forestry & natural resources

ENVIRONMENTAL FORESTRY

Criteria For Evaluating Forestry Activities in Relation to Water Quality Management

P. E. Pope, Department of Forestry and Natural Resources

Forestry activities, potential pollutants, and practices to prevent and reduce pollution are interrelated. The interrelationship and flexibility between these factors allow forest managers to successfully integrate water quality goals with other management objectives, and therefore contribute substantially to a water quality management system on the landscape.

Although any one silvicultural activity affects only a portion of a general forest area at any given time, it is usually a part of a cyclical process designated to yield a continuous supply of wood fiber. Certain activities, such as those associated with establishment and removal of the crop, occur only once during the crop rotation. Depending on the tree species and the area of the country, a crop cycle may span 10 to 100 years or more. However, the impact of certain silvicultural activities on the pollution potential may be heavy during forestry operations and may linger until the forest has sufficiently regenerated to restore the water handling capability of the area to preactivity levels. (This recovery period is usually two to four years.) Other activities, such as those associated with protection from fire, disease, and insects, and those associated with crop improvement, may occur several times during the crop rotation. Thus, the period of silvicultural activities on a given forest site can span the length of the crop rotation.

Potential Pollutants from Activities

The most important pollutants which may be generated by silvicultural activities are sediment and debris, chemicals (including those from nutrients and pesticides), and thermal effects. The origin of the pollutants is generally related to more than one of the activities of the total silvicultural operation.

1. **Sediment**

   An increase in sediment is the most important common form of pollution resulting from silvicultural activities. The additional sediments usually result from accelerated erosion of soils, but may also result from debris and other organic and inorganic waste. Excessive amounts of sediment affect stream ecology by smothering bottom organisms through the formation of "bottom blankets." They also carry nutrients and pesticides, clog streams and downstream reservoirs, inhibit the reproduction of many important fish species, and alter stream flow and speed. Suspended sediments interfere with photosynthetic processes by reducing light penetration.

2. **Nutrients**

   Nutrient loss, above the natural level, may occur when fertilizers are carelessly applied during the course of a silvicultural operation. Soluble nutrients may reach surface or ground water through runoff, seepage, and/or percolation. Insoluble forms may be absorbed on soil particles and reach surface water through erosion processes. Nutrients may also reach surface water by direct washoff of slash, debris, and recently applied fertilizer. Excessive nutrients can lead to imbalance in the natural life cycles of water bodies.

3. **Pesticides**

   Pesticides, when applied during forest management operations, may be insoluble or soluble. Pesticides when applied aerially and in a broadcast manner may directly enter the surface waters. These chemicals then follow approximately the same pattern as nutrients.

Pesticides, applied carelessly in the manner mentioned above, may result in acute toxicity problems in the water bodies, but these high levels usually occur for only a short duration. Insidious toxicity problems throughout the entire food chain could possibly result, but little or no information is available on this. In Indiana, the most common methods of pesticide application include individual stem injection or application directly to the ground cover; both methods offer only remote possibilities for surface or ground water contamination.

4. **Organic Pollutants**

Debris, and other non-merchantable wood materials generated by silvicultural activities, may result in organic pollution if an inordinate amount is placed or washed in the streams. This organic material may reach surface water through direct dumping, washoff, or leachate from log storage. The organic material places an oxygen demand on the receiving waters during decomposition. In addition, these materials may lead to other problems, such as changes in taste, odors, colors, and excessive nutrients.

5. **Thermal Pollutants**

Thermal pollution may result from silvicultural activities where the removal of the canopy cover from stream bodies causes the water temperature to rise. Temperature is a significant aspect of water quality. In some cases, it may strongly influence dissolved oxygen concentrations and bacterial populations in streams. The saturated, dissolved oxygen concentrations in streams are inversely related to temperature.

Description of Activities

Though all silvicultural activities are interrelated, activities producing pollutants are associated with 1) access and transport systems (log roads, etc.), 2) harvesting, 3) crop regeneration, and 4) intermediate activities (thinning or fire, insect and disease control). The type and amount of pollutants generated from these activities are strongly influenced by the characteristics of the climatic events, the physical characteristics of the area (soil, topography, etc.), and the characteristics of the individual operations as they are practiced in a specific area.

1. **Access Systems**

Access to forest areas for the purpose of conducting silvicultural operations usually is provided through a combination of roads and trails. The roads, which generally make up a part of a broader interconnected transportation system, serve many forest uses, including recreation and fire protection. They range from very narrow unsurfaced trails to high-speed paved roads. The intensity with which these access systems are used for silvicultural purposes varies from frequent to only occassional use over a number of years.

The forest access road system is often a major contributor of sediment to the streams in forested areas. These sediment loads may originate as a result of road construction (including stream crossings), associated mass soil movement, direct erosion from the roads, and indirect erosion caused by changes in drainage patterns and systems. In addition to sedimentation problems, other pollution problems may be created due to organic debris resulting from road construction and log transport, and from herbicides used to control the growth of undesirable vegetation on the right-of-way.

2. **Harvesting**

Harvesting includes the process of felling the tree, preparing it by limbing, cutting it into desired lengths, and moving it to a central, accessible location for transport out of the forested area. The usable material is removed (skidded or yarded) to a temporary storage site or landing by one of three basic methods: tractor (on skid trails), groundlead or highlead cable, or various skyline cable methods. Balloons and helicopters are also being used to a limited extent in some areas. In Indiana, rubber-tired skidders are most frequently used. Therefore, at least a part of the logged material is dragged over the ground surface.

The harvesting of timber results in a partial to complete removal of forest cover and may compact the soil and disturb the protective cover of the soil surface. Thus, harvesting methods may affect the erosion process and consequently, the potential for sediment pollution. In addition to sediment production, harvesting can create an accumulation of organic debris and slash which may be washed into streams from the forest floor. Harvesting can also result in thermal pollution due to the removal of the canopy over streams.

There are two basic systems of harvesting used in the United States. These are 1) uneven-aged (selection), and 2) even-aged shelterwood, (seed tree and clearcutting). Each of these systems results in a different type and degree of pollution-generating potential because of the differences in associated site disturbance.

3. Forest Regeneration

Forest regeneration refers to the re-establishment of a forest cover on areas from which trees have been removed by some past occurrence, such as wildfire, timber harvesting, or temporary conversion to some other use than the growing of trees. When trees have been absent from a site for a number of years, regeneration must generally be achieved through seeding and planting. Regeneration of a harvested area includes both the natural regenerative process and man's activities in preparing the site and subsequent planting or seeding. The method of regeneration is determined largely by the silvical characteristics of the tree species involved, site limitations, economic considerations, and the land manager's desire for forest composition. In some plant communities, natural regeneration under any of the harvesting systems may also occur by regrowth from roots or stumps.

Preparation, as well as protection of an area, is sometimes needed for regrowth of a stand. Where site preparation for regrowth is needed, major activities may include 1) debris removal to reduce fire hazard and allow use of equipment for subsequent operations, 2) reduction or removal of brush or shrub cover and undersirable tree species, and 3) cultivation of the soils.

When used indiscriminately for site preparation, fire, chemicals, and soil-disturbing machinery increase the potential for sediment and other pollution to occur. The time required before such pollution occurs is variable depending upon climatic factors, soil productivity and its influence on the rate of plant growth, the species planted or seeded, and the operational schedule. In some areas, the time span may be a single growing season, while in others, it may cover several years.

4. Intermediate Practices

Other silvicultural practices relating to thinning of an immature forest, fertilizer application, and pesticide treatments may be undertaken during the crop rotation. The thinning process involves removal of selected trees from both mature and immature forest. In essence, this is a type of harvesting which would tend to create potential sediment-generating conditions if carelessly carried out. Chemical application of fertilizers and pesticides during intermediate practices can result in water pollution, if improperly applied or adversely affected by an extreme and unexpected natural event.

Disturbances Associated with Silvicultural Activities

Non-chemical forms of pollution that result from silvicultural activities generally relate to disturbances of the soil and vegetation. The kind and amount of disturbance is largely dependent on five main factors: 1) characteristics of the area on which the silvicultural activities are carried out, i.e., nature of the soils, vegetation, climate, and topography; 2) the type and character of the activity, e.g., the specific regeneration system used in carrying out timber harvesting (selection, shelterwood, seed tree, or clearcutting); 3) the method or technique used to carry out the activity, such as in timber harvesting (tractor, highlead cable, skyline cable); 4) the specific features of the activity, that is, intensity, and size and shape of the area on which it is applied; 5) the location of the activity, that is, its proximity to streams and lake shores.

Timing of the activity is another factor which may be important in some situations. Where applicable and feasible, the amount of soil disturbance may be reduced by logging when the ground is frozen, when it is covered with snow, or when the soil moisture is relatively low.

Although generalities may be misleading and must be carefully examined by appropriate professionals for application to local situations, they are useful in establishing a common framework for examining alternate solutions to water pollution problems. To illustrate, the relative impacts of the different categories of harvesting systems on potential water pollution are generalized in the following discussion.

Soil and Vegetation Disturbance

It may be necessary to construct additional roads and trails when the access system is inadequate to serve the particular harvesting system. This construction activity can result in severe to complete disturbance of soil and vegetation. The extent of such disturbance can be minimized by fitting the access roads to the terrain, by minimizing stream crossings, by using appropriate design criteria, and by using the least soil disturbing and soil impacting equipment and techniques.

1. Selection Cutting Systems

Due to the scattered nature of cutting, the selection systems require an extensive system of roads and skid trails and usually employ crawler tractors or rubber-tired skidders to move the logs from the stump to a central landing. Disturbances of the general forest area are usually limited to soil and undergrowth in the area immediately around the individual trees or groups of trees harvested, with little deterioration of the soil-holding network

of plant roots. The selection method of reproduction involves the removal of only the mature, over-mature, or dead trees. Intermediate cuttings may be made among the younger trees at the same time that the older trees are removed. Maintenance of a healthy stand of trees often requires more frequent entry into the harvest area than other regeneration methods. Further, disturbance of the soil, although relatively small, can occur at fairly short re-entry intervals.

2. **Shelterwood Cutting Systems**

The shelterwood method involves the gradual removal of the entire stand in a series of partial cuttings which extend over a fraction of the rotation. The method may also be applied to cutting in strips or in groups. Tractor logging is generally adapted to this system, but where strip or group shelterwood modifications are used, or where the wood volumes and terrain are favorable, other logging methods, such as highlead cable or skyline cable, may be employed. An extensive system of roads and skid trails is generally needed where tractor logging is used. Fewer, more widely spaced roads may be adequate with the cable systems. Since the most important function of the series of partial cuttings is to create ideal conditions for the germination of natural seedfall, a certain degree of disturbance to soil and ground cover throughout the cut area is necessary. Where initial cutting fails to create the proper seedbed conditions, artificial methods to prepare small seed spots at close intervals are often used. A minimum of two cuttings is required in the simplest application of shelterwood cutting. Under intensive management, more than five cuttings often are made in the gradual process of simultaneously freeing the reproduction and removing the mature stand. Often, the regeneration period ranges from ten to twenty years, but may extend to sixty years. Therefore, some degree of redisturbance to soil and vegetation does occur.

3. **Seed Tree Systems**

In some classifications, the seed tree system has been included under clearcutting systems, since the area is clearcut except for certain seed trees which ordinarily make up less than ten percent of the total number of trees on the area. Like clearcutting, any one or a combination of the logging methods may be appropriate, depending on the site conditions, economics, volume of timber, and many other factors. In comparison to selection cutting, fewer roads and skid trails are needed in seed tree systems. Severe disturbance of soil and vegetation may occur over most of the cutover area. The amount and degree of disturbance are usually less with highlead systems than with tractor logging.

After the crop is established, the seed trees can be removed in a second cutting or deadened. If the seed trees are removed, some redisturbance of soil and vegatation occurs. Both the seed tree and clearcutting systems can result in at least a temporary deterioration of the soil holding network of tree roots over a relatively large area. This can be a particularly important consideration in steep terrain and in areas immediately adjacent to stream channels.

4. **Clearcutting Systems**

The disturbance of soil and vegetation by clearcutting systems is similar to that of seed tree systems. The most important difference is that all commercial size material is cut. In many of the larger clearcuts, reforestation involves site preparation for artificial reproduction. This involves removing much of the remaining ground cover and adding further to the disturbance of soil and vegetation. On those clearcuts where logging is done by methods which lift the harvested material clear of the ground or where revegetation occurs naturally without further site preparation, the overall amount of soil and vegetation disturbance between crop removal operations can be less than with systems that require more frequent entry. Redisturbance does not occur until the reproduction is ready for thinning.

Natural Drainage Way and Stream Channel Disturbance

1. **Selection Cutting**

Except for disturbances associated with roads and other means of access, natural drainage ways and stream channels are not normally affected by selection cutting unless the logs are dragged across the drainage way or channel, or unless limbs or other unmerchantable portions of the tree are allowed to accumulate in the channels.

2. **Shelterwood Cutting**

The degree of disturbance to natural drainage ways by shelterwood cutting depends on how the system is applied. Where the system involves general progressive cutting, the impact is similar to that of selection cutting. Strip or group shelterwood cutting methods, which involve concentrated cuttings in small areas, may also result in disturbance by logging equipment of minor tributary drainage ways.

3. **Seed Tree Cutting**

In addition to disturbances associated with road and trail crossings, disturbance of natural drainage ways and stream channels may occur whenever logs are dragged across the land surface. Such disturbance can be minimized with a properly designed network of skid trails and the proper location of landing and loading sites. In seed tree cutting, the danger of woody debris entering drainage ways and stream channels within the cut area is relatively high.

4. **Clearcutting**

Disturbances of natural drainage ways and stream channels are similar to those associated with the seed tree cutting method. As with the seed tree system, the degree of disturbance is proportional to the amount of material that is dragged across or through the drainage ways and channels.

Best Management Practices

"The term 'best management practices (BMP)' means a practice, or combination of practices, that is determined by a state (or designated area-wide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation to be the most effective and practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by nonpoint sources of pollution at a level compatible with water quality goals."[1]

Among the various technical aspects to be considered in BMP design and selection are:

- The variability and characteristics on individual source areas in terms of topography, soils, geology, etc., and their effect on natural pollution hazards of the area.
- The variability in climatic factors which influence both the detachment and the transport processes.
- The variability in recovery time of a site as it is influenced by factors, such as climate, soil productivity, and plant species.
- The variability in the transport behavior of different pollutants and the reaction of the receiving waters to these pollutants.

In most cases, this variability will prevent a single BMP from covering all activities and situations. BMP must be structured with these variations clearly in mind and with full consideration of the particular water quality problem to be solved. Further considerations include the practicality of securing early implementation of appropriate best management practices, the social and economic costs of implementation, and the benefits (water quality and/or otherwise) to society that will result.

[1]Code of Federal Regulations, Federal Register, Volume 40, Number 230. Part 132.2, paragraph Q, November 28, 1975, p. 55338.

The control measures that are used should be fully integrated into the total management system for a particular forest area and should be feasible not only from the technical standpoint, but also from the financial, legal, and institutional standpoint. To the extent feasible, soils, nutrients, pesticides, and other chemicals must be kept on the land area where they perform their intended function of assisting tree growth and health.

Best management practices applied to silvicultural operations can be classified as two major types. These are 1) prevention measures as part of planning, policy and managment; 2) reduction measures applied to the land as an integral part of the silvicultural activity. The reduction and prevention measures are generally described in "Processess, Procedures, and Methods to Control Pollution Resulting from Silvicultural Activities," EPA 420/9-73-010.

1. **Prevention**

Prevention through management decision involves the incorporation of water quality protection into organizational policy and in the planning design and scheduling of silvicultural activities. At this stage, location and design of logging access roads, intermediate activities, harvesting methods, and reforestation decisions should be made to prevent or minimize the aggravation of inherent pollution hazards.

2. **Reduction**

The reduction measures to control erosion and sediment runoff generally utilize some physical, biological, or chemical method or technique. They modify and reduce the unavoidable disturbances caused by an activity, for example, revegetation of cleared areas, mulching of roadcuts and fills, and removal of debris from water courses, the construction of berms, rip-rapping, baffles, drop structures, catch basins, and slope stabilization on road sites.

Because of the widespread nature of sediment runoff, erosion control measures must be a principle thrust of the water quality management program on each management unit. In the areas where nutrients, pesticides, and other chemicals cause particular problems on surface or ground waters, further control measures may be necessary. These measures could relate to the application (timing methods and amount), utilization, and management of the fertilizers, pesticides, and fire retardant chemicals. Particular attention should be taken to keep chemicals away from streams. Care must be exercised to insure that thermal problems are not created in streams by excessive removal of shade canopy. **Attention to proper forest management, engineering, and harvesting principles can substantially reduce pollution attributed to silviculture.**

Suggested References

Information reported in this publication was gathered from the following sources.

1. Blum, B. M., 1977 "Proceedings of the symposium on intensive culture of northern forest types." USDA Forestry Service General Technical Report NE-29. Northeastern Forestry Experiment Station, 6816 Market Street, Upper Darby, Pennsylvania 19082.
2. Pope, P. E., 1977. "Water Quality and Forestry: A review of water quality legislation and the impact of forestry practices on water quality." Department of Forestry, Purdue University Station Bulletin 161, 19 pp.
3. Singer, R. J. and R. C. Maloney., 1977. *Nonpoint source control guidance for silviculture.* U.S. EPA. Office of Water Planning and Standards, Washington, D.C. 20460.
4. Smith, D. M., 1962. *The Practice of Silviculture.* 7th Edition. John Wiley and Sons, Inc. New York, N.Y. 578 pp.

RR 9/93 (2M)

Cooperative Extension work in Agriculture and Home Economics, state of Indiana, Purdue University, and U.S. Department of Agriculture cooperating; H. A. Wadsworth, Director, West Lafayette, IN. Issued in furtherance of the acts of May 8 and June 30, 1914. The Cooperative Extension Service of Purdue University is an affirmative action/equal opportunity institution.