United States
Department of
Agriculture

Forest Service

Northeastern Area
State & Private Forestry

Forest Resources
Management

Radnor, PA

NA-PR-07-91

RIPARIAN FOREST BUFFERS

Function and Design for Protection and Enhancement of Water Resources

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Prepared by
David J. Welsch

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Maryland Department of Natural Resources, Forest Park and Wildlife Service

The United States Department of Interior (USDI) Fish and Wildlife Service

Cover: A natural riparian forest provides excellent protection for water resources

Jeff Horan Maryland Department of Natural Resources

Streamside forests are complex ecosystems vital to the protection of our streams and rivers

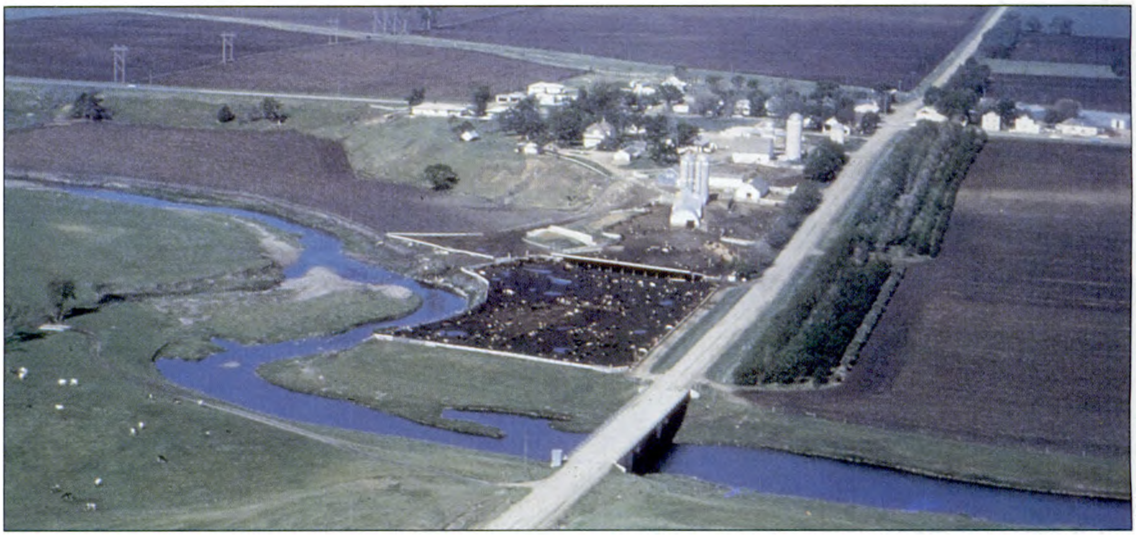
Streamside forests are crucial to the protection and enhancement of the water resources of the Eastern United States. They are extremely complex ecosystems that help provide optimum food and habitat for stream communities as well as being useful in mitigating or controlling nonpoint source pollution. Used as a component of an integrated management system including nutrient management and sediment and erosion control practices, streamside forests can produce a number of beneficial effects on the quality of water resources. Streamside forests can be effective in removing excess nutrients and sediment from surface runoff and shallow groundwater and in shading streams to optimize light and temperature conditions for aquatic plants and animals. Streamside forests also ameliorate the effects of some pesticides, and directly provide dissolved and particulate organic food needed to maintain high biological productivity and diversity in the associated stream.

Jeff Horan Maryland Department of Natural Resources

▲ *Streamside forests are crucial to water resource protection.*

USDA Forest Service

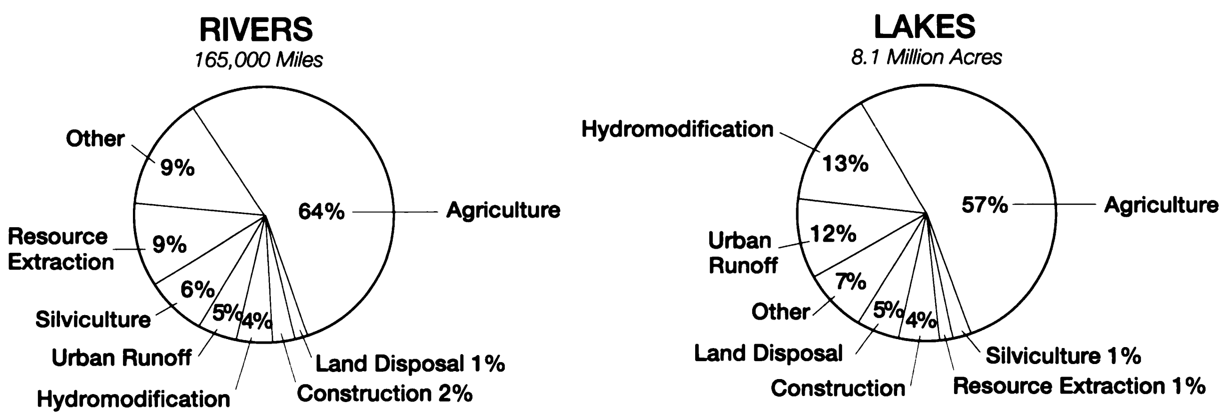
▲ *Forested watersheds are the generally accepted benchmark of quality for water resources.*



USDA Soil Conservation Service

▲ *Deforestation associated with agricultural expansion has left our waters vulnerable to pollution from animal waste and fertilizer.*

RELATIVE PORTION OF ASSESSED WATERS IMPACTED BY VARIOUS CATEGORIES OF NPS POLLUTION

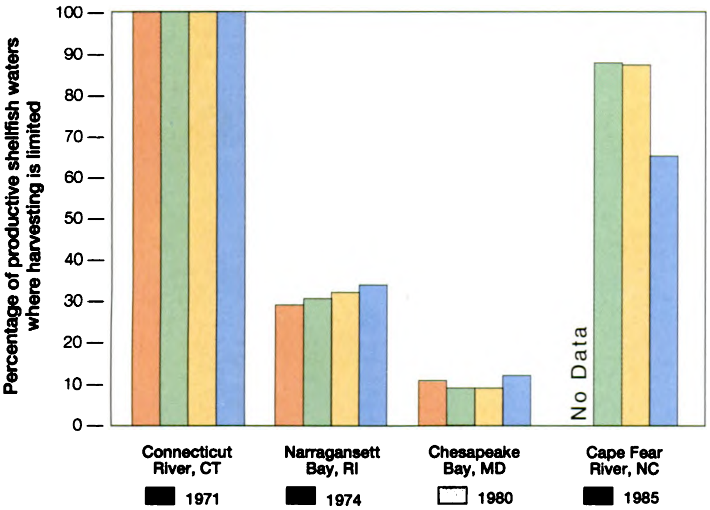


Reference: 1985. America's Clean Water: The State's Evaluation of Progress.

USDA Soil Conservation Service

▲ *Many of America's waters have been rendered unfit for use.*

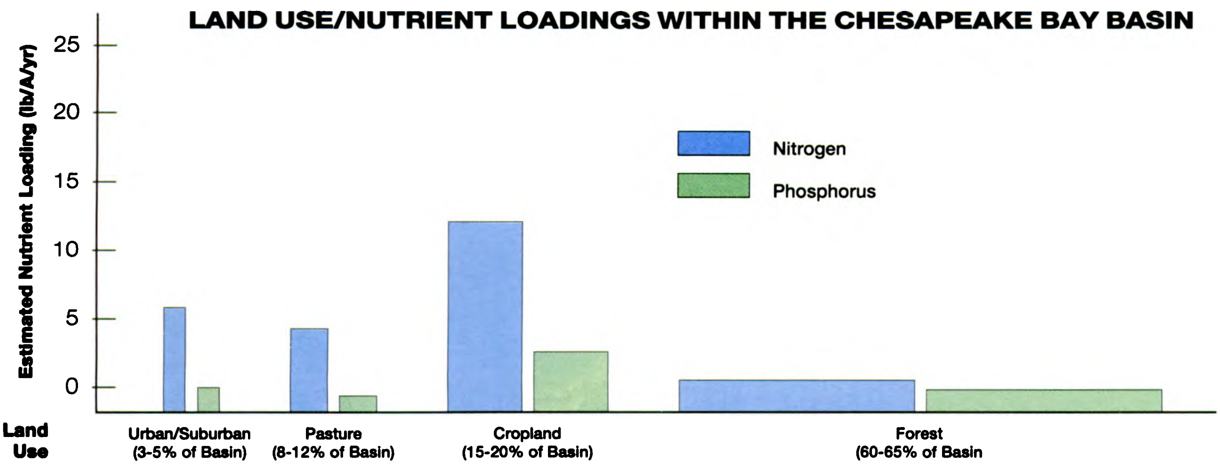
HARVEST–LIMITED SHELLFISH WATERS FOR SELECTED ESTUARIES, 1971-1985



Reference: 1989. Environmental Trends, Council on Environmental Quality.

The removal of streamside forests has adversely affected the vitality of our water resources

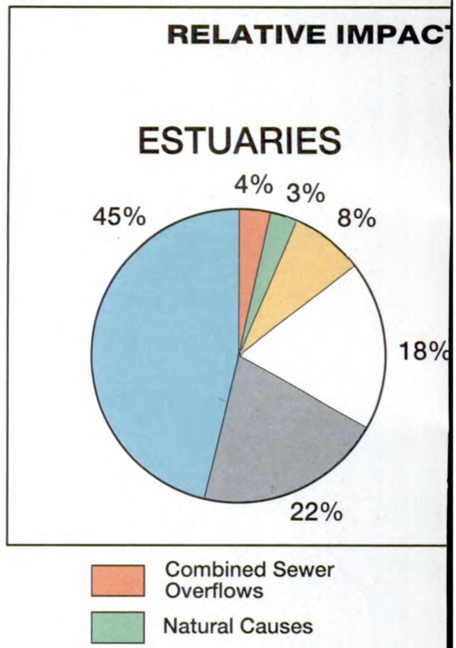
In natural conditions, streamside forests protected most of the rivers and streams of our nation, but deforestation associated with agricultural and urban expansion has drastically reduced the extent of streambank protected by forest. The result has been an adverse effect on the quality of water and aquatic habitats. In many of our streams and estuaries, water is unfit for human consumption, industrial use or recreation. Shellfish and finfish production is also reduced. These problems are linked, in part, to contamination from nutrients, sediment, animal waste, and other pollutants associated with agricultural and urban runoff.



Reference: Magette and Weismiller 1983. Agriculture and the Bay.

Continued Strengthening of the Clean Water Act Reflects the Public's Concern for Clean Water

The Water Pollution Control Act of 1948 or "Clean Water Act" and its subsequent amendments through 1987 demonstrate strong congressional determination to improve the quality of our water resources. These laws have done much to clean up point source contaminants by requiring states to establish and enforce water quality standards, by requiring specifications and licensing for the discharge of effluents, and by funding the installation of municipal sewage treatment plants. As a result of the cleanup of concentrated pollution from specific sites, nonpoint source pollutants, which are typically dispersed in origin, have increased in relative importance and now account for more than 50% of the pollution in our nation's waters. Nonpoint source pollutants include sediment, nutrients, pesticides, animal wastes and other substances which enter our water supply as components of runoff and ground water flow.



Excess Nitrogen and Phosphorus Spur Algal Growth, Deplete Oxygen and Kill Fish

Aquatic plants, like their terrestrial counterparts, require nutrients to grow and reproduce. The growth of algae and other vegetation in water bodies is usually controlled by the nutrient whose supply is most limited. This concept, first described by Justis Liebig in 1840, is known as "Liebig's Law of the Minimum". Phosphorus is usually the limiting nutrient in brackish or freshwater, while nitrogen is usually the limiting nutrient in saltwater. When excess nutrients applied to the land in the form of manure or commercial fertilizer find their way into the water, blooms or overabundant growth of algae and other aquatic plants can result. Algal blooms at the surface can interfere with photosynthesis of submerged plants by blocking sunlight, causing them to die. When this happens, dissolved oxygen levels near the bottom drop abruptly because oxygen demand by decomposing bacteria is great while little or no oxygen is being produced by the dying plants. The problem is compounded when organisms which flourish in oxygen starved environments release hydrogen sulfide and methane. These substances are toxic to fish and other aquatic life.

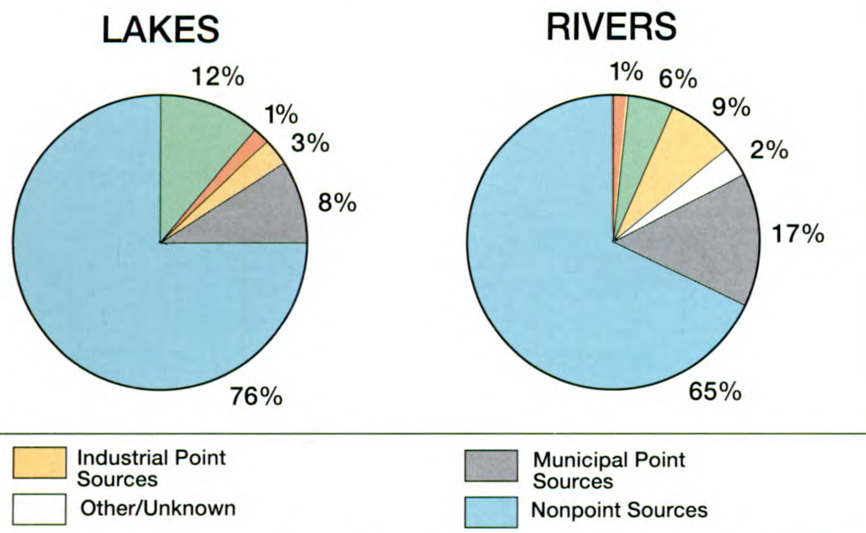
Jeff Horan Maryland Department of Natural Resources

▲ *Dense algal growth from excess nutrients blocks sunlight, causing plants to die.*

Excessive algal growth in estuaries can result in the decline of Eelgrass and the loss of shellfish beds. Shellfish die and the beds fail to recolonize when thick layers of algae prevent animals such as oysters from pumping water through their bodies to provide adequate food and oxygen. Eelgrass, a submerged grass eaten by many waterfowl, is lost when floating algal mats and or phytoplankton in the water reduce light penetration and interfere with photosynthesis.

Some species of fish, as well as other animals lower in the food chain, are very sensitive to low levels of oxygen or food and generally die. The loss of species simplifies the food chain of an ecosystem and makes it more vulnerable to further destruction.

...F NONPOINT SOURCE POLLUTION PROBLEMS IN IMPAIRED WATERS



Reference: 1989. Environmental Trends, Council on Environmental Quality.

Streamside Forests Remove Pollutants in Several Ways

Recent research has shown that streamside forests can improve the quality of water resources by removing or ameliorating the effects of pollutants in runoff and increase the biological diversity and productivity of stream communities by improving habitat and adding to the organic food base. Streamside forests function, often simultaneously, as **FILTERS, SOURCES, TRANSFORMERS** and **SINKS...**

▲ *Aquatic grasses are important to the food web.*

▲ *Many species, including fish, are sensitive to low oxygen levels and die as a result.*

Excess Nitrogen in Drinking Water is Detrimental to Children and Livestock

Excess nitrogen, in surface and groundwater systems used for drinking water, is dangerous to the health of certain groups of people and animals. For example, infants less than six months old are particularly susceptible to harm because their stomachs are not acidic enough to prevent the growth of certain bacteria which convert nitrate to nitrite. High levels of nitrites can oxidize hemoglobin to form methanoglobin which is unable to carry oxygen. Brain damage or death by suffocation can result from this condition known as methemoglobinemia or blue baby syndrome. Pregnant cows can also suffer from the syndrome which usually results in death of the cow, calf or both.

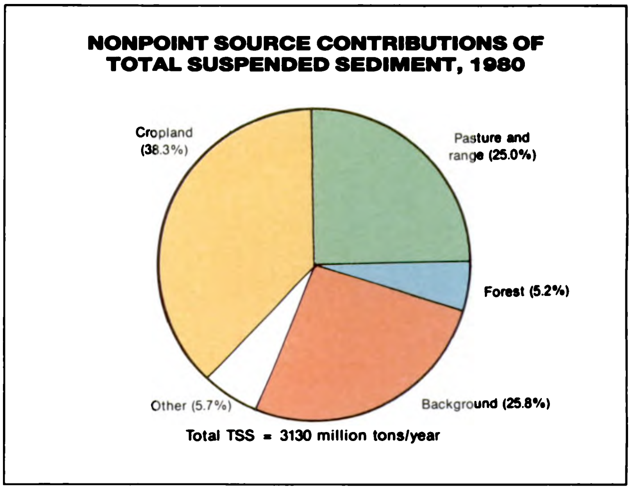
The allowable level of nitrogen in water for children six months of age or less is 10 ppm (10mg/1) as nitrate nitrogen or 45 ppm (45 mg/1) as nitrate. Adults and older children can probably tolerate higher levels, but the standard is usually set at the more conservative level. Should ground water become contaminated, nitrate removal at a community treatment plant is presently estimated to cost about $10 to $15/month for a family of three.

The Streamside Forest Removes Sediment and Sediment Attached Phosphorus by Filtration

The streamside forest functions as a FILTER by removing sediment and other suspended solids from surface runoff. Sediment is probably the most common and most easily recognized of the nonpoint source pollutants. Cropland erosion accounts for about 38% of the approximately 1.5 billion tons of sediment that reach the nation's waters each year. Pasture and range erosion accounts for another 26%.

Sediment suspended in the water can reduce or block the penetration of sunlight adversely affecting the growth and reproduction of beneficial aquatic plants.

Sediment deposited on the stream bottom can interfere with the feeding and reproduction of bottom dwelling fish and aquatic insects, weakening the food chain. Large deposits of sediment can overfill stream channels and floodplains, greatly increasing



Reference: 1989. Environmental Trends, Council on Environmental Quality.

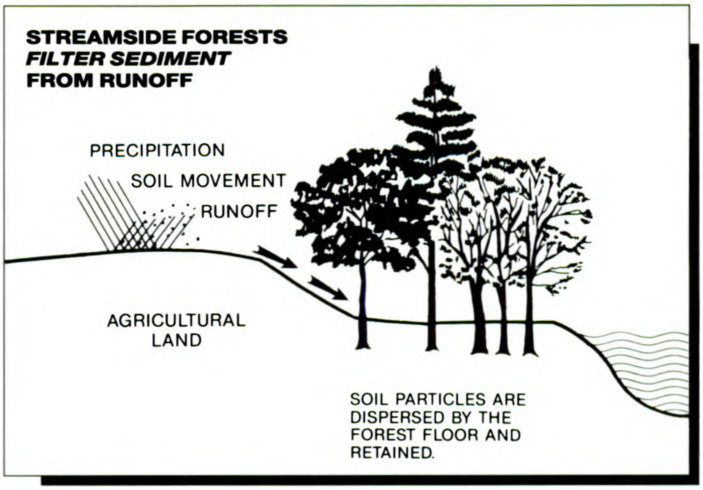
USDA Soil Conservation Service

▲ *Agricultural runoff can carry sediment, nutrients and pesticides to surface waters.*

USDA Soil Conservation Service

▲ *Sediment is the most easily recognized of the nonpoint source pollutants.*

▲ *Streambank erosion also contributes to stream sediment load.*



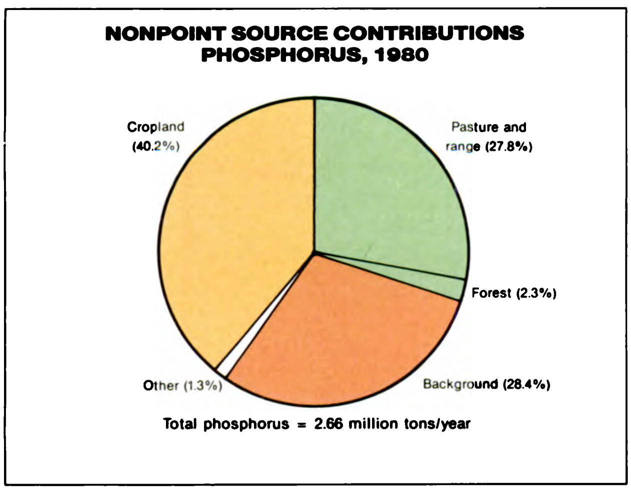
Reference: Maryland Department of Natural Resources

the potential for flooding.

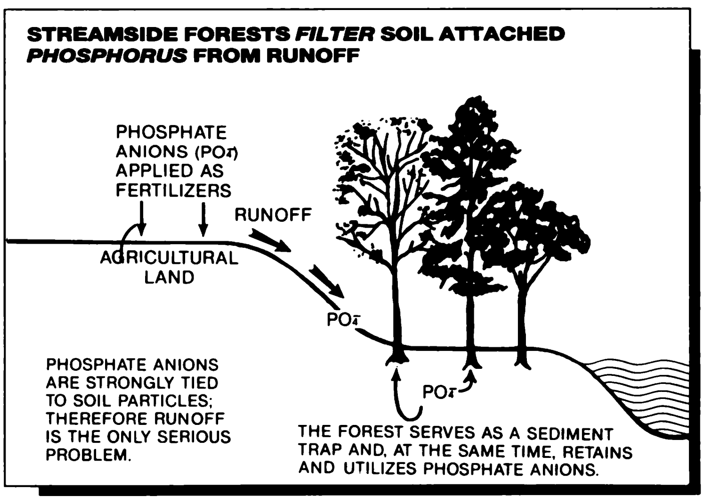
Several mechanisms of sediment removal are at work in the streamside forest. Some sediment settles out as the the speed of the flow is reduced by the many obstructions encountered in the forest litter. Additional sediment is filtered out by the porous soil structure, vegetation and organic litter as the runoff flows over and into the floor of the streamside forest.

Phosphorus is also reduced by the filtering action of the streamside forest because about 85% of available phosphorus is bonded to the small soil particles comprising the sediment. Approximately 4% of the phosphorus is attached to soil particles too small to be filtered by these processes resulting in a removal of about 80% of phosphorus by the riparian forest filter. The minor amount of ammonium which is bound to sediment can be filtered out in the same way.

However, dissolved phosphorus and nitrate must be removed by either microbial or biochemical transformation processes.



Reference: 1989. Environmental Trends, Council on Environmental Quality.



Reference: Maryland Department of Natural Resources

The Streamside Forest Transforms Nitrate to Nitrogen Gas

The streamside forest functions as a TRANSFORMER when chemical and biological processes occurring within it change the chemical composition of compounds. For example, under well oxygenated soil conditions, bacteria and fungi in the streamside forest convert nitrogen in runoff and decaying organic debris into mineral forms (NO_3). These forms can then be synthesized into proteins by plants or bacteria. When soil moisture is high enough to create anaerobic conditions in the litter and surface soil layers, denitrifying bacteria convert dissolved nitrogen into various nitrogen gasses, returning it to the atmosphere. Studies have shown that the amount of nitrogen in runoff and shallow groundwater can be reduced by as much as 80% after passing through a streamside forest.

USDA Soil Conservation Service

▲ *Excess nitrogen from animal waste can reach streams with runoff.*

The streamside forest can also function as a TRANSFORMER when toxic chemicals such as pesticides are converted to non-toxic forms. Because of continued improvements in the for-

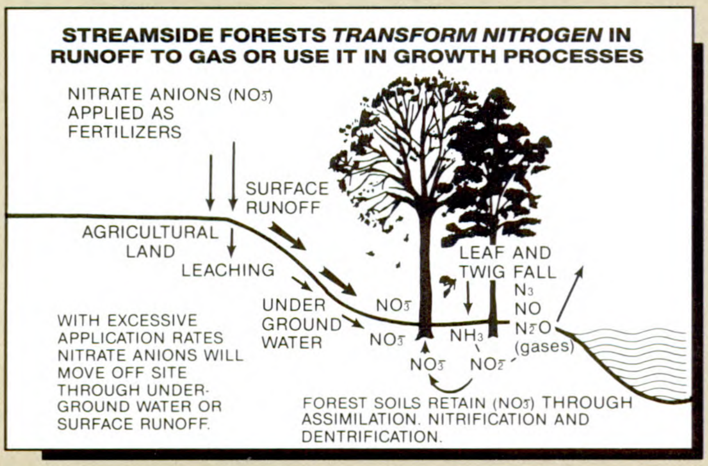
Nature Provides Safe Storage for Nutrients in Biological Cycles

The basic elements that occur in nature move through the environment in a series of naturally occurring chemical and biological states, a process commonly referred to as a cycle. The cycle describes the state, chemical form, and relative abundance of the element at each point along it's route through the environment. There is usually a state, chemical form, and location in the cycle in which nature safely stores the bulk of the element. In the case of the nitrogen cycle, the bulk is stored as nitrogen gas in the atmosphere. Pollution occurs when, through man's interference, an element occurs at some point in the cycle in an inappropriate form or amount, thus disrupting the environmental balance.

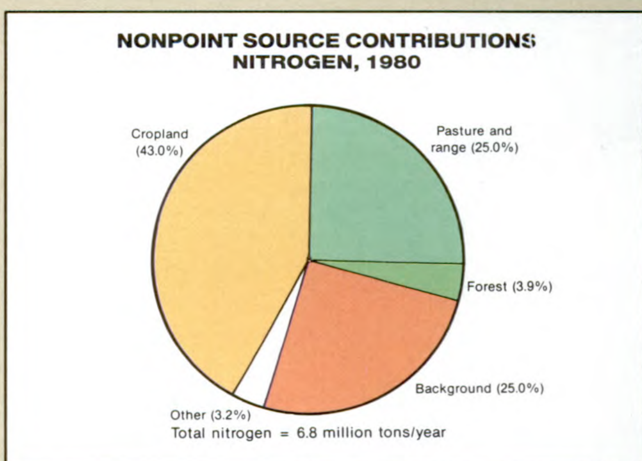
Nitrogen and phosphorus, elements essential to plant growth, move through the environment in such cycles. Fertilizers and animal wastes both contain nitrogen and phosphorus. When these elements are applied to crop and pasture lands in amounts in excess of plant needs, they can adversely affect water quality.

Phosphorus, the less mobile of these two nutrients, is quickly bound to soil particles or taken up by plants. Because about 85% of phosphorus is bound to soil and organic particles, eroding sediments and organic materials borne by runoff are the chief sources of phosphorus in water.

In contrast, nitrogen from fertilizer and animal waste is soluble in water as nitrate, and not held by soil particles. Nitrate ions which are not taken up by plants or converted to gaseous forms by microbial action can leach downward through the soil into the groundwater or move laterally with surface and subsurface flow to contaminate surface waters.



Reference: Maryland Department of Natural Resources



Reference: Maryland Department of Natural Resources

USDA Soil Conservation Service

▲ *Cattle trodden and grazed streambanks offer little protection from runoff and associated pollutants.*

USDA Soil Conservation Service

▲ *Careful metering of fertilizer and pesticides and minimum tillage methods help reduce nonpoint source pollution.*

mulation and management of pesticides, only very small amounts manage to leave the area of application. These residues, borne by runoff, are converted to non-toxic compounds by microbial decomposition, oxidation, reduction, hydrolysis, solar radiation and other biodegrading forces at work in the soil and litter of the streamside forest. While scientists have long understood the biological processes at work in the streamside forest, additional data are necessary to fully quantify their importance with respect to pesticide degradation.

Technological Improvements Have Reduced the Impact of Pesticides on the Aquatic Environment

The chemical, physical and biological properties which determine the effect of pesticides on water resources and the fate of these pesticides in the environmenthave been advanced significantly in the years since Rachel Carson's "Silent Spring". Wide spectrum pesticides, which kill a wide variety of non-target organisms and remain active for a long period of time are no longer used. For example, DDT is a wide spectrum chlorinated hydrocarbon with a half life of ten years (i.e. the time required for one half of a compound to decay). DDT, and other pesticides like it, have been banned in the United States because they concentrate in fatty tissue and tend to accumulate in the food chain where they can interfere with the reproduction and survival of many non-target species.

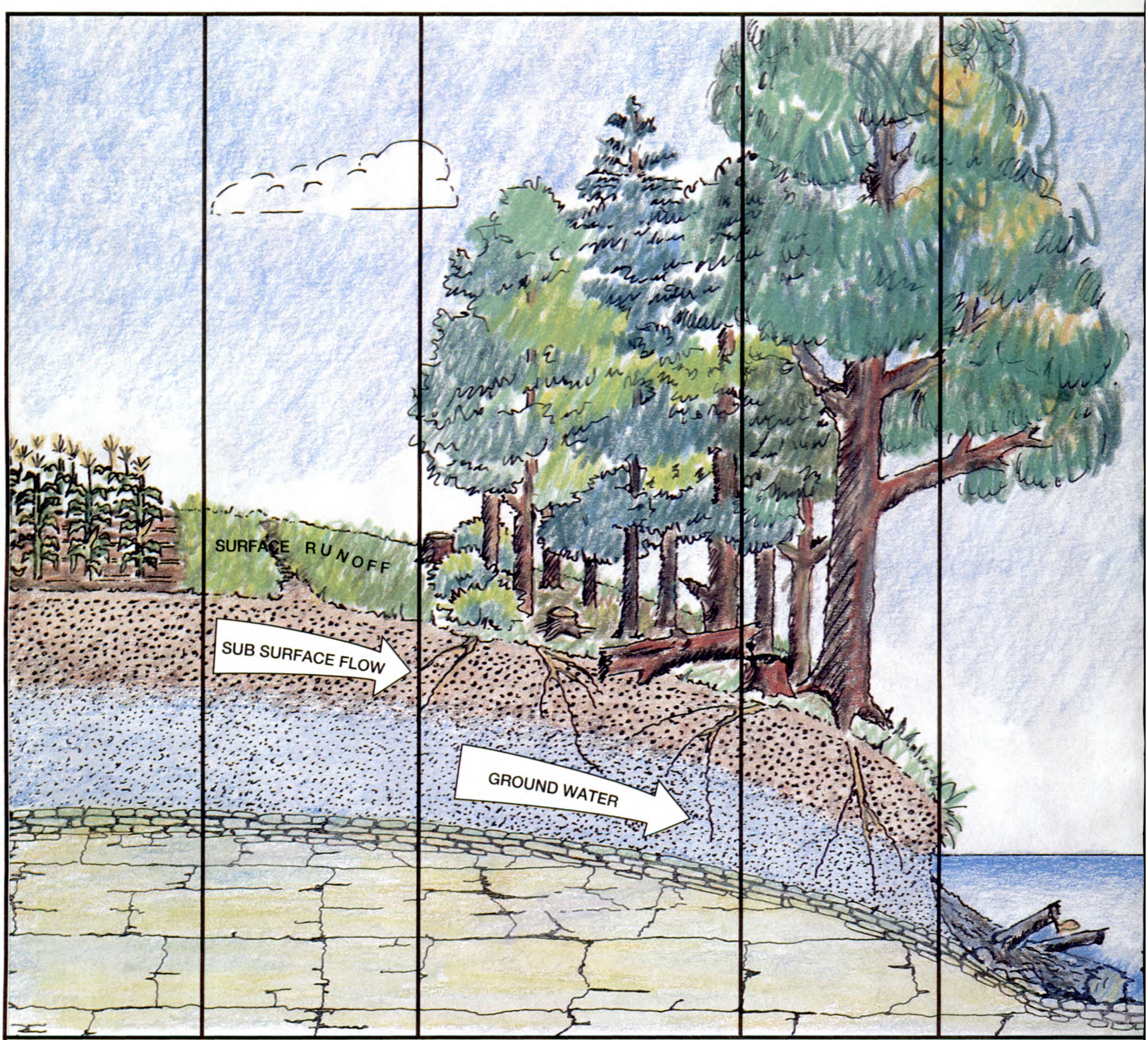
Many contemporary insecticides, such as Organophosphate and Carbamate have half lives of only a few days to several weeks, are not fat soluble, and are often much more specific in the targets they affect. While these insecticides do not accumulate up the food chain and are safer environmentally, they are very soluble in water and usually quite toxic to fish.

In contrast, most herbicides currently in use break down by the end of the growing season and are relatively less toxic to to fish than insecticides. However, if herbicides reach surface waters, many species of aquatic plants can be killed. Along with shorter half lives, newer pesticides utilize more effective stickers, the chemicals which keep them in place, and are thus effective in much lower concentrations. This makes them easier to control and adds less chemical to the environment. In addition, biological controls, viruses and bacteria that occur in nature, are being refined and adopted for use as natural microbial pesticides, such as Bacillus thuringiensis for the control of gypsy moth.

USDA Soil Conservation Service

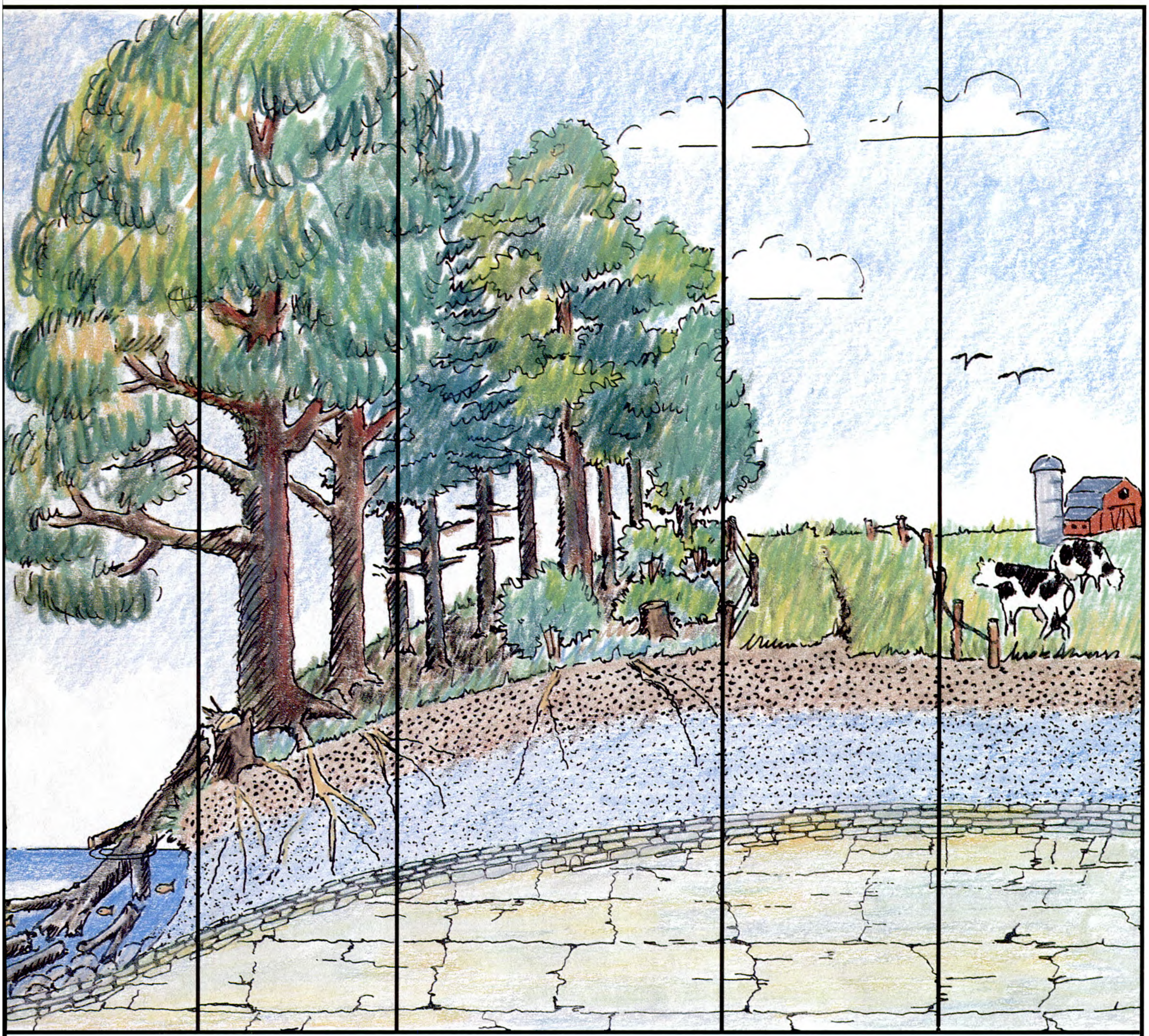
▲ *Large droplet sprayers and low level application help to control placement of pesticide.*

THE STREAMSIDE



	20'	60'	15'	
CROPLAND	**ZONE 3 RUNOFF CONTROL**	**ZONE 2 MANAGED FOREST**	**ZONE 1 UNDISTURBED FOREST**	**STREA**
Sediment, fertilizer and pesticides are carefully managed.	Concentrated flows are converted to dispersed flows by water bars or spreaders, facillitating ground contact and infiltration.	Filtration, deposition, plant uptake, anaerobic denitrification and other natural processes remove sediment and nutrients from runoff and subsurface flows.	Maturing trees provide detritus to the stream and help maintain lower water temperature vital to fish habitat.	Debris dams hold c by aquatic fauna ar cooling shade for fi dwellers.

FOREST BUFFER



	15'	60'	20'	
OTTOM	ZONE 1 UNDISTURBED FOREST	ZONE 2 MANAGED FOREST	ZONE 3 RUNOFF CONTROL	PASTURE
us for processing rovide cover and nd other stream	Tree removal is generally not permitted in this zone.	Periodic harvesting is necessary in Zone 2 to remove nutrients seques-tered in tree stems and branches and to maintain nutrient uptake through vigorous tree growth.	Controlled grazing can be permitted in Zone 3 under certain condi-tions.	Watering facilities and livestock are kept out of the Riparian Zone insofar as practicable.

The Streamside Forest Acts as a Sink by Storing Nutrients for Extended Periods of Time

The streamside forest can function as a SINK when nutrients are taken up by plants and sequestered in plant tissue. Some estimates indicate that 25% of the nitrogen removed by the streamside forest is assimilated in tree growth which may be stored for extended periods of time in woody tissue and possibly removed as logs or other forest products. Nitrogen and other nutrients may also be passed up the food chain when plant tissues are consumed by animals and converted to animal tissues. In wetter areas, nutrients in leaf litter can be stored for longer periods as peat. Sediments filtered out by the streamside forest remain to become incorporated into the forest soil.

USDA Forest Service

▲ *Nutrients can be filtered, transformed or stored by processes taking place in the forest litter.*

The Streamside Forest Provides a Source of Energy for Aquatic Life

The streamside forest functions as a SOURCE when it provides energy to streams in the form of dissolved carbon compounds and particulate organic detritus. These materials are critical to processes within the stream itself, helping to restore and maintain nature's equilibrium. In small, well shaded upland streams, as much as 75% of the organic food base may be supplied by dissolved organic compounds or detritus such as fruit, limbs, leaves and insects that fall from the forest canopy. Benthic detritivores, the stream bottom bacteria, fungi and invertebrates that feed on the detritus, form the basis of the aquatic food chain. They pass on this energy when they are consumed in turn by larger benthic fauna and eventually by fish. Thus the streamside forest functions as an important energy source for the entire aquatic food chain from headwaters to estuary.

David Funk

▲ *Energy for aquatic life is added to streams in the form of leaves,and twigs, a part of the mixture call detritus.*

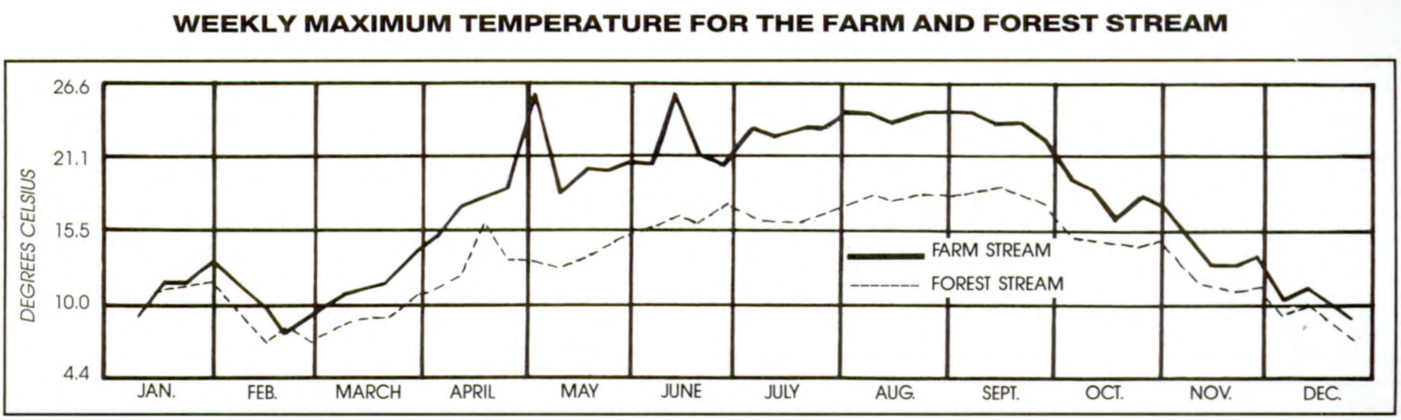
Insects, the Favorite Food of Trout are Abundant in Stream Reaches Cooled by Streamside Forests...

Water temperature, habitat structure, food availability and sediment flux are four important factors affecting the survival of trout (Salmonids) and other fish that are directly affected, to a large extent, by streamside forests.

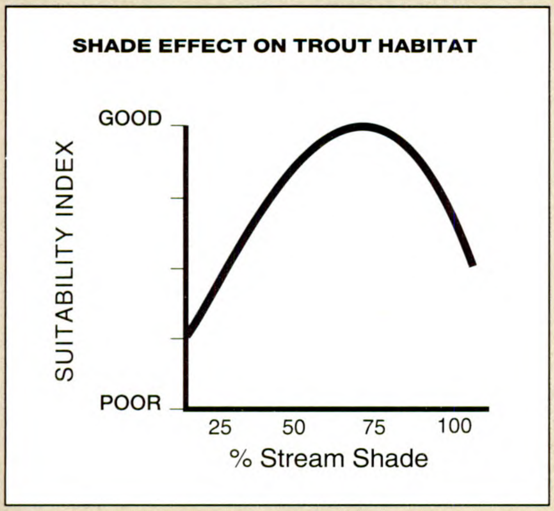
In most small streams and rivers, the seasonal pattern of water temperature, the first of these factors, is determined largely by the extent that direct solar radiation and air temperature can modify the temperature of the water. In a given region, groundwater stays fairly constant in temperature throughout the year (± 1 degree C of mean annual air temperature for the region) and provides most of the baseflow for stream systems. Loss of shade from streamside forests can greatly warm streams, increasing a trout's demand for dissolved oxygen and, at the same time, reducing the amount of dissolved oxygen available in the water.

Headwater streams of first to third order comprise about 85% of the total length of running waters, and because of the ratio of

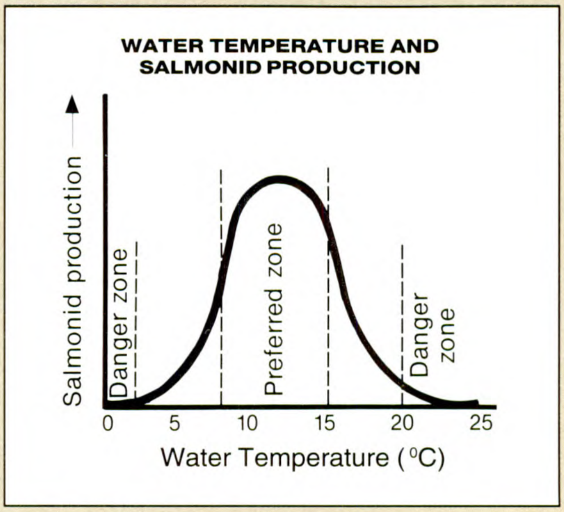
▲ *Quality water resources, as evidenced by a natural, healthy headwater stream.*



Reference: G. F. Greene, 1950. Land Use and Trout Streams, Journal of Soil and Water Conservation.



Reference: Raleigh, R.F.; Hickman, T.J.; Nelson, K.L; Maughan, O.E. 1980. Riverine habitat evaluation procedures for rainbow trout.



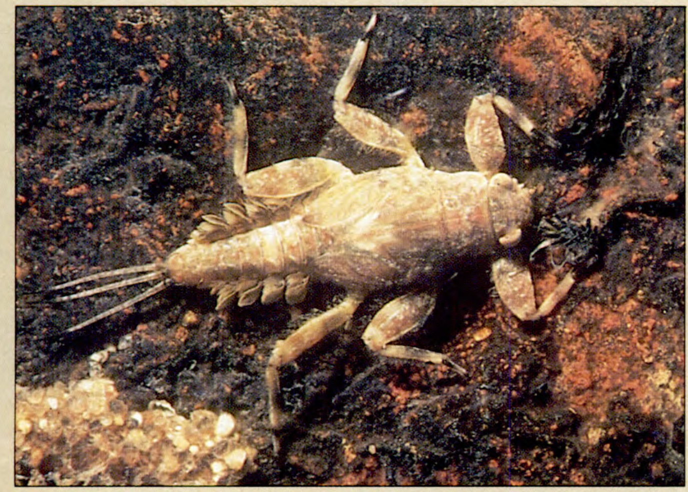
Reference: Everest, F.H.; Harr, D.H. 1982. Influence of forest and rangeland management on anadromous fish habitat in Western North America.

stream bottom to shoreline, are most readily influenced by exposure to solar energy. Agricultural drainage systems which intercept cool groundwater and drain it to streams in unshaded ditches contribute significantly to the increase in stream temperature.

Manipulation of the streamside forest canopy can be used to moderate and stabilize stream temperature to optimize the survivorship, growth, and reproductive needs of fish and aquatic macro-invertebrates and even benthic algae.

Habitat structure, the second factor affecting Salmonid survival, is enhanced by the addition of large woody debris to the stream channel which forms pools and important rearing areas. It also provides cover from predators and protection from high flows.

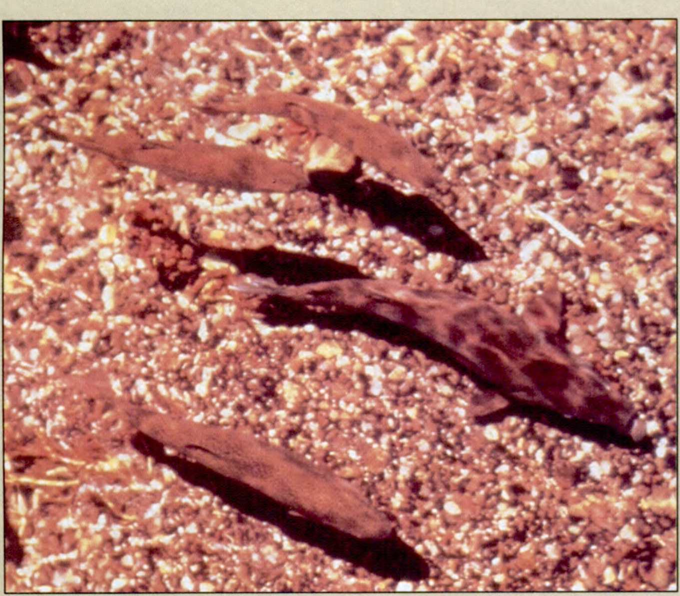
To understand the third factor, food availability, the natural stream must be viewed as a continuum from headwaters to mouth with a significant amount of the energy for aquatic life coming from organic material such as leaves, twigs, flowers, animals and insects originating from the streamside forest. These kinds of materials dominate the food base of small headwater streams flowing through forests. The food supports a diverse invertebrate community which in turn provides the principal food source for Salmonids in healthy ecosystems. Large amounts of leaf litter and other coarse organic matter enter small forested headwater streams and are rapidly consumed by aquatic invertebrates. These animals function as shredders because they reduce large pieces of organic debris to smaller pieces which in turn move downstream and can be used by other animals who feed by filtering or gathering these fine par-



▲ *Mayfly nymphs and Mayfly adults are both primary trout foods and important components of the food web.*

ticles of food.

As stream channels get wider in a downstream direction, the widening partition between the streamside forest canopies allows sufficient light to promote the growth of benthic algae, especially diatoms. Many species of invertebrates known collectively as "grazers" specialize in eating diatoms and, in turn, provide important food to fish. In large rivers that are very wide and deep, planktonic algae can become the domi-

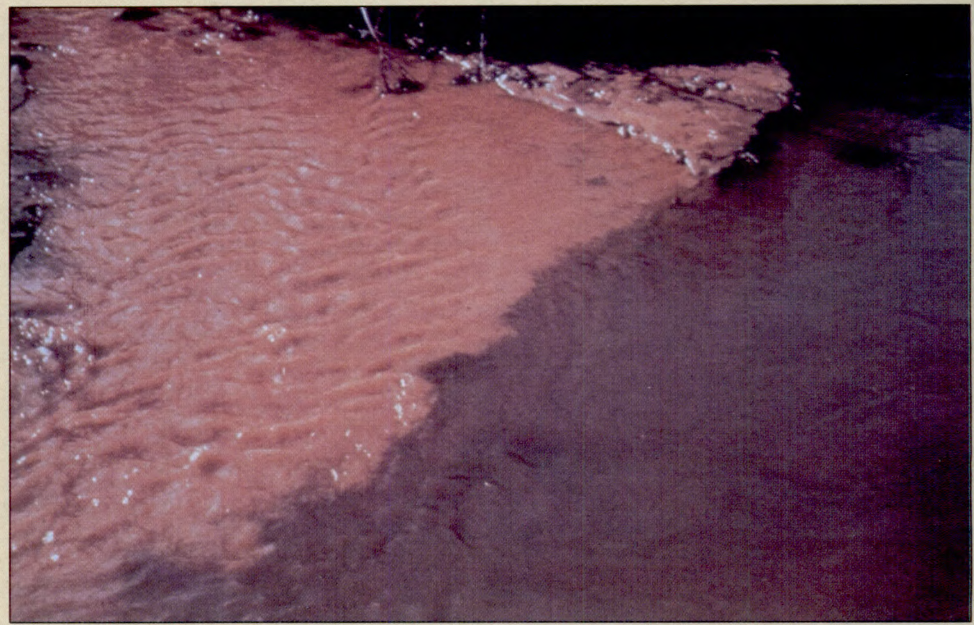


Stephen J. Brady

▲ A well washed gravel stream bottom is necessary for Salmonid spawning beds.

USDA Forest Service

▲ Well developed root systems help stabilize stream banks.



John Dickerson USDA Soil Conservation Service

▲ An example of a sediment laden branch entering a less turbid stream.

nant food resource with forest litter being less important. The downstream changes in channel size and shape and the organic food base along the river continuum greatly affect the fish population. For example, fish populations change from invertebrate eating Salmonid fishes, such as trout and salmon, in the headwaters to plankton feeding Cyprinids and Catostomids, such as carp and suckers, in large rivers.

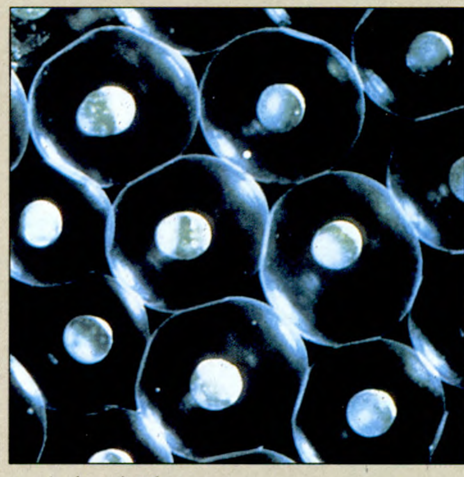
Streamside forests facilitate the downstream flow of food by contributing large stable debris to the streambed. This stable debris is the mechanism by which the detritus is held long enough to be processed by the invertebrate community. Without debris dams, much of the organic input from streamside vegetation would be washed downstream without contributing to the life processes of the aquatic food chain. Only as the streamside forest nears maturity is it able to produce organic debris in sufficient size and quantity to provide relatively stable detritus catchments.

The streamside forest helps to control sediment flux, the fourth factor affecting Salmonid survival, by stabilizing streambanks. Sediment concentrations must be very high, above 20,000 ppm, to cause mortality in adult fish by clogging the gill filaments and by preventing normal water circulation and aeration of the blood.

However, much lower concentrations can cause behavioral changes and disrupt normal reproduction by covering spawning grounds and preventing the emergence of recently hatched fry. Sediment covering spawning grounds reduces the flow of intragravel water, limiting oxygen availability to incubating eggs and newly hatched alevins and hindering removal of metabolic wastes. It similarly affects aquatic insect habitat, thus altering species composition of a major trout food source. Large instream debris can help store sediment, moderating transport rates and buffering against rapid changes in sediment loads that could cover spawning gravels, fill rearing pools and reduce invertebrate populations.

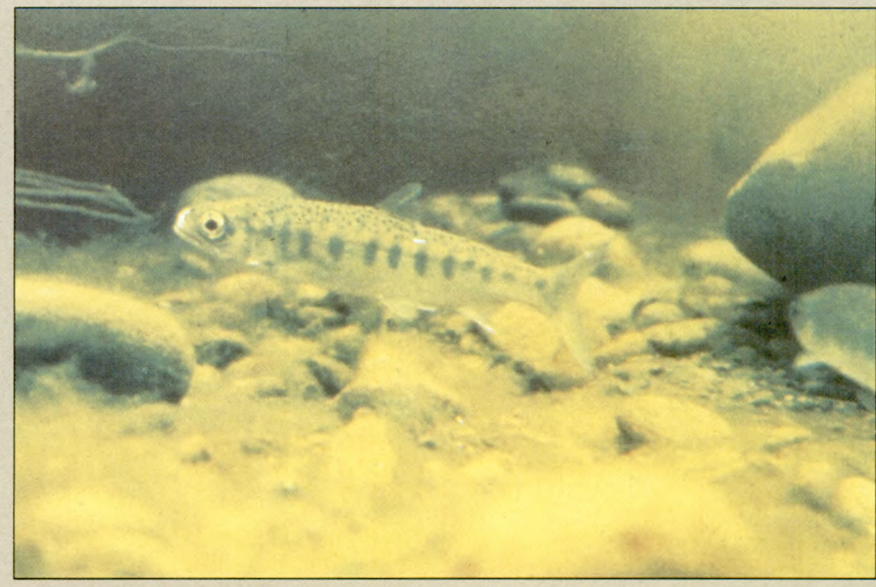
USDA Forest Service

▲ *Increased stream sediment concentrations cause behavioral changes in fish and can result in migration, reduced reproduction and/or death of a species.*



USDA Forest Service

▲ *Incubating eggs.*



USDA Forest Service

▲ *A newly hatched Salmonid.*

A balanced, integrated, adaptive community of riparian and aquatic organisms comparable to the

Establishment Guidelines

Simple removal of nonpoint pollutants is not enough to improve the quality of water resources. A balanced, integrated, adaptive community of riparian and aquatic organisms comparable to the natural systems of the region with stability and capacity for self repair must be reestablished. The restoration of a healthy aquatic ecosystem from the headwaters to the estuaries to the oceans requires the reestablishment of significant amounts of riparian forest.

Control of point source pollutants was a start; control of nonpoint pollutants and repair of the aquatic ecosystem through reestablishment of the streamside forest is a logical next step in improving the quality of our water resources.

Specifications for such a streamside forest should consider the following:

1. Streamside forests should be used in conjunction with sound land management systems that include nutrient management and sediment and erosion control.
2. Sediment removal - The streamside forest must be wide enough to filter sediment from surface runoff. Maximal effectiveness depends on uniform shallow overland flow. Percent removal of Total Suspended Solids is a good indicator of effectiveness.
3. Nutrient removal - Periodic flooding and the presence of forest litter contribute to conversion of nitrate to gaseous nitrogen by denitrification. Plant uptake also accounts for significant removal of nitrogen. Trees must be removed periodically to remove nutrient sequestered in woody biomass and to maintain system efficiency.
4. Periodic minor ground shaping

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▲ *Remaining riparian forests must be preserved and extended*

natural systems of the region with stability and capacity for self repair must be reestablished.

may be necessary to encourage dispersed flow and prevent concentrated flow.

5. A portion of the riparian forest immediately adjacent to the stream should be managed to maintain a stable streamside ecosystem and to provide detritus and large stable debris to the stream.
6. Crown cover should be managed to minimize fluctuations in stream temperature and to maintain stream temperatures within the range necessary for instream aquatic habitat.
7. Instream slash and debris removal practices should be revised to conserve existing large stable debris by retaining useful stable portions of jams whenever possible. Unstable tops and smaller debris with potential to form problem jams should be removed a sufficient distance to prevent re-entry during storm events.

The attached specification is an example of an effort by several state, federal and private resource management and research organizations to develop criteria for the establishment of effective forest buffers based on current research findings.

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▲ *Riparian forest buffers are most effective when used in conjunction with sound land management systems that include nutrient management and sediment control systems*

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Requirements

Vegetation will be composed of dense grasses and forbs for structure stabilization, sediment control and nutrient uptake. Mowing and removal of clippings is necessary to recycle sequestered nutrients, promote vigorous sod and control weed growth.

Vegetation must be maintained in a vigorous condition. The vegetative growth must be harvested, grazed or otherwise removed from Zone 3. Maintaining vigorous growth of Zone 3 vegetation must take precedence and may not be consistent with wildlife needs.

Zone 3 may be used for controlled intensive grazing when conditions are such that earthen water control structures will not be damaged.

Zone 3 may require periodic reshaping of earth structures, removal or grading of accumulated sediment and reestablishment of vegetation to maintain effectiveness of the riparian buffer.

Determining need for protection

Buffers should be used to protect any body of water which will not be:

treated by routing through a natural or artificial wetland determined to be adequate treatment;

treated by converting the flow to sheet flow and routing it through a forest buffer at a point lower in the watershed.

Determining total width of the buffer

Note, that while not specifically addressed, slope and soil permeability are components of the following buffer width criteria.

Each of the following criteria is based on methods developed or used by persons conducting research on riparian forests.

Streamside Buffers

The minimum width of streamside buffer areas can be determined by any of several methods suitable to the geographic area.

1) Based on soil hydrologic groups as shown in the county soil survey report, the width of Zone 2 will be increased to occupy any soils designated as Hydrologic Group D and those soils of Hydrologic Group C which are subject to frequent flooding. If soils of Hydrologic Groups A or B occur adjacent to intermittent or perennial streams, the combined width of Zones 1 and 2 may be limited to the 75 foot minimum.

2) Based on area, the width of zone two should be increased to provide a combined width of Zones one and two equal to one third of the slope distance from the stream bank to the top of the pollutant source area. The effect is to create a buffer strip between field and stream which occupies approximately one third of the source area.

3) Based on the Soil Capability Class of the buffer site as shown in the county soil survey report, the width of Zone two should be increasedto provide a combined width of zones one and two as shown below.

Capability Class	Buffer Width
Cap. I, II e/s, V	75'
Cap. III e/s, IV e/s	100'
Cap. VI e/s, VII e/s	150

Pond and Lake-Side buffer strips

The area of pond-or lake-side buffer strips should be at least one-fifth the drainage area of the cropland and pastureland source area. The width of the buffer strip is determined by creating a uniform width buffer of the required area between field and pond. Hydrologic Group and Capability Class methods of determining width remain the same as for streamside buffers. Minimum widths apply in all cases.

Environmentally Sensitive Wetlands

Some wetlands function as nutrient sinks and when they occur in fields or at field margins can be used for renovation of agricultural surface runoff and/or drainage. However, most wetlands associated with open water are subject to periodic flushing of nutrient laden sediments and therefore require riparian buffers to protect water quality.

Where open water wetlands are roughly elipsoid in shape they should receive the same protection as ponds.

Where open water wetlands exist in fields as seeps along hillslopes, buffers should consist of Zones 1, 2 & 3 on sides receiving runoff and Zones 1 & 3 on the remaining sides. Livestock must be excluded from Zones 1 and 2 at all times and controlled in Zone 3. Where zones 1 and 3 only are used, livestock must be excluded from both zones at all times, but hay may be harvested in Zone 3.

Vegetation Selection

Zone 1 & 2 vegetation will consist of native streamside tree species on soils of Hydrologic Groups D and C and native upland tree species on soils of Hydrologic Groups A and B.

Deciduous species are important in Zone 2 due to the production of carbon leachate from leaf litter which drives bacterial processes that remove nitrogen as well as to the sequestering of nutrients in the growth processes. In warmer climates evergreens are also important due to the potential for nutrient uptake during the winter months. In both cases a variety of species is important to meet the habitat needs of insects important to the aquatic food chain.

Zone 3 vegetation should consist of perennial grasses and forbs.

Species recommendations for vegetated buffer areas depend on the geographic location of the buffer. Suggested species lists should be developed in collaboration with appropriate state and federal forestry agencies, the Soil Conservation Service and the Fish and Wildlife Service. Species lists should include trees, shrubs, grasses, legumes, forbs, as well as site preparation techniques. Fertilizer and lime, helpful in establishing buffer vegetation, must be used with caution and are not recommended in zone 1.

Maintenance Guidelines

General

Buffers must be inspected annually and immediately following severe storms for evidence of sediment deposit, erosion or concentrated flow channels. Prompt corrective action must be taken to stop erosion and restore sheet flow.

The following should be avoided within the buffer areas: excess use of fertilizers, pesticides, or other chemicals, vehicular traffic or excessive pedestrian traffic and removal or disturbance of vegetation and litter inconsistent with erosion control and buffering objectives.

Zone 1 vegetation should remain undisturbed except for removal of individual trees of extremely high value or trees presenting unusual hazards such as potentially blocking culverts or creating dangerous hydraulic obstructions.

Zone 2 vegetation, undergrowth, forest floor, duff layer and leaf litter shall remain undisturbed except for periodic cutting of trees to remove sequestered nutrient and to maintain an efficient filter by fostering vigorous growth, and for spot site preparation for regeneration purposes. Controlled burning for site preparation, consistent with good forest management practice could also be used in Zone 2.

Zone 3 vegetation should be mowed and the clippings removed as necessary to remove sequestered nutrient and promote dense growth for optimum soil stabilization.

Zone 3 vegetation should be inspected twice annually and remedial measures taken as necessary to maintain vegetation density and remove problem sediment accumulations.

Stable Debris

As Zone 1 reaches 60 years of age, it will begin to produce large stable debris. Large debris, such as logs create small dams which trap and hold detritus for processing by aquatic insects thus adding energy to the stream ecosystem, strengthening the food chain and improving aquatic habitat. Wherever possible, stable debris should be conserved.

Where debris dams must be removed, try to retain useful, stable portions which provide detritus storage.

Deposit removed material a sufficient distance from the stream that it will not be refloated by high water.

Planning Considerations

1. Evaluate the type and quantity of potential pollutants that will be derived from the drainage area.
2. Select species adapted to the zones based on soil and site factors and possible commercial goals such as timber and forage.
3. Plan to establish trees early in the dormant season for maximum viability.
4. Be aware of visual aspects and plan for wildlife habitat improvement if desired.
5. Consider provisions for mowing and removing vegetation from Zone 3. Controlled grazing may be satisfactory in Zone 3 when the filter area is dry and firm.

SPECIFICATION
RIPARIAN FOREST BUFFER

Definition

An area of trees and other vegetation located in areas adjacent to and upgradient from water bodies and designed to intercept surface runoff, wastewater, subsurface flow and deeper groundwater flows from upland sources for the purpose of removing or buffering the effects of associated nutrients, sediment, organic matter, pesticides or other pollutants prior to entry into surface waters and ground water recharge areas.

Scope

This specification establishes the minimally acceptable requirements for the reforestation of open lands and renovation of existing forest to be managed as Riparian Forest Buffers for the purposes stated.

Purpose

To remove nutrients, sediment, organic matter, and some pesticides from surface runoff, subsurface flow and near root zone groundwater by deposition, absorption, adsorption, plant uptake, denitrification, and other processes, thereby reducing pollution and protecting surface water and ground water quality.

Conditions Where Practice Applies

Subsurface nutrient buffering processes, such as denitrification, can take place in the soil wherever carbon energy, bacteria, oxygen, temperature and soil moisture are adequate. Nutrient uptake by plants occurs where the water table is within the root zone. Surficial filtration occurs anywhere surface vegetation and forest litter is adequate.

The riparian forest buffer will be most effective when used as a component of a sound land management system including nutrient management and runoff, sediment and erosion control practices. Use of this practice without other nutrient and runoff, sediment and erosion control practices can result in adverse impacts on buffer vegetation and hydraulics including high maintenance costs, the need for periodic replanting and the carrying of excess nutrients and sediment through the buffer by concentrated flows.

This practice applies on lands:

1) adjacent to permanent or intermittent streams which occur at the lower edge of upslope cropland, grassland or pasture;
2) at the margins of lakes or ponds which occur at the lower edge of upslope cropland, grassland or pasture;
3) at the margin of any intermittent or permanently flooded, environmentally sensitive, open water wetlands which occur at the lower edge of upslope cropland, grassland or pasture;
4) on karst formations at the margin of sinkholes and other small groundwater recharge areas occurring on cropland, grassland or pasture.

   Note: In high sediment production areas (8-20 in/ 100 yrs.), severe sheet, rill and gully erosion must be brought under control for this practice to function correctly.

Design Criteria

Riparian Forest Buffers

Riparian forest buffers will consist of three distinct zones and be designed to filter surface runoff as sheet flow and downslope subsurface flow which occurs as shallow ground water. For the purposes of these buffer strips, shallow ground water is defined as saturated conditions which occur near or within the root zone of trees and other woody vegetation and at relatively shallow depths where bacteria, oxygen, and soil temperature contribute to denitrification. Streamside Forest Buffers will be designed to encourage sheet flow and infiltration and impede concentrated flow.

Zone 1

Location

Zone 1 will begin at the top of the stream bank and occupy a strip of land with a fixed width of fifteen feet measured horizontally on a line perpendicular to the streambank.

Purpose

The purpose of Zone 1 is to create a stable ecosystem adjacent to the water's edge, provide soil/water contact area to facilitate nutrient buffering processes, provide shade to moderate and stabilize water temperature encouraging the production of beneficial algal forms and to contribute necessary detritus and large woody debris to the stream ecosystem.

Requirements

Runoff and wastewater to be buffered or filtered by Zone 1 will be limited to sheet flow or subsurface flow only. Concentrated flows must be converted to sheet flow or subsurface flows prior to entering Zone 1. Outflow from subsurface drains must not be allowed to pass through the riparian forest in pipes or tile thus circumventing the treatment processes. Subsurface drain outflow must be converted to sheet flow for treatment by the riparian forest buffer or treated elsewhere in the system prior to entering the surface water.

Dominant vegetation will be composed of a variety of native riparian tree and shrub species and such plantings as necessary for streambank stabilization during the establishment period. A mix of species will provide the prolonged stable leaf fall and variety of leaves necessary to meet the energy and pupation needs of aquatic insects.

Large overmature trees are valued for their detritus and large woody debris contributions to the stream ecosystem. Therefore, management of Zone 1 will be limited to bank stabilization and removal of potential problem vegetation. Occasional removal of extreme high value trees may be permitted where water quality values are not compromised. Logging and other overland equipment shall be excluded except for streamcrossings and stabilization work.

Livestock will be excluded from Zone 1 except for designed stream crossings and designed watering sites.

Zone 2

Location

Zone 2 will begin at the edge of Zone 1 and occupy an additional strip of land with a minimum width of 6O feet measured horizontallyin the direction of flow. Total minimum width of Zones 1 & 2 is therefore 75 feet. Note that this is the minimum width of Zone 2 and that the width of Zone 2 may have to be increased as described in the section "Determining the Total Width of Buffer" to create a greater combined width for Zones 1 & 2.

Purpose

The purpose of Zone 2 is to provide necessary contact time and carbon energy source for buffering processes to take place and to provide for long term sequestering of nutrients in the form of forest trees. Outflow from subsurface drains must not be allowed to pass through the riparian forest in pipe or tile thus circumventing the treatment processes. Subsurface drain out flow must be converted to sheet flow for treatment by the riparian forest buffer or treated elsewhere in the system prior to entering the surface water.

Requirements

Runoff and wastewater to be buffered or filtered by Zone 2 will be limited to sheet flow or subsurface flow only. Concentrated flows must be converted to sheet flow or subsurface flows prior to entering Zone 2.

Predominant vegetation will be composed of riparian trees and shrubs suitable to the site, with emphasis on native species and such plantings as necessary to soil stabilization during the establishment period. Nitrogen fixing species should be discouraged where nitrogen removal or buffering is desired. Species suitability information should be developed in consultation with state and federal forestry agencies, Soil Conservation Service, and Fish and Wildlife Service.

Specifications should include periodic harvesting and timber stand improvement (TSI) to maintain vigorous growth and leaf litter replacement and to remove nutrients and pollutants sequestered in the form of wood in tree boles and large branches. Management for wildlife habitat, aesthetics, and timber are not incompatable with riparian forest buffer objectives as long as shade levels and production of leaf litter, detritus and large woody debris are maintained. Appropriate logging equipment recommendations shall be determined in consultation with the state and federal forestry agencies.

Livestock shall be excluded from Zone 2 except for necessary designed stream crossings and designed watering sites.

Zone 3

Location

Zone 3 will begin at the outer edge of Zone 2 and have a minimum width of 20 feet. Additional width may be desirable to accommodate land shaping and mowing machinery. Ungrazed grassland meeting the purpose and requirements stated below may serve as Zone 3.

Purpose

The purpose of Zone 3 is to provide sediment filtering, nutrient uptake and the space necessary to convert concentrated flow to uniform, shallow, sheet flow through the use of techniques such as grading, and shaping, and devices such as diversions, basins and level lip spreaders.