing sediment were halted from 1984-1986 when some spawning areas failed to show continued improvement as measured by average particle size of streambed substrate. Sediment rates were stabilized at about 113 percent of background, and anadromous fish habitat was estimated to be 55 percent of potential. A hatchery program, improved downstream fish passage, and other mitigating measures are contributing to increasing fish populations. (Seyedbagheri et al. 1987).

Additional Information.

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Reports: An annotated bibliography has been compiled by Seyedbagheri et al. (1987) which includes the relevant published and unpublished reports on fishery and hydrology studies conducted in the South Fork of the Salmon River drainage.

Blue Mountains

Umatilla Barometer Watershed Project, Oregon

Site Description. The High Ridge Evaluation Area is located in the Blue Mountains, 18 km (11 mi) northeast of Elgin, Oregon. The area is approximately 227 ha (560 ac) in size and is comprised of four small watersheds: High Ridge One (HR1) is 30 ha (73 ac); High Ridge Two (HR2) is 24 ha (60 ac); High Ridge Three (HR3) is 53 ha (132 ac); and High Ridge Four (HR4) is 118 ha (292 ac).

Elevations in the High Ridge Evaluation Area range from 1,148-1,615 m (4,750-5,300 ft) above sea level. It is situated at the headwaters of Buck Creek, a tributary to the South Fork Umatilla River. Soils in the area are developed from parent material consisting of basalts and lacustrine sediments, and are silt loams. Slopes range from 2 to 25 percent. Timber species in the area consist of grand fir, subalpine fir, Douglas-fir, lodgepole pine, and Englemann spruce. Average annual precipitation is 134 cm (53 in), of which approximately 78 percent is in the form of snow.

Best Management Practices. The three watersheds were harvested by various harvest methods in 1976. One was selected as the control watershed and treatment was deferred. HR1 was clearcut in two blocks and 43 percent of the stand was removed. Half of each clearcut was planted with Englemann spruce and western larch in 1977. Fifty percent of the stand of HR2 was removed, and the watershed was not reforested. HR4 was clearcut in small patches removing 22 percent of the stand. The final watershed, HR3, was the uncut control.

Monitoring. Monitoring was conducted to determine the effect of timber harvest on water yield. Discharge was monitored from 1966 to 1982.

A second harvest of the watersheds, with a greater percentage of stand removal, was conducted in 1984. Ongoing monitoring included water temperature, flow, streambank stability, and water quality.

Discussion. There was a slight increase in annual stream flow after harvesting, and no difference in peak flow timing or magnitude when pre- and post-harvest runoff were compared. Results from the second harvest are not expected to become available until after at least 5 years of monitoring.

Additional Information.

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Chapter 4

ANALYSIS OF NONPOINT SOURCE MONITORING

This chapter evaluates and summarizes the current status of nonpoint source (NPS) monitoring efforts in the Pacific Northwest. Chapters 2 and 3 indicate that NPS control programs are collecting a wide range of data, although a number of projects collect baseline data only. If these less extensive programs were excluded, a large data base would be lost which would limit the usefulness of this report. The approaches and methods reported in Chapters 2 and 3 were given close analysis. This chapter:

- characterizes the current NPS monitoring approaches,
- assesses the relative degree of success of the current monitoring efforts in the Pacific Northwest, and
- summarizes the projects described in Chapters 2 and 3 in a matrix delineating the parameters measured for each project.

In association with this chapter, Appendix D reviews the monitoring techniques and comments on the advantages and limitations of some of these techniques.

Characteristics of Current NPS Monitoring Effort

The fundamental purpose of a monitoring program is to detect and measure change in the environment, although the sought after condition may be no change. Monitoring programs typically identify trends, i.e., change in an environmental parameter over time. Change is observed with respect to the achievement of management goals and regulatory standards. Characterization of environmental conditions by acquisition of time-dependent data is often a principal goal.

Data collected in the Pacific Northwest on NPS control programs have come from a mixture of monitoring, research, and NPS investigations. Most of the data are collected to identify sources and impacts of NPS pollutants and to help design appropriate BMPs; thus, the approach taken usually focuses on a specific objective or action. Monitoring for the purpose of identifying long-term trends in the environment is rare and usually associated with long-term research on experimental watersheds.

Types of Monitoring

Four types of monitoring are used in NPS programs: baseline, implementation, effectiveness, and validation. A generalized comparison of the comprehensiveness of these monitoring approaches is presented in Table 4-1.

Baseline Monitoring. Baseline monitoring typically involves the collection of data used to describe conditions before an action is taken. Ideally, baseline monitoring is conducted over a sufficient period of time to provide adequate data to estimate the natural variability that may occur. The purpose is to have the information necessary to distinguish effects induced by an action from naturally variable conditions.

In many of the NPS control programs that have been implemented in the Pacific Northwest, baseline monitoring has focused on collecting data that characterize seasonal changes in water quality; rarely are baseline data collected over the course of more than 1 year or on biological features of aquatic systems. It is unlikely that representative data can be obtained in only 1 year. Active exchange of data between projects within the same ecoregion may help project managers estimate variability. Often, "one-time" investigations are conducted to portray conditions and spatial variation at the time of sampling, particularly when a small area is thought to contribute a disproportionally large amount of pollution.

Most watersheds appear to have been investigated reasonably well to determine whether nonpoint source pollution is a serious problem, what the likely sources are, and which BMPs may be most appropriate. Extant physical and chemical data are often more than adequate for post-implementation monitoring, but biological data is of uncertain value.

Implementation Monitoring. Implementation monitoring ensures that required or agreed BMPs are actually implemented and maintained. Any tendency to assume that implementation monitoring need be done only once should be resisted. Land use practices are readily modified over time by social and economic conditions, particularly in the agricultural sector. As a result, implementation monitoring is particularly important to determine whether the BMP is being continued and maintained. The standard practice of USDA SCS is to annually inspect continued implementation of BMPs by farmers under PL-566 contract. Implementation monitoring is also an integral part of the USFS logging program.

Effectiveness Monitoring. Effectiveness monitoring is needed to document whether a BMP provides the intended protection to water quality and aquatic resources. Documentation of post-BMP conditions is especially important where compliance with environmental quality criteria or standards is required.

Table 4-1. Level of Effort for Monitoring Approach

	Baseline	Implementation	Effectiveness		Validation
			Selective	Intensive	
Cost	Moderate	Moderate	Low	High	High
Labor	High	High	Low	High	High
Technology	Moderate/ High	Low	Low	High	High
Time Frame	Varies	Varies	Long	Long	Long
Intensity of Effort	Moderate/ High	Low	Low	High	High
Scientific Training	Moderate/ High	Moderate	Low/ Moderate	High	High
# Parameters	Many	Few/ Moderate	Few	Many	Many

Note: Baseline monitoring is more extensive, demanding, and costly if the program is designed for intensive effectiveness or validation monitoring following BMP implementation.

Effectiveness monitoring requires pre-implementation (baseline) data and post-implementation monitoring data and analysis. Effectiveness monitoring is also useful to demonstrate recovery and rehabilitation of aquatic resources following implementation of BMPs.

Examples of effectiveness monitoring occur predominately on watersheds managed for research and development purposes (e.g., H. J. Andrews Forest and in Polk County, Oregon) and in projects involving long-term commitments of federal resources (e.g., the Rock Creek RCWP, the Moses Lake Clean Lake Project, the Silver Creek Project, and the Reynolds Creek Project). Effectiveness monitoring is typically costly.

Validation Monitoring. Validation monitoring is useful when theoretical analyses and numerical modeling were used to define the nature and magnitude of a problem and in projecting the response of the environment to BMP implementation. Data collection in this type of monitoring may be designed to refine model assumptions. Calibration and verification of mathematical models should occur prior to use of a model in compliance monitoring.

Types of Monitoring Parameters

Tables 4-2 and 4-3 summarize in matrix form the scope of environmental parameters incorporated in the NPS control activities described in Chapters 2 and 3. Projects are listed by ecoregion in the order used in Chapters 2 and 3. Page numbers are given for ease of reference to project descriptions. The parameters used in each monitoring program are given in the matrix.

Biological and Habitat. Biological indices used in the Pacific Northwest to assess NPS impacts include measurable features of riparian vegetation, fish populations, benthic macroinvertebrates, algae, and fecal bacteria. Certain BMPs are designed to protect and maintain riparian habitat.

Riparian vegetation as a habitat type provides benefits that include stabilization of stream banks, moderation of air and water temperature, fish and wildlife food and cover, and regulation of stream flow. Riparian habitat quality is commonly included in monitoring to assess the effects of grazing practices (Table 4-2). BMPs are often implemented to reestablish or improve riparian habitat types. BMPs to protect riparian habitat are important components in both silviculture and agriculture. Planted streamside vegetation is monitored (Tables 4-2 and 4-3), although changes in natural riparian vegetation are not commonly followed.

Monitoring the status of fish populations may be the most direct method of evaluating the success of NPS control programs because the majority of BMPs implemented in the Pacific Northwest

Table 4-2 Parameters and Techniques Used in Monitoring Agricultural Nonpoint Source Pollution

PROJECTS / PARAMETERS	Stream Discharge	Turbidity	Sediment	Channel Morphology	Substrate Composition	Riparian Habitats	Fish Population	Macro-invertebrate	Bacteria	Algae	Temperature	pH	Dissolved Oxygen	Conductivity	Salinity	Alkalinity	Nitrogen	Phosphorus	Carbon	Ions	Metals	Pesticides	MONITORING OBJECTIVES	PAGE
CONFINED ANIMAL AND FEEDLOT OPERATIONS																								
TILLAMOOK	X	X							X		X	X			X								● ▲ ✸	8
JOHNSON	X	X				Q1	Q1		X		X	X	X				N3	T					● ▲ ✸	10
NEWAUKUM	X	X	SS			Q1	Q1	X	X	X	X	X	X	X		X	A	T		X	X	X	● ▲ ✸	12
KAMM SLOUGH	X	X	SS		X	Q1	E		X		X	X	X	X		X	A,N2, N3	T					●	14
TENMILE	X	X	SS	Q1		Q1	E	Q1	X		X	X	X	X		X	A,N2, N3	T					●	16
SAMISH	X								X														●	17
SEQUIM									X													X	●	19
QUILCENE/DABOB	X								X		X				X								● ▲	19
SNOHOMISH		X	SS						X		X		X				N3						● ▲ ✸	21
CLOVER									X				X	X									●	23
TOTTEN	X		SS						X		X	X	X	X	X		?	?			X		●	24
BURLEY/MINTER	X	X	SS						X		X	X		X			A,N2 N3	T, oP					● ▲ ✸	25

X indicates standard technique (See Appendix D). Specific techniques identified as follows:

SS	suspended sediment	I	species identification	Ch	chlorophyll	N2	nitrite nitrogen
B	bedload	W	wood inventory	K	Kjeldahl nitrogen	oP	orthophosphate
V	overhang	E	electrofishing	A	ammonia nitrogen	T	total phosphorus
C	canopy	Sn	snorkeling	N3	nitrate nitrogen	H	hydrolyzable phosphorus
						O	organic phosphorus

Q1 qualitative analysis

? specific techniques not identified in information provided

Monitoring Objective: ● Baseline ▲ Implementation ✸ Effectiveness ✱ Validation

Table 4-2 Continued

PROJECTS	Stream Discharge	Turbidity	Sediment	Channel Morphology	Substrate Composition	Riparian Habitats	Fish Population	Macro-invertebrate	Bacteria	Algae	Temperature	pH	Dissolved Oxygen	Conductivity	Salinity	Alkalinity	Nitrogen	Phosphorus	Carbon	Ions	Metals	Pesticides	MONITORING OBJECTIVES	PAGE
COWEEMAN	X		SS						X		X	X		X			A						●	27
LACAMAS						?			X								K,A, N3	T					●	28
IRRIGATED FARMING																								
POLK COUNTY	X	X	X											X			A,N3	T					* *	29
BEAR			SS				Q1		X		X						?	?					●	30
KLAMATH	X				X		?	X			X	X	X	X						X	X	X	●	32
MOSES LAKE	X	X	SS							X,Ch	X	X	X	X			K,N2, N3	oP,T					● ▲ *	33
S. YAKIMA	X	X	SS	X	X		X	X	X		X	X	X	X		X	X	X	X	X		X	● ▲ * *	35
HARNEY/MALHEUR	X			Q1			?	X			X	X	X	X		X	N2, N3			X	X	X	●	37
ROCK CREEK - RCWP	X		SS	X	X	?	E	X	X		X	X	X	X			K,A, N2,N3	oP,T	X	X	X	X	●	38
DRYLAND FARMING																								
IDAHO AWQP	X	X	SS					X	X		X	X	X	X			K,A, N2,N3	oP,T					● ▲	41
PALOUSE	X	X															N2, N3						●	42

X indicates standard technique (See Appendix D). Specific techniques identified as follows:

SS	suspended sediment	I	species identification	Ch	chlorophyll	N2	nitrite nitrogen
B	bedload	W	wood inventory	K	Kjeldahl nitrogen	oP	orthophosphate
V	overhang	E	electrofishing	A	ammonia nitrogen	T	total phosphorus
C	canopy	Sn	snorkeling	N3	nitrate nitrogen	H	hydrolyzable phosphorus
						O	organic phosphorus

Q1 qualitative analysis

? specific techniques not identified in information provided

Monitoring Objective: ● Baseline ▲ Implementation * Effectiveness * Validation

Table 4-2 Continued

PROJECTS / PARAMETERS	Stream Discharge	Turbidity	Sediment	Channel Morphology	Substrate Composition	Riparian Habitats	Fish Population	Macro-invertebrate	Bacteria	Algae	Temperature	pH	Dissolved Oxygen	Conductivity	Salinity	Alkalinity	Nitrogen	Phosphorus	Carbon	Ions	Metals	Pesticides	MONITORING OBJECTIVES	PAGE
SOUTHEAST WASHINGTON			SS				E,Sn				X	X	X										●	44
GREASEWOOD			SS																				● ▲ ✱	45
TAMMANY	X	X	SS						X		X	X	X				A,N2, N3	T					●	46
PINE	X	X	SS						X		X	X		X			K,A, N2,N3	oP,H T					●	48
CANYON	X					C			X		X	X					K,A, N2,N3	oP					●	49
ROCK CREEK	X	X	SS					X	X		X	X	X	X			K,A, N2,N3	oP,T		X	X		●	50
GRAZING																								
FREMONT	X		SS	X		V,C, I		X			X		X										● ▲	52
EAST FORK SALMON RIVER	X			X	X	V,C	E,Sn				X												●	54
MEADOW	X			X					X														● ✱	55
BURNT		X	SS			V,C		X			X	X	X			X	N2, N3	oP,T	X	X			●	56
DOUGLAS						V,C, I,W																	●	58
JOHN DAY	X			X		V,C, I,W	?		X		X	X					N3	oP	X				● ▲ ✱	59

X indicates standard technique (See Appendix D). Specific techniques identified as follows:

SS	suspended sediment	I	species identification	Ch	chlorophyll	N2	nitrite nitrogen
B	bedload	W	wood inventory	K	Kjeldahl nitrogen	oP	orthophosphate
V	overhang	E	electrofishing	A	ammonia nitrogen	T	total phosphorus
C	canopy	Sn	snorkeling	N3	nitrate nitrogen	H	hydrolyzable phosphorus
						O	organic phosphorus

Ql qualitative analysis

? specific techniques not identified in information provided

Monitoring Objective: ● Baseline ▲ Implementation ✱ Effectiveness ✱ Validation

Table 4-2 Continued

PROJECTS \ PARAMETERS	Stream Discharge	Turbidity	Sediment	Channel Morphology	Substrate Composition	Riparian Habitats	Fish Population	Macro-invertebrate	Bacteria	Algae	Temperature	pH	Dissolved Oxygen	Conductivity	Salinity	Alkalinity	Nitrogen	Phosphorus	Carbon	Ions	Metals	Pesticides	MONITORING OBJECTIVES	PAGE
CROOKED	X			X	X	V,C, I		X	X		X	X	X	X				T					● ✸	61
UPPER TETON			SS,B	X		V,C	E,Sn																●	62
BLM RIPARIAN	X	X	SS	X		V,C	E	X			X	X	X	X									●	64
REYNOLDS	X	X	SS	X					X		X	X	X	X			K,A, N3	oP,T	X	X			● ▲ ✸	65

X indicates standard technique (See Appendix D). Specific techniques identified as follows:

SS	suspended sediment	I	species identification	Ch	chlorophyll	N2	nitrite nitrogen
B	bedload	W	wood inventory	K	Kjeldahl nitrogen	oP	orthophosphate
V	overhang	E	electrofishing	A	ammonia nitrogen	T	total phosphorus
C	canopy	Sn	snorkeling	N3	nitrate nitrogen	H	hydrolyzable phosphorus
						O	organic phosphorus

Ql qualitative analysis

? specific techniques not identified in information provided

Monitoring Objective: ● Baseline ▲ Implementation ✸ Effectiveness ✱ Validation

Table 4-3 Parameters and Techniques Used in Monitoring Silvicultural Nonpoint Source Pollution

PROJECTS / PARAMETERS	Stream Discharge	Turbidity	Sediment	Channel Morphology	Substrate Composition	Riparian Habitats	Fish Population	Macro-invertebrate	Bacteria	Algae	Temperature	pH	Dissolved Oxygen	Conductivity	Salinity	Alkalinity	Nitrogen	Phosphorus	Carbon	Ions	Metals	Pesticides	MONITORING OBJECTIVES	PAGE
INDIAN RIVER	X	X	SS,B																				●	68
KADASHAN RIVER	X		SS,B																				●	70
AUKE BAY LAB.	X			X	Q1	C,I, V,W	E	X		?	X												● ▲	71
CARNATION CREEK	X	X	SS,B	X	X		E,Sn	X		X	X					X	N3		X				● ▲ ✱	74
OLYMPIC		X		Q1	?	?	E				X												● ▲ ✱	76
CLEARWATER RIVER	X	X	SS	X	X	X	E	X															● ▲	78
ALSEA RIVER	X		SS		X	X	X		v		X		X										● ▲ ✱	79
SIUSLAW RIVER	X	X	SS	Q1		V			X		X			X									●	81
COOS BAY DISTRICT		X	SS,B	Q1	?	C	X	X			X	X	X	X									●	82
ELK RIVER	X		SS	X		X	X				X												● ▲ ✱	84
SISKIYOU	X	X				V,C, W	?				X											X	● ▲ ✱	86
LAKE WHATCOM		X						X	X	X,Ch	X	X	X	X		X	A,N2 N3	T,O	X	X	X	X	● ▲ ✱	88
CAPITOL FOREST	X		SS								X												●	89

X indicates standard technique (See Appendix D). Specific techniques identified as follows:

SS suspended sediment
B bedload
V overhang
C canopy

I species identification
W wood inventory
E electrofishing
Sn snorkeling

Ch chlorophyll
K Kjeldahl nitrogen
A ammonia nitrogen
N3 nitrate nitrogen

N2 nitrite nitrogen
oP orthophosphate
T total phosphorus
H hydrolyzable phosphorus
O organic phosphorus

Q1 qualitative analysis

? specific techniques not identified in information provided

Monitoring Objectives: ● Baseline ▲ Implementation • Effectiveness ✱ Validation

Table 4-3 Continued

PROJECTS \ PARAMETERS	Stream Discharge	Turbidity	Sediment	Channel Morphology	Substrate Composition	Riparian Habitats	Fish Population	Macro-invertebrate	Bacteria	Algae	Temperature	pH	Dissolved Oxygen	Conductivity	Salinity	Alkalinity	Nitrogen	Phosphorus	Carbon	Ions	Metals	Pesticides	MONITORING OBJECTIVES	PAGE
ENTIAT RIVER	X	X	SS								X	X		X		X	A,K, N3	T		X			● ▲	90
GOAT CREEK	X	X	SS	Q1		Q1																	●	92
WILLAME CREEK		X		Q1		C					X												● ▲ ✹ ✱	93
WIND RIVER	X																					X	● ▲ ✹	94
BULL RUN	X	X	SS	X		W,V, C			X	X,Ch	X	X	X	X		X	K,A, N3	oP,T	X	X	X	X	● ▲ ✹	96
MIDDLE SANTIAM	X	X	SS	Q1							X												●	98
H.J. ANDREWS	X	X	SS,B	X	X	V,C, I	E,Sn	X		X	X	X	X	X	X	X	K,N2 A,N3	oP,T	X	X			● ▲ ✹ ✱	100
UMPQUA	X	X	SS				E,Sn	X	X		X										X	X	●	102
EVANS CREEK	X	X	SS	X	Q1	V,C, I	E	X	X	X,Ch	X	X	X	X			K,N2 A,N3	oP,T	X	X			● ▲ ✹	103
IDAHO STATE			SS		Q1																		● ▲ ✹ ✱	105
BOISE				X	X																		● ▲ ✹ ✱	107
SAWTOOTH				Q1		V,C, I,W	E	X	X		X		X									X	● ▲	109
COEUR D'ALENE	X				Q1			X				X		X		X							●	110

X indicates standard technique (See Appendix D). Specific techniques identified as follows:

SS	suspended sediment	I	species identification	Ch	chlorophyll	N2	nitrite nitrogen
B	bedload	W	wood inventory	K	Kjeldahl nitrogen	oP	orthophosphate
V	overhang	E	electrofishing	A	ammonia nitrogen	T	total phosphorus
C	canopy	Sn	snorkeling	N3	nitrate nitrogen	H	hydrolyzable phosphorus
						O	organic phosphorus

Q1 qualitative analysis

? specific techniques not identified in information provided

Monitoring Objectives: ● Baseline ▲ Implementation ✹ Effectiveness ✱ Validation

Table 4-3 Continued

PROJECTS \ PARAMETERS	Stream Discharge	Turbidity	Sediment	Channel Morphology	Substrate Composition	Riparian Habitats	Fish Population	Macro-invertebrate	Bacteria	Algae	Temperature	pH	Dissolved Oxygen	Conductivity	Salinity	Alkalinity	Nitrogen	Phosphorus	Carbon	Ions	Metals	Pesticides	MONITORING OBJECTIVES	PAGE
THREE MILE CREEK	X	X	SS								X	X	X	X									● ▲ ◆	111
HORSE CREEK	X		SS,B	X	X		E	X		Ch	X					X	N3	T					● ▲ ◆ ✱	113
SILVER CREEK	X		SS,B	X	X	C		X			X	X		X		X	A,N3	oP		X	X		● ▲ ◆ ✱	114
SOUTH FORK SALMON	X	X	SS,B	X	X		E,Sn	X	X		X	X	X	X		X	K,N2 A,N3	oP, T,P		X	X		● ▲ ◆ ✱	116
UMATILLA	X			X							X	X	X	X									● ▲ ◆	118

X indicates standard technique (See Appendix D). Specific techniques identified as follows:

SS	suspended sediment	I	species identification	Ch	chlorophyll	N2	nitrite nitrogen
B	bedload	W	wood inventory	K	Kjeldahl nitrogen	oP	orthophosphate
V	overhang	E	electrofishing	A	ammonia nitrogen	T	total phosphorus
C	canopy	Sn	snorkeling	N3	nitrate nitrogen	H	hydrolyzable phosphorus
						O	organic phosphorus

Ql qualitative analysis

? specific techniques not identified in information provided

Monitoring Objective: ● Baseline ▲ Implementation ◆ Effectiveness ✱ Validation have protection and restoration of fish as the prime objective. Fish populations were sampled in 38 percent of the agricultural and in 31 percent of the silvicultural projects described (Tables 4-2 and 4-3). Some of these observations included assessments of size of fish populations or magnitude of fishing activity.

The composition of benthic invertebrate communities is monitored in some NPS programs relating to agricultural and silvicultural practices (Tables 4-2 and 4-3) east of the Cascades. Benthic invertebrates are used as an index of both water and fish habitat quality. Variance in data results in difficulties in interpretation of statistical significance of changes or trends.

Monitoring of algal populations in relation to NPS control programs occurs primarily in lakes or streams where nutrient impact may cause excessive eutrophication or nuisance conditions. Algae are also monitored in comprehensive programs, and where the water supplies a municipality and taste and odor could be a nuisance (e.g., Bull Run).

Bacterial enumerations, particularly fecal coliforms, are common in projects involving confined animal and feedlot operations and rangeland management (Table 4-2). This is expected since a major objective of BMPs in such situations is to reduce fecal coliform contamination of streams, lakes, and estuaries. Water quality standards typically include limitations to contamination by fecal coliform bacteria. Bacterial contamination is used as an indicator of risk to human health from exposure to pathogenic bacteria and viruses. Fecal coliform levels become especially meaningful when NPS discharges enter water containing harvestable shellfish.

Physical. Physical measurements made in NPS assessment and control programs include: flow, turbidity, suspended sediments, substrate embeddedness, pH, dissolved oxygen, and temperature. Other key aquatic habitat parameters used in the Pacific Northwest in assessing NPS impacts include channel morphology, stream substrate composition, presence or absence of large organic debris, and pool-riffle ratios. All of these physical parameters can be indicators of the quality of fish habitat and are commonly used as indices of impacts on biota. Flow, temperature, pH, dissolved oxygen, conductivity, and suspended solids data are basic needs in assessing the ecological significance of water chemistry conditions.

Flow, turbidity, suspended sediments, and temperature are measured in almost all NPS assessment and control programs (Tables 4-2 and 4-3). The majority of BMPs developed and implemented in the region are designed to control erosion, either to reduce the loss of topsoil or to protect and enhance fish habitat. Thus, the common demonstration of effectiveness of BMPs includes reductions in turbidity and levels of suspended sediments. Analyses of stream sediment characteristics and channel morphology are commonly done in the silvicultural sector but to a lesser extent than turbidity and suspended sediment because of costs in collecting field data and interpreting results.

Chemical. A variety of water chemistry parameters are included in NPS monitoring programs, because federal and state water quality standards set limits on water chemistry, and because of the value of measurements in demonstrating environmental quality. In the agricultural sector (Table 4-2), measurement of nutrients is a common aspect of monitoring. Measurements of standard mineral and dissolved solids levels are frequent in NPS programs relating to dryland and irrigated agriculture.

Silvicultural programs (Table 4-3) show less variation in the lists of chemical parameters that are included in water quality analyses. Silvicultural BMPs in Alaska, Idaho, Oregon, and Washington meet or exceed the FPAs established by the states. The FPAs enforce rules that are most often tied to a reduction or prevention of erosion and the maintenance of natural water chemical and temperature characteristics. In the majority of cases, FPA standards and BMPs are designed to protect fish and wildlife habitat quality.

Chemical measurements for toxic substances, especially pesticides, associated with agriculture and silviculture are of increasing concern. These substances are likely to occur more often in the future in baseline and effectiveness monitoring.

Beneficial Use. Monitoring changes in beneficial uses, following full implementation of BMPs, has generally not been included in NPS control programs in the Pacific Northwest, perhaps because it is assumed that once the water quality standards are met, beneficial uses will be protected or restored. Exceptions are NPS control programs designed to reopen commercial shellfish beds (such as Tillamook Bay, and Burley-Minter Creeks). Additionally, some information on recreational fishing is compiled by state fisheries agencies, although these data are rarely collected as part of an NPS control program.

Changes in fishing activity can be measured when a fisheries resource assessment is part of a stream habitat enhancement program (e.g., those funded by the Northwest Power Act through Bonneville Power Administration). These assessments could provide useful baseline data for post-implementation evaluations when habitat enhancement involves BMPs directed at nonpoint sources (e.g., grazing practices in the Upper Teton River Valley in Idaho).

Groundwater. In some locations, groundwater quality is monitored as part of NPS control programs in the Pacific Northwest. Projects with a planned groundwater monitoring program associated with BMP implementation are: Thurston County, Washington (confined animal systems); Polk County, Oregon, and the

Rock Creek RCWP (irrigated cropland); and Crooked River, Oregon and Reynolds Creek, Idaho (grazing land). The latter program, however, focuses primarily on geohydrology and water budgets on the watershed, rather than quality of groundwater. A limited amount of groundwater sampling has occurred in the region to examine the effects of herbicide application on timberlands and transmission line rights-of-way, but these monitoring programs usually fall under the category of vegetation management programs rather than NPS control programs.

The impact of specific BMPs on groundwater is being researched at the Institute of Watershed Studies at Western Washington University (Gayden pers. comm.) and by the USDA SCS in King County, Washington (Fitch pers. comm.). Investigative work is being conducted by the USGS as part of its review of water quality conditions in irrigation drainage projects in the western states.

Common Monitoring Techniques

Appendix D describes common techniques used to collect and analyze biological, physical, and chemical data and discusses some of the advantages and limitations of the various techniques. In general, standard procedures are well established for measuring water chemistry and little variation in technique occurs. There is, however, great variability in techniques for measuring physical and biological characteristics.

Assessment of Current NPS Monitoring Efforts

An important distinction between silvicultural and agricultural land-use is reflected in baseline monitoring efforts. Baseline monitoring of silvicultural land produces information on a relatively undisturbed system about to be dramatically altered. Baseline monitoring of agricultural systems produces information about land altered by years of seasonal use.

Agricultural NPS Control Programs

The most common form of monitoring in the agricultural sector establishes baseline water quality conditions. Baseline data are collected to identify the characteristics of water quality and degree of pollution (as defined by established water quality standards). Data are used to target farms that have particularly severe NPS pollution problems. Much of the monitoring undertaken through the Idaho State Agricultural Water Quality Program, for example, is baseline monitoring. Baseline monitoring programs vary significantly in their design in the agricultural sector.

Irrigated and Dryland Agriculture. Two-thirds of the projects described in this review collected baseline data only. At a minimum, suspended sediment and flow data were collected, although most studies were more extensive. Most included chemical measurements and a few studied biotic and physical parameters (Table 4-2). The Idaho State Agricultural Water Quality Program includes one of the more intensive baseline monitoring efforts; data are collected for approximately 1 year.

Effectiveness of BMPs applied to dryland and irrigated farmland is not commonly monitored in the Pacific Northwest. In part, this may be due to the nature of these BMPs, most of which focus on erosion control. Historically, these BMPs have aimed primarily at "soil conservation" and less at protection of water quality and fish habitat. In dryland agriculture, specific BMPs are linked to a reduction in soil erosion as calculated by the Universal Soil Loss Equation (USLE). Generally, effectiveness of BMPs on dryland and irrigated farmland, if it is evaluated with respect to aquatic systems, focuses on physical and chemical attributes of surface water. Effectiveness monitoring is an important part of the Rock Creek RCWP in Idaho, of the Moses Lake Clean Lake Project in Washington, and of the South Yakima River Project in Washington.

Grazing and Range Management. Forty percent of the projects reviewed in this report monitored the effectiveness of specific BMPs (e.g., John Day River, Meadow Creek). All of the projects include not only typical physical and chemical measures, but also assessment of change in riparian habitat or fish communities (Table 4-2).

Confined Animal and Feedlot Operations. BMP implementation monitoring is common for confined animal (e.g., high density pasture) and feedlot operations of farmers involved in cost-sharing programs. Monitoring effectiveness of BMPs, however, occurs for only a fraction of those installed and is generally executed at the project level. Fecal coliforms, nutrients, temperature, and flow are often the minimum monitoring program in confined animal and feedlot operations (Table 4-2).

Silvicultural NPS Control Programs

The majority of BMPs on timberlands are designed to reduce erosion and sedimentation in streams. In most cases, BMPs are incorporated into state FPAs and therefore required on private timberlands and state lands in Washington, Alaska, Idaho, and Oregon. The Washington Department of Natural Resources follows its own set of BMPs on state lands which meet or exceed the FPAs. A limited amount of effectiveness monitoring occurs at the local level on timberlands.

Of the silvicultural programs reviewed in Chapter 3, the most intensive monitoring of BMP effectiveness is done by universities in cooperation with USFS research stations on experimental watersheds. The data collected at H.J. Andrews Experimental Forest, for example, date back to 1948. The monitoring of the watershed rehabilitation program on the South Fork Salmon River was implemented in conjunction with a 1965 moratorium on logging and road construction. The Silver Creek and Horse Creek projects in Idaho, operated by the USFS, provide extensive data on timber harvest practices and effects of road construction. Bull Run Watershed, the main water source for Portland, Oregon, is monitored extensively due to public interest in water quality.

Success of Effectiveness Monitoring Programs

The a priori objectives of a project must be clearly defined to determine whether the project was successful or not. For example, an objective can be very localized, such as reducing the NPS pollution from one farm (e.g., Sequim Bay) or a large-scale attempt to reduce NPS pollution from a watershed (e.g., the Palouse Watershed). The project objectives may be to improve the water quality in a few selected criteria (e.g., the Little Greasewood and West Fork Greasewood Project) or to more generally improve or increase the beneficial uses of the water (e.g., Moses Lake).

Successful Effectiveness Monitoring. The Johnson Creek Project in Washington is unusual in its low-technology evaluation of the effectiveness of the NPS control program. Local landowners played a large role in setting the objectives and carrying out the monitoring program. The farmers and a representative from the local soil conservation office walk the stream bank annually, noting qualitative changes in riparian vegetation, bank stability, water appearance, and fish use. Although the information obtained is not quantitative, it is sufficient to support the conclusion that the objectives established by local landowners have been met. Furthermore, local farmers have "pride of ownership" in the monitoring program. However, both the farmers and the local SCS officials believe that more extensive and traditional quantitative monitoring of the water chemistry should be undertaken by DOE to confirm the perceived improvement in water quality.

Other noteworthy, successful effectiveness monitoring programs include three major undertakings involving substantial participation by federal, state, and local agencies. These include the Rock Creek RCWP (irrigation land in Idaho), the Moses Lake Clean Lake Project (irrigation land in Washington), and the Crooked River Project (grazing land in Oregon). These projects have undergone extensive phases of planning, starting with careful definition of problems and collection of extensive baseline data, and continuing through designing experimental tests of various BMPs and frequent reevaluation of progress. The Reynolds Creek Experimental Watershed in southwest Idaho is operated by the USDA Agricultural Research Service and focuses on range management and grazing practices in high desert habitat. This research program also offers a substantial amount of data on the effectiveness of BMPs.

Unsuccessful Effectiveness Monitoring. Monitoring the effectiveness of BMPs at the watershed level appears to be less successful than monitoring effectiveness of specific BMPs implemented on a definable site. For example, the Little Greasewood and West Fork Greasewood Creeks Project noted the effectiveness of BMPs where they were applied, but no change was seen in suspended sediments at the mouth of the watershed. (Perhaps suspended solids are not an appropriate indicator for effectiveness.) Similarly, the Totten/Henderson/Eld Inlets Project and Burley/Minter Project were expected to reduce fecal coliform levels in their respective estuaries to levels that would allow commercial shellfish harvest. Commercial shellfish harvesting is still not permitted due to high fecal coliform counts. If, however, a BMP is implemented with the stated objective of reducing a farm's contribution to bacterial levels in an adjacent stream, it is rare to find failure.

Silvicultural projects frequently include measurements of turbidity or suspended sediments. Extensive research at Bull Run Watershed has shown these parameters to be very important indicators of BMP efficacy. However, several projects have found their baseline data to be highly variable, and impacts due to logging were masked by the statistical variance (e.g., Indian River Project, Alaska and Olympic National Forest, Washington). The placement of the sampling station is also critical to the finding of water quality impacts (e.g., Middle Santiam River Project, Oregon).

Summary

Chapter 4 and Appendix D are intended to complement each other. Chapter 4 discusses monitoring programs in general and the broad categories of projects undertaken in the Pacific Northwest. Appendix D reviews and evaluates the techniques generally used in monitoring projects.

The broad categories of monitoring parameters included biological, habitat, physical, and chemical. The specific techniques are described in further detail in Appendix D. Monitoring beneficial use and groundwater occurs rarely, although neither are generally included in existing programs.

This chapter provides a broad overview of monitoring programs before concentrating on the characteristics of current NPS efforts in the Pacific Northwest. Baseline monitoring, the collection of data to describe conditions before an action is taken, is regularly undertaken, often as a mix of monitoring and investigation. It commonly incorporates physical and chemical parameters rather than biotic. Implementation monitoring, to ensure the BMPs are implemented and maintained, is an integral part of silvicultural (required by the Forest Practices Acts) and PL-566 agricultural programs. Effectiveness monitoring, designed to understand whether the BMP is having the desired effect on water quality, is costly and is most often conducted on experimental watersheds. Validation monitoring, conducted when mathematical models played a major role in defining the NPS problem, is more complete and specific than effectiveness monitoring and is generally found only in research projects.

Finally, the current effectiveness monitoring efforts for each land use type is addressed. Irrigated and dryland agriculture tend to rely on water column chemistry analyses. Grazing projects focus on riparian management, often using a photographic record, channel morphology, and biota. Confined animal and feedlot operations tend to measure water column bacteria and nutrients, and usually identify specific farms as a quasi-point-source needing BMPs. Silvicultural projects are regulated by the FPAs which determine the BMPs, identify the probable results, and set minimum monitoring schedules. In each land use category, there are large and long-term projects gathering validation data or defining the effectiveness of specific BMPs.

Chapter 5

RECOMMENDED GUIDELINES FOR MONITORING EFFECTIVENESS OF NONPOINT SOURCE CONTROLS

Introduction

Best Management Practices are usually derived from empirical knowledge gained from observing a cause-effect relationship between an activity and the degradation of a natural resource. For example, observing streambanks that are freely accessible to cattle and comparing them with protected streambanks leads to obvious conclusions about how to protect riparian habitat and water quality. The idea, therefore, is to change the activity in ways that avoid or abate the degradation and still allow the accrual of benefits from the activity. The prescribed element of the activity that avoids or abates the degradation is the BMP.

In some instances the relationship between use of a BMP and protection of a resource is clear and measurable, while in other instances it may be masked by other conditions and events and thus be theoretical in description. Deciding where the BMP/effect-on-natural-resource relationships fall on the continuum, from clear to purely theoretical, significantly influences the design of a monitoring program and is given consideration in the following text. The availability of technology to produce and interpret data and the cost are also important considerations.

Previous chapters presented information on BMPs pertaining to agricultural and silvicultural and associated monitoring programs. Four types of monitoring were defined in Chapter 4: baseline, implementation, effectiveness, and validation. All four types are interrelated and may appear together or singly in particular monitoring programs. Guidelines for the selection and use of these monitoring types are identified and discussed in this chapter; however, emphasis is placed on effectiveness monitoring, which is subdivided into selective and intensive levels of effort.

General Considerations

It is generally assumed that the proper implementation of an appropriate BMP will avoid or abate the pollution or other adverse effects for which the BMP is prescribed. This assumption seems acceptable because of the empirical knowledge used in the prescription of a BMP. Monitoring can therefore fulfill different functions in the protection of aquatic resources with various land uses and related BMP programs. (Forest Practice Act Regulations are synonymous with BMPs for the purposes of this discussion.)

Baseline monitoring data may influence the determination of need for different BMPs and also establish the starting condition from which to measure change. Implementation monitoring determines whether required BMPs were actually applied as prescribed and subsequently maintained over time. Effectiveness monitoring can demonstrate the degree of protection and, when appropriate, the restoration derived from BMPs; or conversely the failure of BMPs to achieve the intended objective and goals. Validation monitoring may serve to refine assumptions or the selection of input data used in models that project desired results based more on theory than empirical knowledge.

It is evident that all four types of monitoring must be considered and evaluated in view of the specific conditions and circumstances of each monitoring program. The planning and design effort in establishing a monitoring program should initially identify and describe concise objectives and goals. Monitoring activities thereafter become the strategy and tactics to achieve objectives.

Statement of Objectives

To generate an objective, the problem to be addressed must first be defined. In the context of this report, the environmental problem tends to be defined by the environmental need for the use of a BMP. A BMP prescribing water bars on logging roads may abate erosion (problem), the transport of fine sediment into streams (problem), and the siltation of salmonid spawning habitat (problem). The monitoring response may be to ascertain that water bars are installed as prescribed (implementation monitoring), observation for evidence of gully erosion (effectiveness monitoring), and quantitative analysis of spawning gravels for percent of materials less than 1 millimeter (0.04 in) in diameter (effectiveness monitoring).

In this particular case, the general nature of the problem is accelerated soil erosion which may have adverse effects on salmonid spawning gravels. The BMP is one remedial action. Monitoring must determine results of the action; objectives can state what is intended to result from the BMP; and the elements constituting the monitoring measure or give evidence about the occurrence of the intended result.

A stated objective relative to monitoring a BMP should fulfill certain rules of formulating objectives:

1. state fully what the monitoring is intended to accomplish,

2. exclude from the statement what will not be accomplished, and

3. specify a goal or endpoint so progress or attainment can be determined.

An objective may be worded in performance terms.

The objective statement for monitoring in the example case may be: **to measure the effectiveness of environmental protection afforded by prescribed water bars on:**

1. **soil loss by runoff erosion,**

2. **change in percent of fines less than 1 millimeter in diameter in spawning gravel immediately downstream, and**

3. **turbidity greater than 25 NTU 48 hours following storm events.**

This objective statement conforms to the three guidelines. Monitoring is intended to accomplish measurements that define in comparable ways the effectiveness of the BMP. The monitoring would use standard methods to measure and record parameters directly related to soil erosion. It would also have a direct relationship to the BMP if the stream is responding only to the perturbations causing the BMP to be implemented. If soil erosion is wide-spread and from different causes, the instream monitoring becomes less discrete and must be evaluated with respect to the influences of other sources.

In the more complex situation, the objective may be stated differently: **to measure the effectiveness of <u>specified</u> BMPs in the restoration and protection of spawning gravels and fishing in a <u>named</u> creek between points x and y:**

1. **reduce the percent of fines (< 1 millimeter [0.04 in] in diameter) in spawning gravels to below 10 percent, and**

2. **reduce turbidity to less than 25 NTU 48 hours following storm events.**

In cases where there is a program to abate erosion using several BMPs over a large watershed, the effects become cumulative and may not be discernable and related to any one BMP or parcel of land. Monitoring strategies may require the combined efforts of baseline monitoring to develop the base from which to measure change, implementation monitoring to document the application and maintenance of BMPs, and direct measures of accomplishment by demonstrating changes in percent fines in spawning gravel and rate of clearing of water after storm events.

Well formulated statements of objectives lead to savings of time and money. They also make it possible to evaluate and interpret data collected during the monitoring operation.

Monitoring data must be collected for a purpose and be related to the accomplishments for environmental maintenance or change intended by implementation of the BMP.

Recommended Approaches to Effectiveness Monitoring

It is recommended that all NPS control programs include elements of baseline, implementation, and effectiveness monitoring. Effectiveness monitoring may occur at two different levels of effort: "selective" and "intensive". Selective, the lower level of effort for effectiveness monitoring, is recommended when responses to BMP implementation are expected to be readily observable. In general, less sophisticated, simple observations of readily observable changes are preferred so that costs of monitoring will be commensurate with available resources at the local level. Further discussion of possible approaches and the situations in which it would be used is found later in this chapter. An example of this type of approach can be found in the Johnson Creek Project in Washington.

The intensive level of effort in effectiveness monitoring occurs at a typically larger scale and is applied when changes in the environment are expected to be subtle, complex, or the cumulative results of several actions. It entails the use of more quantitative techniques of measuring environmental response. An intensive study is likely to require funding from several sources; examples include cooperation between two or more local soil conservation districts or implementation at the state or federal level. This level of monitoring can not occur for all NPS control programs; rather, criteria should be used to select representative projects to receive "intensive" effectiveness monitoring. Further discussion of approaches is found later in this chapter. An example of this approach can be found in the Rock Creek RCWP project in Idaho.

Selective Effectiveness Monitoring

Silviculture

Selective monitoring is appropriate in areas where road failures are chronic, mass failures of slopes are readily visible, and monitoring the effectiveness of BMPs can be focused with little difficulty. Such monitoring should focus on analyses of flow, turbidity, suspended solids, and temperature at minimum. Consideration should also be given to whether the scale of the impact and activity is sufficient to warrant monitoring changes in fish population characteristics or alternatively, quantifying changes in channel morphology or sediment characteristics.

Silvicultural BMPs are typically implemented to preserve or maintain good quality aquatic habitat. Readily observable impacts are unusual in most areas of the Northwest. The performance of silvicultural BMPs will typically be evaluated by monitoring subtle changes against a context of high natural variability where intensive effectiveness monitoring is expected to be of greater value than selective effectiveness monitoring.

Agriculture

In certain situations, agricultural NPS pollution and land use practices have a readily observable impact on aquatic systems. If BMPs are effective in addressing these problems, the response of the aquatic environment is often also readily visible. Agricultural situations that are amenable to selective effectiveness monitoring include the recovery of riparian vegetation on rangeland, confined animal and feedlot operations following correct management of livestock, and a reduction in suspended solids concentrations in streams draining highly erosive dryland or irrigated farmland when minimum tillage is implemented.

In these situations, effectiveness monitoring should focus on a small number of parameters that are easily observed. The key to selective effectiveness monitoring at the local level is to involve, to the maximum extent possible, local landowners and operators in designing and executing the monitoring program. These individuals represent a valuable resource because they have a lower personnel turnover rate and a vested interest in the effectiveness of the BMP. Within the agricultural sector, the number of landowners and operators and size of operations will influence program design. Ideally, the monitoring survey should be conducted with broad involvement of interested and affected groups. The monitoring techniques should be easy to understand and use, require minimum investments in equipment, and focus on aspects of the aquatic environment that are of interest to affected and concerned parties.

The ecological parameters that will be monitored and the techniques that will be used must depend on site conditions, the stated objectives of the BMPs that have been implemented, and the stated objectives developed for the monitoring program. Elements that could be included in agricultural operations are summarized in the following sections and in Tables 5-1 and 5-2.

Rangeland. Rangeland BMPs are commonly implemented to protect or restore riparian habitat or to reduce nutrient and fecal coliform loadings to streams. Restoration of riparian habitat is usually done to stabilize streambanks and reduce erosion, modify streamflows, reduce temperature, or improve fish habitat. Riparian vegetation is easily photographed, and changes in the vigor of growth and the types (shrubs, trees, forbs, grasses) of vegetation are easily noted. Photographs taken over time at established locations have the added advantage of

Table 5-1. Typical Pollution Problems Associated With Land Use Category.

Confined Animal Feedlot Operations

- Water quality - biotic
- Channel morphology
- Stream bank morphology

Dryland Agriculture

- Channel morphology
- Stream hydrology
- Water quality - nutrients
  pesticides

Irrigated Farming

- Stream hydrology
- Water quality - sediment
- Water quality - nutrients
- Water quality - chemicals
- Water temperature

Rangeland

- Stream hydrology
- Stream bank morphology
- Water quality - biotic

Forestry

- Stream bank morphology
- Stream hydrology
- Water quality - sediment
- Water temperature
- Light
- Channel morphology

Table 5-2. Recommended Parameters

Pollution Problem	Selective Monitoring	Intensive Monitoring
Channel Morphology	Flow; depth qualitative habitat characterization (e.g. pool/riffle ratio; substrate composition, large organic debris.	Flow; depth; substrate composition; pool/riffle ratio; large organic debris; (bank angle).
Stream Bank Morphology	Flow; depth; temperature; riparian vegetation (photo); (suspended solids) (fish +/-).	Flow; depth, temperature, riparian vegetation; suspended solids; bank stability; (turbidity) (fish).
Stream Hydrology	Flow; depth; (fish +/-).	Flow; depth; fish +/-.
Water Temperature	Flow; temperature; dissolved oxygen; vegetative overhang (photo).	Flow; temperature; dissolved oxygen; vegetative overhang; riparian vegetation; (invertebrates); (fish); (algae).
Water Quality Biotic	Flow; dissolved oxygen; (bacteria); (fish +/-).	Flow; dissolved oxygen; nutrients; bacteria; fish; algae.
Water Quality Sediment	Flow; suspended sediment; fish +/-.	Flow; suspended sediment; turbidity; stream bed substrate; nutrients; (invertebrates); (fish).
Water Quality Nutrients	Flow; temperature; dissolved oxygen; pH; nutrients; algae +/-.	Flow; temperature; dissolved oxygen; pH; nutrients; fish; algae +/-; (algal species composition).
Water Quality Chemicals	Flow; pH; conductivity; (fish +/-).	Flow; pH; conductivity; salts; pesticides/herbicides; invertebrates; (fish); (algae).

Special Considerations:

- Large organic debris should be measured for silvicultural monitoring projects.
- Large streams - measure fish age classes, population, length:weight ratio, density.
- Small streams - measure fish +/-.
- Most of watershed treated - measure fish +/-.
- Part of watershed treated - measure fish +/-.
- Bank erosion occurring - measure riparian vegetation, channel stability, and channel morphology.
- CAFO encloses the stream - measure riparian vegetation, channel morphology, fish age structure.
- CAFO near stream - measure invertebrate species density and abundance.

+/- Presence/absence
( ) Optional, at discretion of resource manager

providing a record of conditions that can be subjected to quantitative evaluation later. Some aspects of riparian habitat (Appendix D) should be monitored as part of a selective effectiveness monitoring program. A photographic record of vegetation change following BMP implementation is particularly dramatic. Monitoring of nutrient and fecal coliform loading requires an intensive effectiveness monitoring program.

Observations on the presence or absence of fish and how much of the stream is used by spawning fish may be appropriate if stream conditions permit visual observation and if BMPs are expected to alter use of the stream by fish dramatically. Monitoring of fish populations, however, may be difficult in streams draining rangeland. In some cases, effects of BMPs on fish populations may be noticeable only in water significantly downstream of that part of the watershed in which the BMPs have been implemented. Thus, great care must be taken in considering where in the watershed effects of rangeland BMPs are likely to impact fish populations.

Changes in flow patterns (e.g., less flooding, increased duration of flow in ephemeral streams) provide useful information on effectiveness of BMPs on rangelands. If stream sedimentation and erosion are major concerns in the watershed, sampling with Imhoff cones may provide inexpensive, dramatic, and useful measures of change in sediment concentration. Other measures that can be readily obtained in the field are temperature, dissolved oxygen, and pH.

<u>Confined Animal and Feedlot Operations</u>. Most of the discussion that applies to rangeland agriculture is also applicable to confined animal (e.g., pastureland) and feedlot operations where BMPs are implemented to protect streambanks. Riparian vegetation, sediment concentrations, and flow may need to be monitored.

Observations on the presence or absence of fish and how much of the stream is used by spawning fish may be appropriate if stream conditions permit visual observations and if BMPs are expected to alter use of the stream by fish. Monitoring of fish populations, however, may be of little value if only a small part of the stream is subject to BMPs. If large areas of the drainage are under BMPs, the site may warrant intensive effectiveness monitoring. Great care must be taken in considering where in the watershed effects of BMPs are likely to modify fish populations.

<u>Irrigated and Dryland Agriculture</u>. Severe pollution by suspended sediments may be associated with irrigated and dryland agriculture. If the problem occurs throughout a watershed and much of the watershed is under BMPs, the watershed may be a candidate for intensive effectiveness monitoring. If, however, the problem is severe and specific to only a small area, then the site is a candidate for selective effectiveness monitoring.

In these situations, selective effectiveness monitoring may focus primarily on the concentration of suspended solids in the stream and a few associated physical and chemical parameters. Unless there are compelling site-specific conditions that warrant their inclusion, biological parameters, such as fish habitat condition and populations, should not be included because they respond in subtle ways that are likely to be detected only through intensive monitoring.

Intensive Effectiveness Monitoring

A BMP at a specific site may be very effective in meeting specified objectives such as reduction of erosion without a readily observed improvement in water quality or aquatic habitat. Thus, resource managers need to design intensive monitoring programs that are sensitive to such observations.

Physical and chemical parameters are more often useful as indicators of how effectively a BMP meets specified abiotic objectives such as reduction of soil erosion, but only biological measures can effectively describe the response of aquatic organisms. Indications from ongoing monitoring projects and best professional judgment suggest that intensive effectiveness monitoring should include primarily physical and chemical parameters when a relatively small proportion of a drainage area is under BMPs. Inclusion of biological parameters is more likely to be useful when a larger proportion of the watershed is under BMPs. Invertebrates and algal measurements are good indicators for certain water pollutions (e.g., algae for nutrient enrichment, invertebrates for chemical pollution, and sediment).

Criteria for Site Selection for Intensive Effectiveness Monitoring

Resource managers should select representative sites to reflect the most common types of activities of the Pacific Northwest ecoregions, as defined by Omernik and Gallant (1986). In selecting these sites, the following criteria should be considered:

- The project site should be representative of the targeted land use type in the ecoregion.
- Good baseline data should be available on land use, water quality, and condition of targeted biological resources or sufficient lead time should be available to gather a data base.
- Priority should be given to projects with uncertain responses to BMPs or disturbance.
- Priority should be given to activities that pose a high risk to water quality and aquatic resources.

- The severity of the nonpoint source pollution impacts and the history of land use practices in the watershed should be such that effectiveness of BMPs is likely to be detected.

- Public interest in the aquatic resources in the watershed should be high, thereby increasing the potential use of the monitoring results.

- Large-scale projects should include participation by several agencies at federal, state, and local levels and by researchers at local or regional academic institutions.

- Opportunities to maximize public participation and public education should be identifiable.

- Monitoring should provide a minimum of technical difficulties for sampling, e.g., proximity to an analytical lab for samples susceptible to degradation.

The statement of objectives must be formulated before deciding on the program design and selecting the site for intensive effectiveness monitoring. The program design must take into account the common pollution problems associated with major land use type (Table 5-1). If one or more of these pollution problems are expected or known to occur, resource managers must choose an appropriate array of parameters that should be included in the effectiveness monitoring program.

Table 5-2 lists parameters that should be included for certain pollution problems as well as a few additional options (noted in parentheses in Table 5-2) that would be included if site specific conditions warrant. The special considerations are listed at the end of Table 5-2, and are discussed in more detail in the remainder of this chapter.

Silviculture

Common Impacts. The major impacts of nonpoint source pollution associated with silvicultural practices in the Pacific Northwest are: changes in stream hydrology; input of sediment (erosion from roads and disturbed soils on logged areas); increases in stream temperature or changes in light levels on streams; and changes in debris loading and channel and stream bank morphology (Table 5-1).

Existing Monitoring Techniques. Monitoring conducted as part of timber harvest activities includes measurement of turbidity, suspended sediment, pH, temperature, and flow. Evaluation of substrate composition and channel morphology changes is common on research projects and is increasingly common on other projects. The techniques that are used are relatively standardized throughout the region, and are described in more detail in

Appendix D. These techniques are generally useful in describing effectiveness from the standpoint of habitat quality, but do not specifically address the response of aquatic resources.

Recommended Physical and Chemical Monitoring. The existing monitoring techniques should be continued in most cases. Monitoring should continue for several years after BMP implementation. Root strength of harvested trees, for example, may last for up to 5-6 years after harvest. Reforestation-growth is usually sufficient to stabilize the soil by this time, but soil slide with potential water quality impacts may still result several years after BMP application.

Recommended Biological and Habitat Monitoring. On silvicultural sites, effectiveness monitoring should evaluate the adequacy of forest practices rules as BMPs, where FPAs apply. State forest practices regulations in Idaho, Oregon, and Washington include provisions for protection of the riparian zones in timber harvest areas. Implementation of these BMP provisions should be monitored.

Some monitoring of fish habitat and fish populations is currently occurring. It is recommended that fish habitat monitoring be expanded, depending on the pollution problems expected (Table 5-2). Site-specific conditions will determine the type of monitoring that occurs, but in general, annual assessments of age structure of fish populations would be more indicative of the health of the fish population than density information, since age structure is a better reflection of habitat condition for the full range of life history stages. As noted earlier in the discussion of selective effectiveness monitoring, great care must be taken in considering where in the watershed effects of BMPs are likely to be detected as changes in fish populations and habitat.

Large organic debris (LOD) is an important aquatic habitat parameter to monitor in logging areas. It is suggested that LOD be monitored following logging in both selective and intensive effectiveness monitoring. Other parameters, such as pool:riffle ratio, substrate composition, and temperature should be monitored as deemed appropriate by project objectives.

Rangeland

Common Impacts. The most frequent water quality impacts associated with rangeland grazing are: changes in flow regime resulting from modification or loss of riparian vegetation; increased erosion as a result of streambank modification and loss of riparian vegetation; and bacterial and nutrient loading from animal wastes deposited in the streams or along streambanks (Table 5-1).

Existing Monitoring Techniques. Streambank stability, suspended sediment, turbidity, channel morphology, temperature, flow, bacterial levels, nitrogen levels, and riparian vegetation are most frequently monitored in aquatic habitats on rangeland.

Recommended Physical and Chemical Monitoring. Existing water chemistry and stream morphology monitoring parameters should be continued in most cases.

Recommended Biological and Habitat Monitoring. Crouse and Kindschy (1982) have developed a method for predicting the potential for establishing riparian vegetation on high desert rangelands. A post-implementation monitoring program should include evaluation of change in riparian vegetation. Riparian monitoring efforts should be directed toward community composition and the amount of vegetative shading of the stream. These parameters most readily respond to implementation of BMPs on grazing lands. Riparian vegetation recovers rapidly by the growth of existing plants; grass, for example, will regrow within a few weeks of grazing exclusion. Long term monitoring of riparian vegetation should include species composition. The establishment of woody shrubs and sedges, important in providing shade and bank stabilization, can take 10 years or more (Elmore and Beschta 1987). Channel morphology changes also take place over a longer time-frame.

The species composition and shading of riparian vegetation directly affect fish populations. Direct monitoring of fish populations will depend on site-specific conditions (Table 5-2). In forested areas used for livestock grazing and in perennial streams in high desert areas, fish populations should be monitored for age structure because this parameter can be a sensitive measure of fish habitat quality for all life history stages. In smaller and ephemeral streams, monitoring of fish could be limited to noting species present, or the re-establishment of a fish species in an otherwise suitable stream.

Irrigated Farmland

Common Impacts. Common nonpoint source impacts on irrigated farmland in the Pacific Northwest include: alteration of flow regime; elevated sediment loads resulting from erosion; nutrient loading from fertilizer applications; detectable levels of pesticides and metals in fish tissue; and temperature changes (Table 5-1).

Existing Monitoring Techniques. The majority of monitoring efforts directed toward irrigated agriculture includes a relatively extensive suite of physical and chemical parameters (Table 4-2). These include parameters such as suspended sediment, turbidity, temperature, pH, nutrient loading, conductivity, and selected ions. Occasionally heavy metals are included in the analyses, but pesticides are rarely included (Table 4-2).

Recommended Physical and Chemical Monitoring. Existing monitoring techniques should continued in most cases. Heavy metals and pesticides are rarely included in existing programs (Table 4-2). Monitoring of pesticides should be included for intensive effectiveness monitoring, as should the monitoring of groundwater quality.

Recommended Biological Monitoring. BMPs for irrigated agriculture are typically directed to controlling soil erosion and sedimentation. Riparian vegetation is not likely to respond to changes in turbidity or suspended sediment loads. Riparian vegetation and channel morphology may be monitored if streambank erosion is expected to occur (Table 5-2).

Fish community composition may respond to dramatic change in suspended sediments and turbidity and, therefore, should be included in monitoring effectiveness of BMPs if the majority of the watershed is under a BMP implementation program (Table 5-2). If only a small percentage of total acreage is under BMPs, monitoring responses of fish communities is not likely to provide useful information on the effectiveness of the BMPs.

An aspect of irrigation drainage water that is commonly overlooked in developing BMPs and monitoring their implementation is the effect of pesticides, nutrients, and other chemical constituents on aquatic species. Reduction in levels of chemical pollutants is unlikely to result in measurable changes in fish populations unless water quality standards are exceeded several-fold. Monitoring changes in benthic macroinvertebrate communities may be appropriate in this situation, particularly if the regulatory framework identifies this community as an indicator of biotic integrity of the aquatic ecosystem. In situations where herbicides or nutrients are expected to be major pollutants, algal biomass and species composition may be useful indicators of changes in chemical and nutrient levels, particularly in slow moving waters.

Dryland Agriculture

Common Impacts. Most of the dryland agriculture in the Pacific Northwest occurs in the Snake and Columbia River Basins. The most common NPS impacts include soil erosion; change in flow regime; channel morphology changes; and impacts from fertilizers and pesticides.

Existing Monitoring Techniques. The parameters that are most commonly included in monitoring associated with dryland agricultural practices are suspended sediment, turbidity, flow, temperature, pH, dissolved oxygen, conductivity, and nutrient loading.

Recommended Physical and Chemical Monitoring. Existing monitoring techniques should be continued in most cases, or expanded to include groundwater monitoring. Herbicide levels in groundwater, surface water, and stream sediments should also be analyzed if herbicide use in the watershed occurs.

Recommended Biological Monitoring. BMPs for dryland agriculture are typically directed to controlling soil erosion and sedimentation of stream beds. Riparian vegetation is not likely to respond to changes in turbidity or suspended sediment loads. Extent of riparian vegetation and channel morphology, however, should be monitored if substantial streambank erosion occurs. In much of the dryland agriculture areas of the Pacific Northwest, programs that monitor channel morphology (a measure of fish habitat quality) should be cognizant of the significant background variability of flow and resulting channel changes. Accurate assessment of BMP effectiveness, therefore, may require a long-term baseline measurement period.

Fish community composition may respond to dramatic change in suspended sediments and, therefore, should be included in monitoring effectiveness of BMPs on dryland agriculture sites with perennial streams and if the majority of the watershed is under BMPs. Other fish population characteristics could be useful, specifically age structure and condition. These parameters will likely respond more visibly to subtle changes than will species composition.

Confined Animal and Feedlot Operations

Common Impacts. In feedlot operations and high density pasture that abut or surround streams, the most common impacts are nutrient loading, bacterial levels in violation of water quality standards, streambank erosion, and alteration of channel morphology (Table 5-1). In high density pasture or feedlot operations that are located near streams or that include application of manure to land subject to direct surface runoff to streams, nutrient loading, high bacterial levels, and low dissolved oxygen levels are the most common impacts.

Existing Monitoring Techniques. The parameters that are most commonly included in monitoring associated with feedlots, high density pasture, and similar confined animal operations include suspended sediment, turbidity, flow, temperature, pH, dissolved oxygen, conductivity, bacterial loading, and nutrient loading.

Recommended Physical and Chemical Monitoring. Existing monitoring techniques should be continued in most cases. Monitoring for dissolved volatile organics found in animal wastes below confined animal and feedlot operations may be useful to include as a measure of BMP effectiveness.

Recommended Biological Monitoring. Monitoring effectiveness of BMPs implemented for confined animal and feedlot operations that enclose or abut streams should include monitoring of extent and species composition of riparian vegetation, channel morphology, fish population, age structure and condition factors, and possible macroinvertebrates. Bacterial levels should also be included.

Monitoring of BMPs implemented for feedlots that are near streams or include manure application to land susceptible to direct surface runoff to streams should include species composition of aquatic invertebrate communities and bacterial levels as part of an intensive monitoring program.

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Mr. R. Denman	Stream hydrology	Chapter 3; contributions to Chapters 4, 5, Appendix D
Dr. C. Allen-Morley	Water quality, soil science	Chapter 2; contributions to Chapters 4, 5, Appendix D
Ms. T. Leber	Water quality, toxicology	Appendix D; contributions to Chapter 3
Mr. G. Grette	Fisheries biology	Contributions to Chapters 4, 5, Appendix D

Appendix A

GENERAL FORMAT FOR GATHERING NPS INFORMATIONS

Introduction

- Introduce self and Jones & Stokes Associates; note that JSA is under contract to EPA Region 10.
- Explain nature of NPS work assignment; finding out information about freshwater monitoring programs designed to determine the extent of NPS pollution.
- Are there any projects, past or present, in their region/district which have dealt with silvicultural/ agricultural NPS controls?

If YES

- What is the project background? Name, location, type, objective, type of NPS controls or BMPs applied, time scale.
- Is a report available? If so, request report, ask if they know of other projects, contracts, contacts, phone numbers, and terminate interview. Arrange to call back if necessary.
- If no report is available continue with telephone interview.
- What kind of monitoring program do they have, and what are objectives of monitoring program (baseline, implementation, effectiveness, or validation monitoring).
- What process did they use to define their monitoring program.
- Are there state or agency guidelines to help them develop monitoring program. Request copy.
- Type of monitoring - qualitative/quantitative, instream, cumulative effects, pre- and post- impacts monitoring.
- What parameters are monitored, and methods, techniques, QA/QC.
- Length of time of monitoring program - total and in relation to application of NPS controls/BMPs.

- In general, how effective do they feel the monitoring program has been? Why? What level of quality control do they feel they have. Why?

- Do they feel their monitoring is capable of realizing the full impact of the NPS control/BMP?

- Inquire about future documents.

- Is there any groundwater monitoring effort?

- Are there other people within their agency who are familiar with these types of programs ? Request name and telephone number.

- Are there other people, agencies, or projects dealing with these types of programs? Request name and telephone number.

<u>If NO</u>

- What BMPs or NPS controls apply or are required for agricultural/silvicultural programs in their region.

- Who dictates the scope of these BMPs/NPS controls.

- What process is used to determine if these BMPs/NPS controls are applied.

- What process is used to determine or evaluate the effectiveness of these BMPs/NPS controls.

- Request copy of present or proposed guidelines, if appropriate.

- Are there other people within their agency who are familiar with these types of programs.

- Are there other people, agencies, or projects dealing with these types of programs?

Appendix B

IDAHO AGRICULTURAL WATER QUALITY PROGRAM PROJECT LIST

Pocatello Region

Contact: Blaine Drewes
IDHW-DEQ
Pocatello, ID
208/236-6160

Caribou SCD
Eastside SCD
Madison SCD
Oneida SCD
Portneuf SCD
Teton SCD
Yellowstone SCD

Twin Falls Region

Contact: Tim Litke
IDHW-DEQ
963 Blue Lakes Boulevard, #2
Twin Falls, ID 83301
208/734-9520

Balanced Rock SCD
Northside SCD

Boise Region

Contact: Trish Klahr
IDHW-DEQ
801 Reserve Street
Boise, ID 83720
208/334-3823

Canyon SCD

Lewiston Region

Contact: Hudson Mann
IDHW-DEQ
1118 F Street
Lewiston, ID 83501
208/799-3430

Clearwater SCD
Latah SCD
Lewis SCD
Nez Perce SCD

Coeur d'Alene Region

Contact: Ed Tullock
IDHW-DEQ
2110 Ironwood Parkway
Coeur d'Alene, ID 83814
208/667-3524

Benewah SCD
Kootenai-Shoshone SCD

Project List

Contact, SCD and Phone Number	Project Name
Kevin Davidson Balanced Rock SCD 1701 Main Street Buhl, ID 83316 208/543-6404	Cedar Draw*
Larry Cooke Benewah SCD 222 Seventh Street, Room G-33 St. Maries, ID 83861 208/245-2314	Mission/Sheep Creek* Upper Hangman Creek Tensed-Lolo Creek
John Gleim Canyon SCD 510 Arthur Street Caldwell, ID 83605 208/454-8584	Conway Gulch* Sand Hollow*
Bob Clark Caribou SCD 159 East Second Street, #4 Soda Springs, ID 83276 208/547-3651	Bancroft
Bruce Hanson Clearwater SCD 2200 Michigan Avenue, Box C Orofino, ID 83544	Bedrock Creek

Dennis Hadley Eastside SCD 1820 East 17th, Suite 360 Idaho Falls, ID 83401 208/522-5351 208/522-5137	Badger Creek Meadow Creek Tex Creek Antelope/Pine Creek (planning)
Kim Golden Kootenai/Shoshone SCD 205 North Fourth, Room 215 Coeur d'Alene, ID 83814	Northeast Worley
Ken Houska Latah SWCD 220 East Fifth Avenue, Room 212 Moscow, ID 83843 208/882-0507	South Fork Palouse River Little Potlatch Creek (planning)
Jim Graham Lewis SCD P.O. Box 67 Craigmont, ID 83523 208/924-5561	Little Canyon Creek (planning) Lapwai Creek
David Steube Madison SCD 50 North Second Street Rexburg, ID 83440 208/356-6931	West Canyon Creek (planning)
Byron Chase Nez Perce SWCD 3510 - 12th Street Lewiston, ID 83501 208/746-9886	Pine Creek
Ron Davidson Northside SCD 704 South Lincoln Jerome, ID 83338 208/324-2501	Vinyard Creek*
Travis James Oneida SCD 30 North 100th Street Malad, ID 83252 208/766-4748	Wide Hollow Dairy Creek

Dave Curtis Portneuf SWCD 205 South Fourth, Suite 112 Pocatelo, ID 83201 208/236-6909	Arkansas Basin Lone Pine Lower Portneuf River (planning)
Steve Smart Teton SCD P.O. Box 7 Driggs, ID 83422 208/354-2955	Milk Creek (planning)
Howard Johnson Yellowstone SCD 315 East Fifth St. Anthony, ID 83445	Conant Creek

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*Projects on irrigated farmland. All others are on dryland agriculture.

Appendix C

BLM PILOT RIPARIAN PROJECTS IN IDAHO

Boise District

Rabbit Creek

Contact: Pat Olmstead
BLM Boise District
3948 Development Ave.
Boise, ID
208/334-1582

Shoshone District

Thorn Creek
Magic Reservoir

Contact: Steve Langenstein
BLM Shoshone District
208/886-2206

Burley District

All (12) perennial streams in the district on BLM land.

Contact: Kirk Koch
BLM Burley District
Rt 3, Box 1
Burley, ID 83318
206/678-5514

Idaho Falls District

Wet Creek

Contact: Tim Bozorth
208/529-6367

Salmon District

Warm Springs Creek
Sevenmile Creek
Holly Creek
Road Creek
Herd Creek
Sage Creek
Squaw Creek
Ellis Creek
Morgan Creek
Burnt Creek
Summit Creek
Trail Creek
Pattee Creek
McDevitt Creek
Henry Creek

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Big Elk Creek

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Appendix D

REVIEW OF MONITORING TECHNIQUES

This appendix describes the more common techniques that have been used in monitoring nonpoint source assessment and control programs (Chapter 4). Most of the techniques have been used in projects that include experimental research and investigation of nonpoint sources as well as monitoring effort. The purpose of this appendix is to assist resource managers in assessing the ability of various techniques to meet their management needs. To facilitate the assessment, we have included discussion of the advantages and disadvantages of separate techniques when several that measure the same parameter are available.

The techniques are listed by the parameter measured and then grouped according to whether they are physical, biological, or chemical features of the environment. Emphasis is placed on physical and biological features because these are of greater interest for the objectives of this report (Chapter 1) and because the techniques are not as well standardized as they have been for chemical parameters. Most of the physical parameters that have been used in the Pacific Northwest (Chapter 4) are widely accepted as measures of quality of fish habitat.

Physical Monitoring

Stream Discharge

Although a variety of techniques are used to determine stream discharge, some commonalities exist among methods. All techniques measure water height or stage with a gage and convert this to discharge (volume/time) by means of a rating curve relating the two variables. To develop an accurate relationship, discharge measurements must reflect a wide variety of stages. Individual discharge measurements consist of measuring the average velocity and area of a number of equally spaced cells within a cross-section. Upon establishment of a statistically valid rating curve, discharge measurements are needed less frequently and are conducted to check the reliability of the rating curve. Changes in stream geometry alter the stage-discharge relationship; therefore, gaging stations are typically placed in stable stream reaches. Weirs are sometimes constructed to control flow and maintain a stable cross-section.

Stage measurement techniques can be delineated into two basic categories: recording and non-recording gages. The simplest technique, the non-recording gage, is most often used as an auxiliary gage or for short duration, limited budget studies. Non-recording gages are usually staff gages consisting of rigid, precisely graduated vertical or inclined rods at the edge of the channel. The inclined staff gages have the advantage of being less prone to damage from floating debris, but they must be corrected for slope to obtain true vertical readings. In very simple studies, stage-discharge relationships are not developed and data are simply recorded as stream height, not volume.

Recording gages have been the standard discharge measurement for the last few decades. These devices record the water level at a gage station at specific time intervals (usually 15 minutes) over long periods. Measured water levels are correlated with calculated stream discharges to develop the stage-discharge relationship.

Two basic types of recorders, float and pressure, are most frequently used (Carter and Davidian 1968). Float recorders measure water levels in a stilling well (an enclosed structure with a water level equivalent to that of the stream) by means of a suspended float attached to a recording device. This device usually has the advantage of being cheaper and easier to install but can be prone to damage and is often not as accurate as the pressure gage. The pressure gage uses the head developed by different depths of water against pressure produced by a compressed gas to measure water height. This method is employed by most USGS gaging stations and requires considerably more equipment to operate than a float-gage.

Measurement of stream discharge is a necessity for most NPS monitoring programs. Stream discharge may be considered the independent variable in a monitoring scheme as virtually all of the other parameters measured respond to discharge changes. Further, stream discharge may respond to a BMP as a dependent variable. In most cases, a recording gage will be required to obtain usable data.

Groundwater flow monitoring is sometimes incorporated with streamflow measurements when groundwater is suspected of being a major component of streamflow or when domestic use is an issue. A series of piezometers or well points are needed to define groundwater levels, volumes, and movement accurately. Groundwater quality is measured by extracting water from piezometers or by the use of tension lysimeters buried in the soil.

Turbidity

Turbidity is one of the easiest and most commonly measured water quality parameters.

Only a handful of studies use a qualitative measure of turbidity. The qualitative measures use streamside judgments to describe the water, rather than analysis of water samples. Terms such as clear, murky, and muddy are often used to define turbidity. Visibility, estimated in feet, is sometimes used to help clarify these terms.

The majority of workers measure turbidity quantitatively and express results in terms of Nephelometric Turbidity Units (NTU). This measure is an indication of the intensity of light scattered at some angle, usually 90 degrees, to its original direction. The results of the alternative method, which involves measuring the intensity of candle-emitted light passing directly through a water sample, are reported in Jackson Turbidity Units (JTU). Comparison between the two units is not valid unless specifics concerning calibration techniques are known. A major error that is commonly made when attempting to compare data sets is to assume that the units of measure (NTU and JTU) are interchangeable; they are not.

Field measurements of turbidity are possible and are incorporated into a number of studies. Normally, measurements are taken at gaging stations from grab samples that are not depth integrated. Depending on the specific objectives of the study, samples are taken daily, monthly, yearly, or during storm events. Most sampling is conducted with automatic samplers (see Suspended Sediment section), and analysis is conducted in the laboratory with a standard turbidimeter (American Public Health Assoc. [APHA] 1985).

Commonly, stream discharge is recorded at the time the sample is taken since there is considerable interest in correlating the two. Also, suspended sediment samples are often taken in conjunction with turbidity. Because turbidity is easier to measure than suspended sediment, many researchers are investigating a possible correlation between the two. Although some success has been realized for individual storms on particular watersheds, a regionally valid quantitative relationship between the two parameters has not been developed (Beschta 1980, APHA 1985).

Sediment

Sediment transport in streams is a complex and poorly understood process. The sediment load can be divided into suspended and bedload. Suspended sediment is that portion of the load which is in full suspension, while bedload is that portion which moves in partial or complete contact with the channel bottom.

Regardless of the portion of the sediment load sampled or the technique employed, consideration of sampling location and timing is necessary. Usually the sediment sampling station is located near a gaging station so that an accurate measure of sediment loading can be made by combining stream discharge with sediment concentration. If a gaging station does not exist in reasonable proximity to the site, site-specific flow data must be taken at the time of sediment sampling. The criteria dictating the location of a successful gaging station (such as access and cross-section stability) are equally applicable to the selection of a sediment sampling station (see Stream Discharge). Because of the importance of collecting sediment samples during high stream discharges (as well as ascending and descending limbs of the hydrograph), particular attention should be given to ease of access from a bridge or cable.

Imhoff cones can be used to determine the sediment content of water-sediment mixtures. Resource managers report that these graduated cones are especially effective as a qualitative visual aid when dealing with landowners. Quantitatively, they can be used to determine the textural make-up of sediment based on settling time. The laboratory techniques described in the next section of the report are more commonly used to determine the concentrations of sediment.

The need for an understanding of a basin's total sediment discharge and the varying relationship between flow and sediment concentration dictates that flow records be available for the sediment sampling site. Other important parameters that should be noted when sampling are the hydrograph stage (rising or falling) and the time of year. If a detailed study of sediment transport is planned, water temperature should also be noted as it influences viscosity and hence suspension and deposition of particles. Basic understanding of regional geologic formations is very helpful in analyzing trends in sediment transport data.

Suspended Sediment. The basic requirement of a suspended sediment sampling regime is that samples be representative of the water-sediment mixture. To accomplish this, a number of factors must be considered. First, the sampling device must cause a minimum of disturbance to the flow pattern of the stream, especially at the intake, and allow water to enter the sample container at the same velocity as the surrounding stream. Second, the technique should be capable of collecting a representative sample in a vertically stratified water-sediment mixture. The most representative sampling techniques address this variability by utilizing some form of depth integration.

One technique used for obtaining depth integrated samples uses a hand held sampler that collects the sample as it is lowered to the bottom of the stream and raised back to the surface. The samplers must be moved at a uniform rate in a given direction, but not necessarily at equal rates in both directions (Guy and Norman 1970). Depth integrated samples can be obtained from swift, unwadeable streams by cable-suspended samplers raised and lowered at the desired rate. For streams too deep or swift to sample in a round-trip integration, point-integrated depth samples can be used to represent the mean sediment concentration.

Although these depth integrated techniques provide the most representative samples, they are not often utilized for monitoring suspended sediment concentrations associated with NPS control programs. The primary reason for this is the labor intensive nature of the field sampling. Also, managers may decide these techniques are not necessary if the stream is judged to be shallow and completely mixed.

habitat. These considerations have often steered monitoring programs toward quantification of changes to habitat features rather than measurement of bedload transport itself.

Techniques used to measure bedload movement typically involve use of permanent instream structures or portable samplers. Permanent structures capture transported bed materials for a specified period of time in a trap. These traps vary in sophistication from a pit or pool to a channel with a false bottom. A small pit may be adequate for many studies, but constant monitoring is necessary to quantify the time periods when filling occurs. These types of studies are often undertaken in conjunction with channel cross-section studies described in the <u>Channel Morphology/Physical Habitat</u> section.

A number of different portable samplers are used to quantify bedload movement, the most common of which is the Helley-Smith sampler. This device is usually suspended from a cable or bridge and lowered to the stream bottom at a set number of locations across the channel. It can yield useful results when used properly, but can be difficult to control in the high flow conditions associated with bedload movement.

Laboratory analysis involves fractionation of the sample using a series of graduated sieves. Sieving is done under wet or dry conditions, with dry sieving more commonly used.

<u>Channel Morphology/Physical Habitat</u>

Monitoring programs have incorporated many techniques to identify physical changes to stream channels. The terms "bank erosivity" and "channel stability" are often used to define both quantitative and qualitative methods for assessing channel changes. Most programs use a reference point or set of points and return on a regular schedule to evaluate changes. Locations chosen for evaluation are biologically significant (such as spawning or rearing habitat) or are undergoing obvious dimensional changes. The scheduling of data collection varies considerably, with most programs evaluating changes annually. In a few cases where flow or debris delivery rates have changed dramatically channel sinuosity (channel length/ valley length) is calculated as a measure of overall stability. The more intensive programs using detailed quantitative techniques incorporate measurements following each high water episode. For the purposes of organization, this section separates methods into those utilizing qualitative and quantitative techniques. Platts et al. (1983) provides a detailed description of techniques and is the basis for this discussion.

<u>Qualitative</u>. Qualitative assessments of channel morphology range from simple annual visual inspections of general channel conditions to completion of lengthy evaluation forms. Qualitative methods allow inspection of numerous channel sections over the course of a year. The simplest technique involves a field

technician judging the overall stability of channels and noting specific areas of bank or bed scour. In many projects, this informal technique is incorporated into other tasks assigned to an individual.

Many studies, as part of an impact assessment or baseline monitoring program, use a series of criteria to evaluate channel conditions. In most cases, target stream reaches are walked by a biologist or hydrologist who evaluates specific points on the entire reach. Reaches are usually defined as areas with similar stream gradient, width, and habitat features.

The most common technique evaluates the upper bank, lower bank, and stream bottom independently. Stability indicators are often evaluated in four classes: poor, fair, good, or excellent and range from one statement concerning overall channel stability or erosion up to 15 parameters (USFS 1975). Some measure of stream discharge is nearly always recorded at the time of evaluation.

Photographs are also used as a qualitative tool to assess stream morphology characteristics. Aerial and ground photographs are used to record changes or as a basis for evaluation forms. Aerial photographs, usually used in conjunction with riparian habitat evaluation procedures, are often taken at a 1:2,000 scale; 1:1,000 scale photographs are taken in areas where special problems are known to exist. Use of photographs requires establishment of an organized storage and record keeping system. Use of ground photography requires establishment of permanent photo points from which photos can be consistently taken over time. Photographs are used more extensively by agricultural monitoring programs than by silvicultural programs.

Although qualitative techniques are widely employed, some problems are associated with their use. The primary problem is interpretation. No matter how specific the definition of an indicator class, opinions will vary as to whether the site is in "fair" or "good" condition. Consistency can be improved if personnel changes are kept to a minimum. A photographic record also aids in reducing error in subjective variables. The differences in parameters evaluated and indicator classes also make comparisons between different agencies or regions difficult.

Quantitative. Many monitoring programs, particularly those focusing on one stream or watershed, utilize quantitative techniques to evaluate the effectiveness of NPS controls. Usually a series of reference points are established from which detailed measurements are made. These series are often established in groups to enable monitoring of stream sections with widely different hydrologic and biological characteristics.

The simplest measurements taken are usually of the distance from the reference point to the edge of the stream bank (Clark 1986). Successive changes in this distance are monitored as a measure of channel change. Measurements are taken in the field or from photographs. This technique is most often employed on low gradient streams associated with agricultural programs.

More commonly, complete cross-section profiles are plotted from measurements taken from reference points. The distance from a fixed horizontal line to the channel bottom is usually measured at 1-foot intervals across the channel. This technique, when used over a number of years, allows the manager to determine channel bed as well as bank erosion or deposition.

Some studies incorporate detailed fish habitat evaluations based on physical measurements. Platts et al. (1983) presents detailed descriptions of techniques. Common measurements include pool-riffle ratios, width-depth ratio, pool area, pool volume, and cover. These parameters are used as an index of the stream's capacity to provide cover, and rearing and spawning habitat. Qualitative evaluation of pool quality, based on a numerical score derived from a set of criteria, is sometimes included. In western Oregon and Washington, measurement of the abundance of woody debris in channels is sometimes conducted. Presently there are no standard methods for this evaluation, but it is likely one will evolve as part of the monitoring programs being developed to assess silvicultural impacts in Washington state (see chapter 3).

Reproducibility is a concern with all habitat related measurements. Of particular concern is the delineation of habitat types. Platts et al. (1983) provides an excellent discussion of precision and accuracy by habitat parameter.

Substrate Composition

Qualitative. Platts et al. (1983) present a visual method for assessing substrate composition. In this method, a transect is stretched across the stream and the dominate substrate type is recorded (boulder, rubble or cobble, gravel, fine sediment) at each 1 ft interval. The number of observations in each category are totaled for each transect. Several transects may be necessary to characterize a stream reach. Overall, the precision and accuracy of this method is only fair to poor in the size categories of greatest interest (cobble to fine sediment) (Platts et al. 1983).

A semi-quantitative variable that has a higher degree of accuracy and precision is embeddedness (Platts et al. 1983). This variable expresses the degree to which larger particles (boulder through gravel) are covered or surrounded by fine material, and provides a relative measure of the value of the substrate for spawning and egg incubation, insect production, and interstitial cover for juvenile fish. The exact technique for determining embeddedness varies. Typically, the individual sampling points are defined by a transect (Platts et al. 1983) or a hoop (Clark 1986). Embeddedness is then visually estimated (Platts et al. 1983) or precisely measured with aid of a plexiglass viewing device (Clark 1986).

There are several considerations in assessing the appropriateness of these semi-quantitative techniques. Surficial substrate conditions are not always accurate indicators of subsurface conditions, and surface-oriented surveys may be inadequate if the focus of the effort is spawning habitat. Further, seasonal trends in surficial composition may complicate data interpretation as sampling periods may not coincide with biologically significant events (e.g. spawning and egg incubation). In general, if the intent is to monitor spawning gravel quality intensively, one of the quantitative techniques would likely be more appropriate. But if the focus is on rearing habitats for fish or insect communities, then qualitative or semi-quantitative methods are appropriate because they focus on the substrate-stream interface.

Quantitative. Fisheries biologists have been quantitatively sampling the composition of spawning gravel for about 30 years to assess the effects of land use, particularly logging, on salmonid spawning habitat. Two main sampling techniques are used, and both involve removing samples from the streambed and sieving them to determine the proportion of particles in each of several size classes. Both techniques are described in the following discussion. This description is then followed by discussions of sampling considerations, applicability, and analysis with respect to their use in monitoring effectiveness of BMPs.

The McNeil sampler consists of a stainless steel tube 6-12 inches in diameter attached to a larger tube that functions as a basin for the sample. The device is worked into the substrate, and the sample is hand-excavated into the basin. The tube is then capped to prevent loss of the sample or the turbid waters in the basin; however, suspended sediments in the tube are lost (Platts et al. 1983). The McNeil cylinder as modified by Koski (1966) has a plunger that draws the turbid water from the tube, preserving that portion of the sample.

There are several disadvantages to using the McNeil sampler (based primarily on Platts et al. 1983):

- Analysis of vertical and horizontal particle distribution is not possible because the sample is mixed.
- Core depth is limited by depth of penetration into the substrate, water depth, and the length of the worker's arm.
- If the tube is not modified with a plunger, suspended sediments are not sampled.
- It can be difficult to push into the substrate if large particles predominate or if the substrate is cemented.

Advantages include:

- The McNeil sampler is inexpensive.
- Little support equipment is needed.
- Cryogenic liquids are not needed.
- It is easy to use and transport in remote sites.

The freeze-core sampler is basically a single or multiple probe that is driven into the gravel and cooled with a cryogenic medium (liquid CO_2 or N). The probe is then lifted from the substrate by a tripod-mounted winch, with its adhering sample. Early samplers consisted of a single probe; a tri-tube sampler is now used more often and is recommended because a large sample can be collected using liquid CO_2, whereas liquid nitrogen is necessary to get large samples with a single probe device (Platts et al. 1983).

The disadvantages to using a freeze-core sampler include (based primarily on Platts et al. 1983):

- The sampler is relatively expensive to build and operate.
- The technique is equipment-intensive and requires good access to the site.
- The tri-tube can be difficult to drive into substrates with a predominance of large particles.
- The liquid nitrogen or CO_2 may be difficult to obtain in more remote areas.

Advantages include:

- The vertical and horizontal structure of the sample can be analyzed.
- It can be used to sample in a broad range of depths and water temperatures.
- It can sample eggs and alevins within redds.

Sampling Considerations. The goal of monitoring a specific variable is to detect temporal changes or differences between locations. To detect differences, the worker must sample in a manner that minimizes natural variability. In the case of gravel sampling, gravel composition varies (in decreasing magnitude) between riffles of different streams, between riffles of the same stream, and between locations within a riffle (Adams and Beschta 1980). Also, composition varies seasonally, with highest levels of fine sediment in late summer and lowest levels in late winter after flushing occurs. Given this variability, the design of a monitoring program should consider carefully the spatial and temporal distribution of sampling effort as well as the number of samples. For example, if time constraints limit the total number of samples, the best distribution of effort may be to take all samples on one index riffle rather than sampling several riffles.

In addition to the physical variability, there is also biological variability. Spawning site selection by salmonids is not random. Variability will be minimized by selecting only riffles that are known spawning locations. Spawning salmonids are also very effective at cleaning gravel (Everest et al. 1987), which has led several researchers (Platts et al. 1983, Everest et al. 1987, Chapman and McLeod 1987) to suggest that gravel sampling should be conducted only within redds to assess gravel composition. However, sampling in redds is not really necessary if the desired result is an index of spawning habitat quality, rather than derivation of a survival relationship or a quantitative estimate of survival. Sampling in artificially constructed redds is another option for possibly increasing the utility of the data.

Consideration should also be given to the timing of sample collection. Sampling during the period when eggs are incubating is desirable. However, weather or water conditions may preclude this, while the presence of several species may complicate selection of the proper period. The most important consideration is to sample the same time each year to limit interseasonal variability.

Applicability of Quantitative Gravel Sampling. Gravel composition is only of interest to fisheries biologists if it can be translated to an effect on fish populations. It is well known that high levels of fine sediment can be detrimental to certain life history stages. Before embarking on a gravel sampling program, however, it is desirable to determine whether spawning success is a potential limiting factor for the population of interest.

Many anadromous salmonids rear for extended periods prior to emigration. Everest et al. (1987) state that rearing species are much less likely to be limited by sedimented spawning gravel than are those species that emigrate soon after emergence. For rearing species and resident salmonids, it is the availability of rearing habitat rather than spawning habitat that is generally believed to limit the potential of the population. This argument is correct for unexploited or conservatively managed populations; however, it ignores the cumulative effect of the fishery and habitat alteration. Cederholm et al. (1981) present an example where a population of coho salmon (considered a rearing-habitat-limited species) has been driven to a very low level by the effects of the fishery and degraded spawning habitat. This situation is probably often the case for genetically wild anadromous salmonids in Idaho, Oregon, and Washington because of the intensity with which these stocks are harvested in mixedstock fisheries. The view of Everest et al (1987), that sediment is seldom a problem, may be more applicable to rearing-limited salmonids in Alaska, where escapements are much higher.

The factors determining whether resident salmonids are limited by spawning success will depend on the intensity of the local fisheries and the systemwide availability and distribution of spawning habitat.

<u>Analysis of Data</u>. The composition of spawning gravel has been described by percent fine sediment (varying cutoff points for "fines"), geometric mean particle diameter, and the Fredle Index.

"Percent fines" is defined as the weight of the material passing through a specified sieve divided by the total weight of the sample, expressed as a percentage. Common upper limits for "fines" include <0.85 mm, <1.0 mm, <3.3 mm, and <4.7 mm. The selection of an appropriate cutoff point depends on local geology. For example, in the South Fork Clearwater River in the Idaho Batholith region, coarse granitic sands predominate; therefore, <4.7 mm has been used as the cutoff point for fines. In the Clearwater River of western Washington, much finer textured soils predominate and <0.85 mm has been used to define "fines."

"Percent fines" has been criticized as an index of gravel quality because it ignores the composition of the balance of the sample which also affects suitability for spawning (Platts et al. 1983). Platts et al. (1979) have proposed geometric mean diameter (d_g) as a measure of gravel quality. This has been criticized as an index because gravel mixtures with the same geometric mean can have very different size compositions (Tappel and Bjornn 1983). The Fredle Index, developed by Lotspeich and Everest (1981), addressed the inadequacy of the geometric mean. The Fredle Index is defined by Chapman and McLeod (1987) as the geometric mean particle size divided by the geometric standard deviation.

Fortunately, use of any one or all of these indices is not exclusive, nor must an index be selected prior to data collection. All indices can be calculated from a single set of sieve data, and selection between them can be based on regional or individual preferences and study objectives.

Field and laboratory studies have been conducted to define the precise relationship between gravel composition and survival to emergence for salmonids. Typically, increased fine sediments result in decreased survival (Iwamoto et al. 1978). The relationships have been inappropriately applied at times to predict marginal increases or decreases in survival based on gravel composition (Chapman and McLeod 1987). It is this step in the application of the data to effects on fish populations that requires caution.

A recent report by Chapman and McLeod (1987) concludes that past sampling methods (adjacent to, rather than in, redds) render sediment-survival relationships derived from field studies questionable. Also, they note that laboratory studies have been conducted under conditions that are too artificial and, therefore, the relationships are unreliable. The overall conclusion of the report (Chapman and McLeod 1987) is that little is known about the relationship between sediment and survival. This is an overly pessimistic view of the state of knowledge relative to sediment. Precise predictive application of sediment relationships may be inappropriate, but "rules of thumb" or consideration of upper tolerable levels are useful. For example, existing relationships indicate levels of fines greater than 20 percent are detrimental to salmonids (Iwamoto et al. 1978). Application of this type of criterion to a gravel composition data set is still appropriate, particularly for a monitoring study.

Biological Monitoring

Riparian Habitats

Vegetative Overhang. This technique is described by Platts et al. (1987). It measures a component of riparian vegetation that is directly relatable to fisheries habitat. A transect is run perpendicular to the stream channel and only vegetation intercepted by the transect is evaluated. The horizontal component of vegetation overhanging the water surface within a 12-in vertical distance (excluding tree trunks or downed logs) is measured to the nearest 0.1 ft. Vegetation more than 12 in above the water surface is included in measures of canopy cover. The lateral extent (depth) of bank undercutting is added to calculate total immediate overhead cover.

Streamside cover is rated by the dominant type of cover (e.g., shrubs, trees, grasses, forbs, or non-vegetative). Tests of the procedure indicated poor year-to-year precision and accuracy (Platts et al 1987).

This technique may be a useful monitoring tool in situations where cover is suspected of being a limiting factor for fish populations. It is also useful when stream temperature is a concern, but it is only one of several features of the riparian zone that are important in shading streams. If the purpose of the BMP is to re-establish or expand the extent of riparian vegetation, this technique is of little value as a monitoring technique compared to direct measures of areal extent. Although vegetative overhang directly influences quality of fish habitat, it does not provide any information on the composition of fish communities or the health of fish populations. Grasses, herbaceous plants, and some shrubs provide different amounts of overhang over the growing season. If overhang is to be a parameter, data must be collected consistently at a set time in the growing season to allow meaningful estimation of change in habitat quality.

Vegetative Canopy. This technique is described in detail by Platts et al. (1987). Vegetative canopy typically is vertically stratified. The simplest method of describing canopy is to measure percent cover for herbaceous plants, shrubs, and trees separately. Vegetative cover is a useful parameter in monitoring effectiveness of BMPs in situations where lack of stream shading adversely affects fish populations and BMPs have been established to remedy these effects. If the purpose of the BMP is to re-establish or expand the extent of riparian vegetation, this technique is of little value compared to direct measures of areal extent.

Canopy closure (the area of sky over the stream channel that is bracketed by vegetation) and canopy density (the amount of sky blocked within the closure by vegetation) are two aspects of vegetative canopy. Common methods of measurement include subjective estimates and quantitative measures with a vegetation profile board or a concave spherical densiometer. On smaller streams, densiometer readings are taken at each streambank and at midchannel facing upstream and downstream. On larger streams (stream order 5-7), additional readings are taken at the quarter and three-quarter distance across the stream. Use of a concave spherical densiometer in riparian zones requires procedural modifications described by Strichler (1959) in order to remove bias from overlapping readings lateral to the direction of observation.

Vegetative canopy can also be measured indirectly by calculating mean light intensity on the water surface. This is usually done by determining whether direct sunlight, filtered sunlight, or shade occurs at randomly selected points on the water surface, rating each light condition, and calculating the weighted mean light intensity. Other approaches include calculations of solar heat transfer and solar shade using information on latitude, season, topography, prevailing weather conditions, and vegetative features. These techniques can be used to evaluate change in the quality of riparian habitat. They are used more frequently, however, to calculate the effects of riparian vegetation on water temperature.

Areal Extent of Vegetation. If BMPs have been implemented in an effort to re-establish or expand the areal extent of riparian vegetation, the most direct and potentially the easiest method of monitoring effectiveness is to measure the change in acreage, width, or length (along the streambank) of the riparian habitat. The main disadvantage of this technique is that it requires the ability to recognize plant species that are obligate or facultative wetland species in order to distinguish between upland and riparian zones. In semi-arid environments, this is usually easy to do; it may require strong botanical skills in western Washington and Oregon and higher elevations of Idaho.

Two main approaches to measuring areal extent of riparian vegetation are use of aerial photos and measurements on the ground. Use of aerial photos requires ground-truthing the interpretation of the aerial photos, but the amount of time spent in the field is usually much less than if all measurements were derived from field work. Aerial photos provide a long-term record of conditions that facilitates accuracy and reliability in the data because consistent interpretation is possible. Aerial photos can also be easily used to construct overlays that, used with a base map, graphically portray change over time.

The optimal scale for aerial photos appears to be 1:2000; less resolution may be inadequate to accurately measure change in areal extent that is likely to occur and makes it difficult to distinguish between riparian communities. Higher resolution (e.g., 1:1000) may be useful if great detail is required, but the costs of conducting the survey increase sharply.

Aerial photos are particularly useful in monitoring effectiveness of BMPs in agricultural areas where land use practices modify streambanks (e.g., grazing allotments, dryland agriculture, confined animal and feedlot operations). It may be of less use in monitoring effects of silvicultural practices on riparian vegetation.

Infrared aerial photos are particularly useful in distinguishing between riparian communities. Because of species-specific variations in reflection of light from leaf surfaces, plant species (community composition) are more readily distinguished in infrared than in the visible light spectrum (true color or black/white).

A variety of techniques can be used on the ground to measure areal extent of riparian vegetation. These range from rapid estimations made while walking along the stream to measurements made on transects across the riparian zone or along streambanks. Measurements can be linear (width of riparian habitat or percent of streambank vegetated) or two-dimensional (hectares of habitat). If monitoring is limited to work on the ground, care must be taken to use procedures that are replicable over time. This entails clear definitions of riparian habitat and a method to delineate riparian from upland habitat, use of permanent transect locations or a fixed number of transects within a specified stream reach, and detailed records.

<u>Riparian Species Identification and Inventory</u>. The quality of riparian habitat and fish habitat often depends on the composition of riparian vegetation. Thus, descriptions of the types of riparian vegetation and species composition of riparian communities are often included in monitoring. There are, however, factors that complicate interpretation of these data. Riparian

areas are often occupied by a complex mosaic of plant species because of the complex interaction between soil and hydrologic conditions. Complexity in species composition in some ecological zones of the Pacific Northwest may be augmented in some cases by the naturally high rate of geomorphological change along streams, relative to adjacent upland sites. Thus, some ecological processes (e.g., succession) typical of plant communities are modified in riparian zones.

The duration and extent of water fluctuation (hydrologic regime) are driving forces in the development of riparian vegetation, with large influence also provided by soil characteristics and depth to the water table. Riparian classification schemes, therefore, should entail a description of floristic, soil, and environmental characteristics of the assemblage. Nomenclature typically is tied to the dominant vegetation type, but consideration must be given to constancy and fidelity within the community type.

Forbs and grasses require more effort to inventory than do shrubs and trees and are usually not visually dominant in the landscape. These species, however, are usually more sensitive to changes typically resulting from BMP implementation and change more rapidly than shrubs and trees. Care must be taken in determining how the BMPs are likely to affect forbs, grasses, shrubs, and trees differentially. Judgment must then be made of how to incorporate these various plant forms in the analysis of community composition.

Techniques for describing and inventorying riparian communities vary widely from qualitative visual determinations of landscape-dominating species to quantitative studies of overstory and understory vegetation. Quantitative studies include simple, quick measures such as length of shoreline dominated by shrubs, grasses, trees, or forbs. Although species composition data are generally easy to obtain, it is difficult to analyze the significance of the information, especially with respect to the ecological significance of community change noted as part of a long-term monitoring effort.

The use of large scale (higher resolution, usually 1:2000) aerial photos requires ground-truthing of photo interpretation effort but offers the general advantage of more thorough field coverage with less field time and a long-term record of change. Ground cover, stream width, stream channel and streambank stability, riparian area (width and total acreage), and streamside cover are easily monitored with aerial photo interpretation. Infrared color photos are particularly useful in identifying species composition and density of trees and many shrubs. Over-exposure by 0.5 f-stop permits penetration of water surface, allowing preliminary analysis of stream bottom characteristics in salmonid spawning areas.

Woody Riparian Inventory. This technique is described by Myers (1987). Woody species included in the inventory are those recognized to be obligate or facultative wetland species. The technique assumes that the condition of woody wetland species is a valid index of overall riparian habitat condition. Woody species are selected because of greater efficiency of inventory relative to conducting an inventory of herbaceous species and grasses. This technique has the disadvantage of not measuring more immediate responses of the herbaceous understory vegetation to changes in edaphic and hydrologic conditions.

The technique is suitable to streams where deciduous woody species dominate riparian communities. It does not work in closed canopy conifer sites, nor is it likely to be useful in sites where mature aspen stands provide dense canopy. The technique was developed for use on BLM land in the foothill region of southwestern Montana. The approach is simple but may be time-consuming if woody sprouts are abundant. Estimation of the degree of hedging (effects of foraging by grazers) requires training and is partially subjective.

Large quadrats (4m X 8m) are located at regular intervals along stream banks, with a minimum of 20 quadrats per river reach. All rooted vegetation within the quadrat is classified by size (basal diameter), height, and condition (degree of hedging). Density by species is noted for each category of woody plant, along with riparian community width and wetted channel width. Canopy measurements, bank erosion, and mean values of density data are scored separately, and the sum is used to rate habitat quality by river reach.

The scoring system developed by Myers (1987) is keyed to the mean values and 95 percent confidence intervals calculated for 8 reaches judged to be in very good or excellent ecological condition based on wildlife habitat value. A similar scoring system could be developed that is tied to river reaches providing high fisheries habitat value. Examples of the scoring system and blank field forms are provided in Myers (1987).

Fish Populations

Electrofishing. Electrofishing involves use of electric shock to temporarily immobilize fish, allowing capture. Electrofishing is safe and effective for most species and can be used to calculate statistically reliable population estimates. In addition, determinations of age and growth, biomass, length-weight relationships, and species utilization are possible. Shockers are typically DC (some AC units are available) battery-powered backpack units, or generator-powered units for shore or boat use.

To estimate the fish population in a specific reach, fine mesh block nets are used to isolate the area of interest and a crew, with a shocker, makes several passes through the reach.

Typically, the operator begins at the lower end of the site followed by one or more assistants who aid in the capture of stunned fish.

There are two primary estimation techniques: removal-depletion methods (Zippen 1958; Seber and LeCren 1967) and mark-recapture (Ricker 1975). Both techniques provide valid results and selection between them is based on personal preference. With either method it is important to consider the underlying assumptions to ensure that a valid estimate has been made.

Removal-depletion methods involve two or more passes in the isolated reach with each collection kept separate. Equations for population estimates and standard error of the estimates are presented in Platts et al. (1983). For more rigorous statistical explanation, see Seber and LeCren (1967), Zippen (1958), and Ricker (1975).

The mark-recapture method (Petersen Method) involves marking fish captured on the first pass and re-introducing them to the isolated reach. The population estimate is based on the ratio of marked and unmarked fish in the second pass. Ricker (1975) presents pertinent equations and discusses assumptions.

There are a few limitations to using electrofishing sampling techniques. Very low or very high conductivity of the water can severely limit the ability of the units to shock fish. However, most modern electroshockers allow adjustment of voltage, frequency, and pulse width, and good results can be obtained in most freshwater habitats. Depth, water turbidity and habitat complexity can render sample assumptions invalid, and it is a subjective decision as to whether the resulting estimate is valid. At low temperatures fish are often not responsive to the stimulus and can be difficult to collect. Seasonal restrictions are often in force by state fisheries agencies when eggs or alevins are present, thereby limiting some sampling opportunity. Also, permits must be obtained from the proper authorities before sampling. Mortality is typically low for fishes (a few percent); however, small fishes or benthic species occasionally suffer high mortalities because they are difficult to detect when immobile and are thereby overexposed to the shock.

<u>Snorkeling</u>. Direct observation of fish has become increasingly popular in the past decade. The method can be used to examine species composition, age structure, habitat utilization, and population trends. The technique does not allow accurate measurements of fish size.

The basic technique is simple: an observer enters the stream or river with a mask and snorkel and counts or observes the fishes there. Typically, it is best to move upstream while observing if the entire area of interest cannot be surveyed from one point. In small streams, it is possible to move slowly and inconspicuously upstream without disturbing juvenile or adult fishes, particularly salmonids. Larger streams necessitate traveling downstream with the current and require more observers.

Equipment ranges from a snorkel and mask to full SCUBA gear. The most common gear is a wet- or dry-suit and snorkel and mask. Felt-bottomed wading shoes are helpful in small streams, while rivers require fins.

Population estimation techniques are evolving, but basically one or more observers count the number of fish in a particular reach, stratifying by age group, if possible. Multiple counts are used to increase confidence in the estimates. In larger rivers, several observers travel in parallel paths and count fish to one side of their bodies and a common population estimate is made. The maximum distance that a fish-size object can be discerned should be measured on each sampling trip. For more information see Griffith (1981) and Platts et al. (1983).

Redd Counts. Redd counts are considered rather insensitive measures of population trends; however, a difference of ±50 percent can be detected (Bevan 1961). In general, redd counts are used for establishing long-term trends in abundance. In terms of NPS pollution monitoring, redd counts are generally of limited value as they reflect many impacts unrelated to habitat (overharvest, migration barriers, etc.). However, monitoring the spawning population may be valuable in determining population limiting factors and guiding selection of variables to be monitored.

There are two approaches: one is to survey all spawning areas; the other is to choose an index area. The first approach is appropriate when the scope of the study is large or if spawning areas are limited. The index approach is necessary when spawning areas are widely dispersed or manpower is limited.

The actual counts are typically made by ground crews, or by an observer in a plane or helicopter. Calculation of the final counts requires knowledge of the life of individual redds. If redds are clearly visible for many weeks, a single count near the end of the spawning season may be an accurate measure of total numbers. Often, redds are visible for only a few weeks and this, combined with extended periods of spawning, can require multiple surveys. In this case, redd locations are marked with a dated tag on adjacent riparian vegetation. Tagging reduces the likelihood that redds will be recounted on subsequent surveys. If redd locations cannot be marked (e.g. aerial surveys), all visible redds are counted on each survey. The total number of redds counted on each date is plotted on a graph, and a curve is drawn connecting them. This curve defines an area with the units in "redd-days." Dividing this value by an estimated redd life (e.g., 2 weeks) yields an estimate of total redds. The redd life estimate is based on professional judgment or observation of artificial redds or natural redds of known age. Any redd counting planned in the Columbia Basin should adhere to the protocols being developed by the Columbia River Intertribal Fish Commission (Heindl pers. comm.).

Water clarity, water depth, and personnel changes can affect the confidence in counts. Also, some training is required before field personnel can detect false redds (areas of exploratory digging that contain no eggs) and the limits between redds in heavily used spawning areas. As mentioned earlier, redd counts reflect many influences on the population that are not directly relatable to habitat condition or the BMP of concern. Also, counts are typically limited to particular species or groups (e.g. salmonids) and are of little value in assessing the total fish community.

Method Selection. For most NPS monitoring programs, snorkeling or electrofishing will be the primary methods for evaluating responses of populations or communities to BMP's.

The advantages of electrofishing over snorkeling include:

- Water clarity has less influence on effectiveness.
- Sampling is possible under low light conditions.
- Length and weight measurements are possible.
- Electrofishing is less subjective.

The advantages of snorkeling over electrofishing include:

- Water conductivity is irrelevant.
- Sampling in deep or complex habitats is effective.
- Little specialized equipment is needed.
- Fish are not handled or harassed.

Selection between fish population monitoring techniques will be based on the goals of the program, size of the stream, complexity of the habitat, and the physical characteristics of the water (temperature and turbidity). For example, if statistically valid population estimates in a small stream are desired, electrofishing is the best option due to the general acceptance of the method. In larger streams, snorkeling will likely provide a better estimate of populations than electrofishing due to the latter technique's inefficiency in deep water. Turbid waters necessitate use of electrofishing.

If population age structure data is desired, the difference in length between age groups of species will determine which technique is appropriate. Populations where age groups exhibit discrete lengths can be described by snorkel observations; overlapping age groups will require careful measurement (possibly including scale analysis) of fish captured by electrofishing.

Species composition data can be collected by either method, with habitat complexity and water turbidity governing selection.

Analysis. Selection of the correct parameter for a particular monitoring study requires careful consideration. In general, population levels or biomass may not be responsive to the types of changes that are likely to result from implementation of a BMP. Characteristics of the community such as species composition or characteristics of populations such as age structure, length-weight relationships (condition factor), and length-age relationships may be more appropriate. Selection between these parameters will depend on the type of changes expected from the BMP. For example, if suspended sediment levels are expected to change due to the BMP, changes in condition factor may indicate improvement in feeding opportunities. If a dramatic temperature change is expected, species composition may be the best measurement of effectiveness (e.g. re-establishment of cold-water fishes).

Macroinvertebrate Sampling

Sampling can be either quantitative or semi-quantitative, with the level of effort and cost being much higher for the quantitative sampling. The semi-quantitative methods (rapid bioassessments) are gaining favor in point source investigations due to their lower cost, but to our knowledge have not been used extensively in NPS monitoring programs. Some programs reviewed during this study incorporate the quantitative method developed by Winget and Mangum (1979). This method is focused on analysis of tolerant and intolerant species and involves reduced sample sizes and less effort overall than typical quantitative studies. A limitation of the method is that the underlying relationships have not been tested except on the data set from which the method was developed (Platts et al. 1983).

The following paragraph on techniques is based on Platts et al. (1983). There are two main samplers used for quantitative macroinvertebrate studies: the Surber (Surber 1937), and Modified Hess samplers (Waters and Knapp 1961). Each is placed directly on the substrate and pressed down firmly. The Surber sampler contacts the substrate and the modified Hess sampler penetrates the substrate with the lower portion of the tube (Modified Hess) to prevent entry of organisms from outside the sample area. The frame of the samplers defines a known area that is disturbed carefully to a predetermined depth (50 or 100 mm). The substrate must be cleaned with a soft brush and visually inspected for remaining invertebrates. The dislodged invertebrates drift back into the collection net. The sampler is lifted carefully from the stream, keeping the front end of the collection net pointed into the current and up at about 45 degrees. The sample is removed from the net and preserved in 70 percent ethanol.

Rapid bioassessment sampling can be conducted with either of the above samplers or with a kick sampler. The kick sampler is a net that is held in a riffle downstream from a worker who disturbs the substrate in a given area for a given time. The dislodged organisms are captured in the net.

In quantitative studies, sample collection is typically rapid. Identification of the samples is much more time consuming and requires taxonomic expertise. Typically, the samples are sorted into representative taxonomic groups, then detailed study is undertaken. Rapid bioassessment techniques involve much less detailed taxonomy and are much faster and cheaper because only a portion of the sample is analyzed. Analysis of macroinvertebrate data can be based on species composition, density, biomass, species richness, species diversity, abundance, biomass, functional groups, or biotic indices.

The basis of data analysis and the taxonomic expertise required will depend on the study objectives and the resources available. For monitoring effects of BMPs, species level identifications will usually be required. Analysis can range from consideration of indices calculated from the data to detailed analysis of the macroinvertebrate assemblage from a community ecology perspective. Analysis will usually require significant input by a skilled specialist.

In general, intensive quantitative study will be necessary to evaluate BMPs related to silviculture and agriculture. Rapid bioassessment techniques are probably appropriate if effects are expected to be dramatic or if the BMP applies to impacts that are similar to a point source problem (e.g., outflow from a confined animal feedlot) where upstream and downstream samples can be collected. Selection between these methods must be made on a case-by-case basis by a competent aquatic ecologist based on study objectives. Use of "cookbook" collection and analytical protocols should be avoided because the focus will generally be too broad to yield useful results when evaluating effects of BMPs for silviculture and agriculture.

Bacteria

The presence of fecal coliform bacteria is used to indicate the potential for human pathogens such as Salmonella and enteric viruses. State and federal water quality regulations employ fecal coliform counts to monitor fecal contamination and to define the sanitary status of waters.

Coliforms are a generic group of bacteria capable of lactose digestion with the production of gas within 48 hrs at 35°C. Fecal coliforms are a subset that can survive at 44.5 ± 0.2°C. Human waste has a high percentage of fecal coliforms, whereas animal waste has a high percentage of fecal streptococci. The ratio between the two groups of bacteria gives an indication of the source of the contamination, (human or animal waste), and the type of associated pathogens. The source of microbes is important to discern because pathogens causing disease in humans are generally spread from human to human and not from animal to human.

Methods. Two methods of bacterial enumeration are described in "Standard Methods of Examination of Water and Wastewater." The multiple tube fermentation technique (Standard Methods 908A) relies on the probability of a dilution tube being inoculated with a seed organism. The accuracy increases with the number of replicate tubes, and the index is reported as Most Probable Number (MPN). The membrane filter technique (Standard Methods 909A) is widely used in freshwater systems; reliability is questionable when the water sample is highly turbid or contains chlorine, metals, or phenols. The membrane technique is rarely used for seawater samples because of technical difficulties with the salt content.

Considerations. Coliform bacteria populations exhibit daily and seasonal cycling. Populations usually peak in the early evening due to factors such as stream stage and water temperature (Bohn and Buckhouse 1983). Thus, samples should be taken at the same time of day during monitoring. Annually, populations peak in periods of warm water and low dilution flows, or after a heavy runoff event. Water discharge should be measured so that populations can be expressed in absolute numbers (loading) as well as concentration.

Although data from Gerba (1983) show that indicator and pathogenic bacteria in human sludge applied to soil return to background levels within 3 wks, and that levels of fecal coliforms in runoff were insignificant, coliform and streptococci bacteria may survive 20 days in the soil of cattle-grazed land, and at least 1 yr in cow dung (Bohn and Buckhouse 1983). Saxton et al. (1983) found that it took almost 3 yrs of cattle absence before fecal coliform numbers in runoff returned to background levels. Furthermore, coliforms and streptococci adsorb to sediments (Stephenson and Rychert 1982). Thus, disturbance of the stream sediments may give elevated estimates. As a result, there often will not be an immediate response in indicator bacteria levels to the implementation of BMPs.

The behavior and survival of fecal coliforms and Salmonella is similar in natural waters (Geldreich 1970). However, it is apparent that fecal coliforms are not satisfactory indicators of Giardia spp. (Bohn and Buckhouse 1983). Fecal streptococci survive longer than fecal coliforms in soils and sediments, and contamination can be falsely attributed to animal rather than human sources.

Enterococci (a subgroup of fecal streptococci) may be a more informative indicator of presence of human pathogens. Enterococci are thought to be a more specific indicator of human wastewater pollution than fecal coliform or fecal streptococci numbers, and may be related to human health risk under certain conditions (Heywood pers. comm.).

Algae

Planktonic algae have often been used as indicators of water quality in lakes. Algal populations are usually not monitored in stream communities in the Pacific Northwest, and their value as a parameter is not well known.

Species composition, species diversity, biomass, and cell volume are typical measures applied to planktonic algae. Species composition in particular has been used to identify lakes in which productivity is affected by nitrogen or phosphorous levels. Careful consideration must be given to timing and location of sampling.

Currents and winds cause patchy plankton distribution in lakes, necessitating a number of samples. The surface layer of the lake should not be over-represented, since certain plankton are trapped at the surface microlayer. Furthermore, some planktonic forms migrate vertically in response to light intensity, and most species have periodic blooms of short duration.

Cylindrical tube samplers are more accurate than net samplers since cell damage is minimized and mesh size does not affect sample composition. Enumeration and species identifications usually must be conducted in the laboratory by trained botanists. Frequently the samples must be preserved and concentrated to facilitate analysis, but this can damage and distort algal cells. Thus, use of phytoplankton algae in monitoring programs generally requires considerable expertise and labor.

Periphyton and aufwauchs are attached to rocky substrates of streams and lakes and can be quantitatively sampled. Distribution is typically patchy and replicate samples of the substrate and attached biota should be collected. As with phytoplankton, analysis requires specific expertise and is time consuming.

Chlorophyll _a_ is one of the three chlorophylls found in algae and constitutes 1-2 percent of the dry organic material. Two analytical methods are available: spectrophotometry, which measures the optical density of chlorophyll _a_, _b_ and _c_; and fluorometry, which measures the fluorescence of chlorophyll _a_. The latter method is more sensitive and requires a smaller sample than the former. Pheophytin _a_, a degradation product of chlorophyll _a_, can interfere with both methods. Acid hydrolysis breaks down chlorophyll to pheophytin _a_, which can be measured with the above techniques. A high chlorophyll _a_ to pheophytin _a_ ratio indicates a healthy biomass.

Chemical Monitoring

Water quality criteria identify concentrations of chemicals that allow propagation of fish and wildlife, recreational uses, and protection of public health. Criteria are generally derived from toxicity bioassays of susceptible species and susceptible individuals based on total population assessments. In most cases, the information on susceptibility of individuals (usually derived from standard deviations around mean survival) is used to incorporate a safety factor in the water quality criterion. Thus, large changes in chemical parameters are probably required before measurable changes occur in population characteristics, community structure, or survival of individual organisms.

Monitoring of water chemistry typically occurs for two reasons. First, it determines whether the water quality meets established standards. Second, it is used as an indicator of potentially chronic or subtle effects on aquatic species. Laboratory bioassays are helpful in understanding the response of organisms to particular chemicals under well-defined test conditions. In the field, however, exposure conditions are rarely well defined. Synergistic effects may occur as a result of the mixture of chemicals that exist in the water body and subtle effects may occur on organismal behavior that are difficult to observe in laboratory conditions.

The measurement of chemical levels in water has become routine. Sophisticated equipment is available to detect minute levels, and rugged portable units are available for field use for some of the more common water chemistry parameters. Standardized protocols outlining methodology have been published; some of the more common ones include EPA (1982), USGS (1977), and APHA (1985).

The variety and ease of water quality chemistry necessitates a note of caution; it is easy to fall into a trap of collecting information on a large number of chemical parameters and give little thought to the utility of the data. Many researchers and resource managers are finding that changes in water chemistry do not necessarily coincide with changes in aquatic communities. Species composition, abundance, diversity, stability, and productivity of aquatic organisms often do not show measurable response to changes in water chemistry that one expects from implementation of BMPs. Monitoring chemical changes, however, is very useful in judging whether water quality meets standards established by regulations.

Temperature, pH, Dissolved Oxygen, and Conductivity

Commercially available instruments provide essentially continuous records of temperature, pH, dissolved oxygen and conductivity. The electrodes can be placed directly into a flowing stream. Temperature can also be readily assessed *in situ* through the use of electrometric probes that can be used to take several depth readings at a sampling station.

Water temperature is used with salinity to determine water density. Temperature also affects gas solubility and rates of biological processes.

Temperature influences pH measurements, but better commercial pH meters compensate for temperature effects. Calculations for correcting temperature effects are instrument-specific, depending on the electrode used. Additionally, pH affects the carbonic acid-carbon dioxide balance in water.

Titration using iodometric methods (e.g., Winkler method) remains the most precise and reliable procedure for dissolved oxygen analysis. Membrane electrodes, however, offer advantages of analysis in situ and eliminate sample handling and storage errors. The effect of temperature on electrode sensitivity is proportional to the membrane permeability (i.e., membrane material and thickness). The availability of dissolved oxygen in the water is affected by temperature and the amount of organic matter.

Conductivity can be readily measured with a continuous recorder, or with an electrometric probe. Conductivity is at least as good a criterion as total dissolved solids for assessing the effects of ions on chemical equilibria and physiological effects on plants and animals (APHA 1985).

Salinity

Salinity in estuaries is measured with either a continuous recorder or a portable electrometric probe. With the latter, it is useful to take several readings at different depths.

Salinity affects mixing rates and density distribution in the water column and solubility of dissolved oxygen.

Alkalinity

The alkalinity of water is the capacity to neutralize strong acids and is primarily a function of the carbonate, bicarbonate and hydroxide content. Alkalinity is determined by titration.

Nitrogen

Most effort in monitoring nitrogen levels distinguishes between organic and inorganic forms of nitrogen. Un-ionized ammonia is the most toxic of the nitrogen forms and may be of particular concern in smaller streams. Total nitrogen loading to small streams may also be of concern because of the potential for eutrophication followed by depression of dissolved oxygen levels. Ammonia is an immediate byproduct of the breakdown of urine and therefore may be useful to trace animal wastes in water.

Nitrogen exists in various forms which can be interconverted by chemical and biological means. The interconversion of nitrogen species should be considered when storing samples prior to analysis.

The Kjeldahl digestion reduces organic nitrogen to ammonia, which is quantified colorimetrically. The Kjeldahl process thus measures both organic nitrogen and ammonia.

For chemical analyses, any ammonium in the sample is converted to ammonia, and the total ammonia concentration is measured either colorimetrically or titrimetrically. The relationship between nontoxic ammonium and toxic ammonia is a function of temperature and pH, and these two parameters should be measured in the field to assess ammonia toxicity.

Nitrate can be measured potentiometrically or reduced to nitrite, which is quantified colorimetrically. Nitrite is analyzed colorimetrically, although under most natural conditions it is present in low concentrations since it is rapidly oxidized to nitrate.

Phosphorus

Phosphorus in water occurs predominately in the form of orthophosphate and organically bound phosphates. The division between the species is operationally defined. Filterable (also called dissolved) phosphorus is that which passes through a 0.45 mm filter. The residue is termed particulate phosphorus, and the two fractions added are total phosphorus. The chemical analysis of each fraction provides a further division.

Orthophosphate, a major constituent of fertilizer, is that fraction which reacts in a colorimetric test without a hydrolysis or oxidative digestion pretreatment. Hydrolyzable phosphorus is the fraction that results from a mild acid digestion at 100^{o}C. This process converts the hydrolyzable-P to orthophosphate, which is then measured. Total phosphorus is measured if the sample is digested in strong acid at elevated temperature (boiling point). Phosphate content is determined by colorimetric measurement of orthophosphate. Organic phosphorus can be calculated from total phosphorus minus the hydrolyzable fraction.

Carbon

Carbon exists in water and sediments in inorganic (carbonates, bicarbonates) and organic forms (sugars, mercaptans, oils, cellulose, lignins, tannin).

The saturation of water with respect to calcium carbonate is a function of calcium ion concentration, pH, temperature, alkalinity, ionic strength, and total dissolved solids concentration.

The Langlier Index (LI) (or Saturation Index, SI) is used to determine whether or not water is in equilibrium with $CaCO_3$. Calcium carbonate concentration is equivalent to the measure of hardness and can be quantified by EDTA titration.

Total organic carbon is measured by combustion and subsequent infrared analysis of the evolved carbon dioxide. Terminal combustion of organic compounds converted to carbon dioxide occurs at temperatures of 500-650°C.

Analysis of an untreated sample is a measure of total carbon, while analysis of the acid-treated fraction is a measure of organic carbon. Inorganic carbon is calculated by subtraction. Another method of separation is based on differential thermal combustion. Inorganic carbon is converted to carbon dioxide at 950-1,300°C, organic compounds at 500-650°C.

Tannins and lignins are highly complex organic materials. Acid digestion causes the hydroxyl groups to react with indicator acids, which change color and can be quantified.

Ions

Hardness. Hardness reflects the ability of ions in water to precipitate soap. Since calcium and magnesium ions are most significant, hardness is defined as the concentration of these ions expressed as calcium carbonate. Hardness can be determined by calculation or by EDTA titration.

Calcium and magnesium are analyzed by atomic absorption spectrophotometry after either a filtering or an acid digestion pretreatment.

Potassium and Sodium. Potassium is analyzed by flame photometry, following either a filtration or an acid digestion pretreatment. Sodium is quantified in the same manner.

Chlorine. Chlorine can be determined by titration or potentiometrically with electrodes.

Metals

Metals in streams exist in various forms (dissolved, soluble, complex, and particulate), and the toxicity of the metal is a function of the form it is in. Redox potential, pH, salinity, chelating compounds, and the presence of fine sediments will affect the form and distribution of metals.

Selenium has a toxic effect upon mammals similar to arsenic, and has become an element of concern with respect to irrigation projects on semi-arid lands of the western states. Elevated levels of selenium can be found in water resulting from natural deposits, mining activities, or industrial pollution. Selenium levels can be determined colorimetrically or by use of an atomic absorption spectrophotometer.

Pesticides

Herbicides are commonly chlorophenoxyacetic acids, of which 2,4-D and 2,4,5-TP (Silvex) are the most common. Chlorophenoxy acids and their esters are extracted from acidified water with an organic solvent, and completely converted to methyl esters. The esters are purified on a microabsorption column and are quantified using gas chromatography.

Organochlorine pesticide use has been restricted because of its persistence in the environment. This has caused an increase in the use of organophosphate and carbamate pesticides. These compounds degrade more rapidly than organochlorines but are more acutely toxic because of their cholinesterase activity, a component of the animal nervous system. Because the mode of action of these pesticides is biological, the method of determining their presence is by total in vitro cholinesterase inhibition.

The compound 3,3-dimethylbutyl acetate (DMBA) is used as the substrate for the enzyme cholinesterase. The enzyme-catalyzed reaction of DMBA results in the hydrolysis of the ester to 3,3-dimethylbutanol (DMB) and acetic acid. After the reaction period, the hydrolysis is stopped and the mixture extracted with carbon disulfide. The determination of DMB is made by gas chromatograph using a hydrogen flame ionization detector.