NOTICE: This PDF file was adapted from an on-line training module of the EPA's ***Watershed Academy Web***, found at http://www.epa.gov/watertrain. To the extent possible, it contains the same material as the on-line version. Some interactive parts of the module had to be reformatted for this noninteractive text presentation. Review questions are included at the end of each sub-section within this file and are also compiled at the end of the file as a self-test.

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Welcome to the Watershed Academy's module on forestry best management practices (BMPs) in watersheds. This module, along with similar modules on agriculture and urban management, is about controlling impacts from common land use activities that often affect watersheds, water quality, and the condition of aquatic ecosystems.

This module has been compiled using graphics and information mostly derived from five government sources:

- **Forestry Best Management Practices**, a poster developed by the USEPA and the American Forest and Paper Association.
- **Montana Guide to the Streamside Management Zone Law & Rules**, a booklet compiled by MT Dept of State Lands.
- **Montana Forestry BMPs**, a booklet compiled by MT Dept of Environmental Quality.
- **Forest Management for Water Quality**, a training course prepared by USDA-Forest Service and USEPA.
- **The US Environmental Protection Agency's Non-Point Source Forestry Management Measures**, which provide general guidance on management practices suitable for minimizing impacts on US waters.

After completing this module, you should be familiar with the steps commonly involved in planning and carrying out timber harvest and reforestation, and several of the basic ways to reduce or avoid impacts on water resources during these activities.

How This Module Is Organized

After a brief introduction, there are eight main topics in this training: preharvest planning, streamside management zones, forest wetlands protection, road construction, timber harvesting, revegetation, fire management, and forest chemical management. These eight topics are covered in sub-sections of the module that can be completed in any order. Each subsection introduces a general type of forestry measure, discusses its possible impacts, offers guidance on the basic techniques to minimize impacts, and poses review questions. Completing the whole module may require one to two hours.

Introduction

There are over 736 million acres of forest land in the United States (Figure 1). The single largest holder of forested land is the US Forest Service. Many other forest lands are administered by state and county governments or owned by private citizens and corporations.

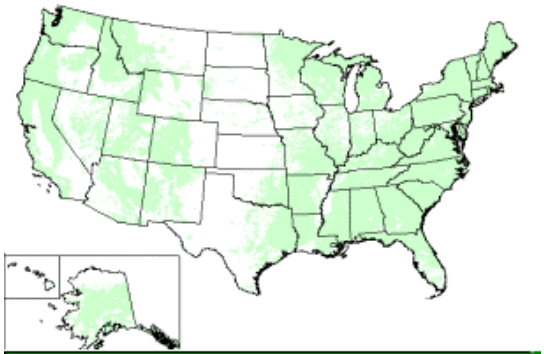


Figure 1

These lands provide water, fish and wildlife habitat, esthetic value, and recreational opportunities. Production of high quality water is a major benefit of forest lands; about two-thirds of the Nation's runoff comes from forest areas. These lands also provide a source of timber for harvesting. To properly manage these lands for multiple uses, best management practices for timber harvesting have

been established. Best Management Practices or BMPs (discussed below) are generally developed by the States and are designed to help landowners, foresters, loggers, and others protect water quality during all stages of forestry. This includes preharvest planning, streamside and wetland area management, road construction and maintenance, timber harvesting, revegetation, and chemical management.

The Clean Water Act and Best Management Practices

In 1972, in response to growing public concern about serious and widespread water pollution, Congress passed the Clean Water Act to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Under the Act, State and federal agencies cooperate to control pollution by setting water quality standards and providing for control of pollution at its source. The Act is mainly administered by EPA, with many of the provisions delegated to the States and Tribes for implementation. The Act makes it unlawful to discharge a pollutant from a **point source** into waters without a permit from EPA or an authorized State or Tribe (Figure 2). **Nonpoint pollution sources** are addressed by the States and Tribes through area-wide management planning processes and voluntary incentive-based programs; some states have regulatory programs that may address nonpoint source pollution. Because nonpoint source pollution causes approximately 60% of water quality impairments, Congress amended the Clean Water Act in 1987 to established the Nonpoint Source Pollution Management Program under Section 319. The program provides States and Tribes with grants to implement controls described in their approved nonpoint source pollution management programs.

Point sources are "any discernable, confined and discrete conveyance from which pollutants are or may be discharged into navigable waters" according to the Clean Water Act.

The Federal Clean Water Act was passed to reduce pollution from point sources (left) such as wastewater discharges and non-point sources (right) such as polluted runoff.

Figure 2

"**Nonpoint sources of pollution** are diffuse and may include excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas; oil, grease, and toxic chemicals from urban runoff and energy production; sediment from improperly managed construction sites, crop and forest lands, and eroding stream banks; salt from irrigation practices and acid drainage from abandoned mines; bacteria and nutrients from livestock, pet wastes, and faulty septic systems. NPS pollution is caused by rainfall or snow melt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water." -- Clean Water Act amendments of 1987.

Traditional end-of-pipe pollution control methods are not appropriate for controlling the type of nonpoint source pollution that may come from timber harvest (Figure 3). For example, forestry activities are dispersed over large areas and affected by natural variables such as weather, channel morphology, or geology and soil characteristics of the watershed, making it difficult to separate the impacts of timber harvest from these natural variables. As an alternative, the concept of land management as a control tool emerged. This concept relies upon the use of **best management practices**, or BMPs. Conscientious use of BMPs includes monitoring to determine if the BMPs are being properly implemented and are achieving the desired effect. Achievement of water quality goals may require modifications in the BMPs originally selected for the forestry activities.

Figure 3

A Best Management Practice is "...a practice or combination of practices considered by a State [or authorized Tribe] to be the most effective means (including technological, economic and institutional considerations) of preventing or reducing the amount of pollution by nonpoint sources to a level compatible with water quality goals."
(40 CFR 130.2(Q))

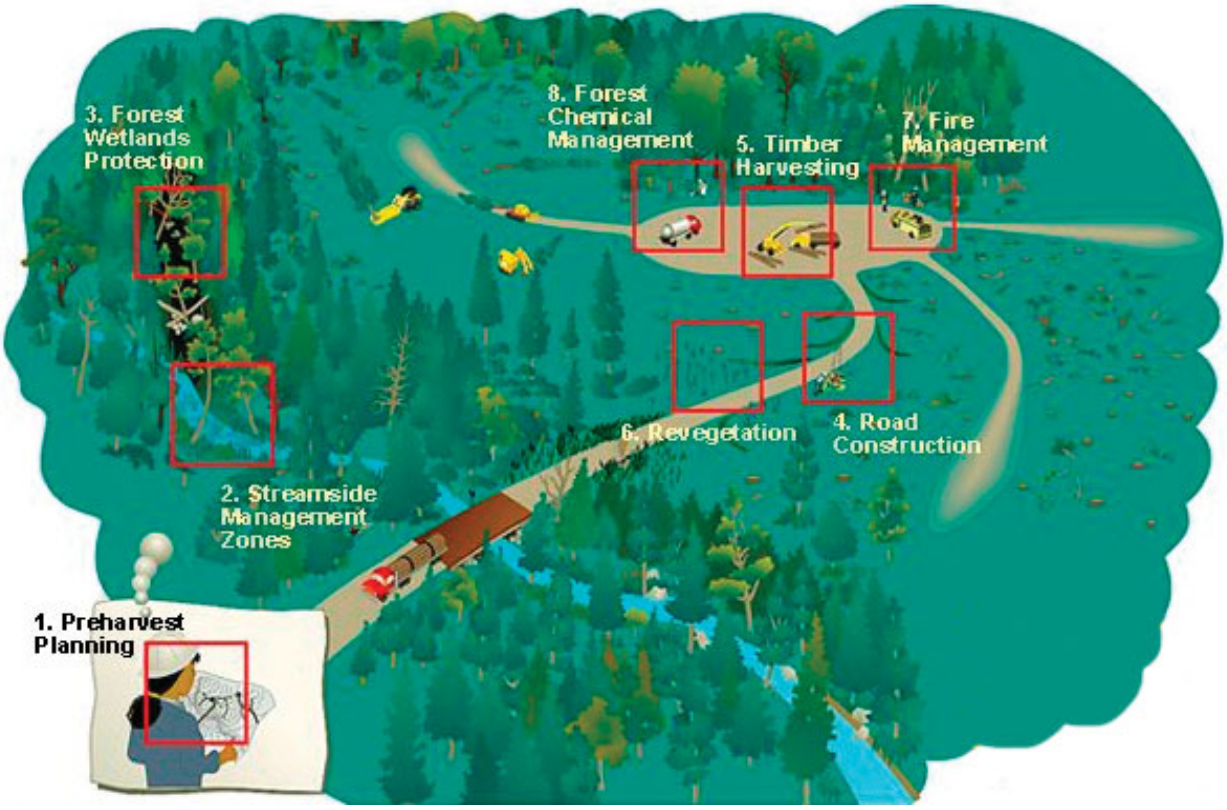


Figure 4

Figure 4 (previous page) shows the eight major categories of forestry practice, explained in individual sub-presentations. Briefly review the 8 numbered forestry measures along with the short descriptions listed below. Sub-presentations on each forestry measure are contained in the following pages.

1. **Preharvest Planning.** Protect water quality and control erosion and sedimentation by performing advanced planning for efficient forest harvesting, site harvesting, and road systems.

2. **Streamside Management Zones.** Establish and maintain a streamside management zone (SMZ) along surface waters to buffer against detrimental changes in the temperature regime of the waterbody, to provide bank stability, to provide a filter to keep sediment and pollutants out of the stream, and to withstand wind damage. The SMZ should be sufficiently wide, and should include a sufficient number of canopy species.

3. **Forest Wetlands Protection.** Protect the function of forest wetlands by tailoring forestry practices to reduce or minimize impacts to this unique environment.

4. **Road Construction.** Minimize delivery of sediment from road construction or reconstruction by following the preharvest plan layouts and designs for the road system, incorporating adequate drainage structures, and properly installing stream crossings.

5. **Timber Harvesting.** Maintain roads, lower maintenance costs, and protect water and soil quality by conducting harvesting, yarding, and hauling activities in accordance with the pre-harvest planning. Constructing landings away from steep slopes and the SMZs guards against erosion and sedimentation.

6. **Revegetation.** Reduce erosion and sedimentation by rapid revegetation of areas disturbed by harvesting operations or road construction.

7. **Fire Management.** Guard against excessive sedimentation from prescribed fire and reduce potential nonpoint source pollution during wildfire suppression and rehabilitation.

8. **Forest Chemical Management.** Minimize the use and maximize the benefit of chemicals through skilled and appropriate management and application.

*1. Pre-harvest Planning BMPs**

***Note:** BMPs outlined below are examples. Check with the appropriate state agency to determine applicable BMPs in your area.

Figure 5

As man becomes active in the forest environment - building roads, harvesting trees and preparing sites for new trees to grow - several types of impacts can occur. The topsoil of the forest floor is disturbed; the natural filtering action of the soil is changed; and the topography and drainage features of the land are modified. Trucks and other heavy equipment compact the soil affecting the ability of surface water to infiltrate. When it rains or the snow melts, the surface water is no longer well absorbed and begins to flow over and onto the roads and collect in ditches. These new man-made channels can increase the velocity and volume of runoff and increase erosion. Heavy equipment can also break down stream banks.

All of these activities can move too much sediment into the forest streams and degrade water quality. Excessive runoff and sediment loads can increase filtering costs for drinking water systems and increase flood potential. Fish eggs laid in stream gravels can become buried in fine sediment and suffocate. Poorly planned timber harvest can destroy natural stream cover, raise water temperature, harm fish and degrade other wildlife habitat. Careful planning can help reduce the potential for nonpoint source pollution and help identify any potentially sensitive areas. A pre-harvest or forest management plan should be developed prior to any site work (Figures 5 and 6).

In preparing a pre-harvest plan, several resources are available and should be used including topographic maps, aerial photographs, and soil surveys along with field trips to determine site conditions (Figure 7). Many of these information sources are now available in digital format, or can be scanned. Global positioning systems (GPS) are useful in the field trips to note the location of important features. Field data geolocated with a GPS can be combined with electronic maps in a PC-based mapping system or Geographic Information System. In this manner, the new information revealed by field visits and aerial photo analysis can vastly improve the mapped information used for harvest planning.

Figure 6

Natural drainage channels, threatened and endangered species habitat, topography, and soil types should be major considerations in determining the:

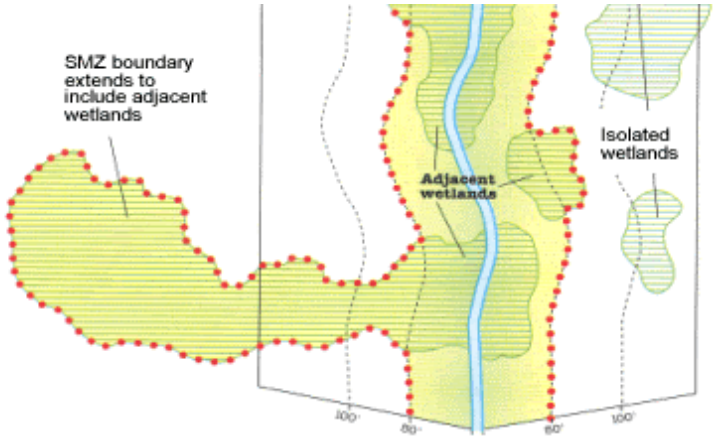
- boundaries of timber harvest activities;
- location and design of roads and landings;
- selection of harvesting method; and
- reforestation techniques.

Topographic maps (left) and aerial photos (right) are essential tools for pre-harvest planning.

Figure 7

Sensitive areas, such as wetlands and unusually important habitats for wildlife, should be avoided (Figure 8). If this is not possible, choose harvest practices that have the least serious effects or arrange schedules to avoid these areas during critical time periods (e.g., nesting or breeding seasons).

Where access to adjacent land will allow for a more efficient road system or avoidance of sensitive areas, consider working with the landowner to obtain an easement.



Planning should identify boundaries of sensitive areas to be avoided, such as wetlands (green lined areas) and streamside management zones (SMZ, in yellow).

Figure 8

Natural drainage channels, threatened and endangered species habitat, topography, and soil types should be major considerations in determining the:

- boundaries of timber harvest activities;
- location and design of roads and landings;
- selection of harvesting method; and
- reforestation techniques.

Construction and harvest operations should be timed to take advantage of seasonal conditions (Figure 9). The driest months are generally the best times for road construction to avoid runoff and drainage problems. Constructions during heavy rains, freeze/thaw conditions increases the

potential for runoff and erosion. The pre-harvest plan should outline the best management practices which will be followed before, during and after the harvest (Figure 10) and should:

- clearly identify the area to be harvested;
- locate special areas of protection, such as wetlands and streamside vegetation;
- plan for the proper timing of forestry activities;
- describe management measures for road layout, design, construction, and maintenance; and
- describe management measures for harvesting methods and forest regeneration

Seasonal considerations during planning can minimize the chances of weather-related problems during timber harvest .

Figure 9

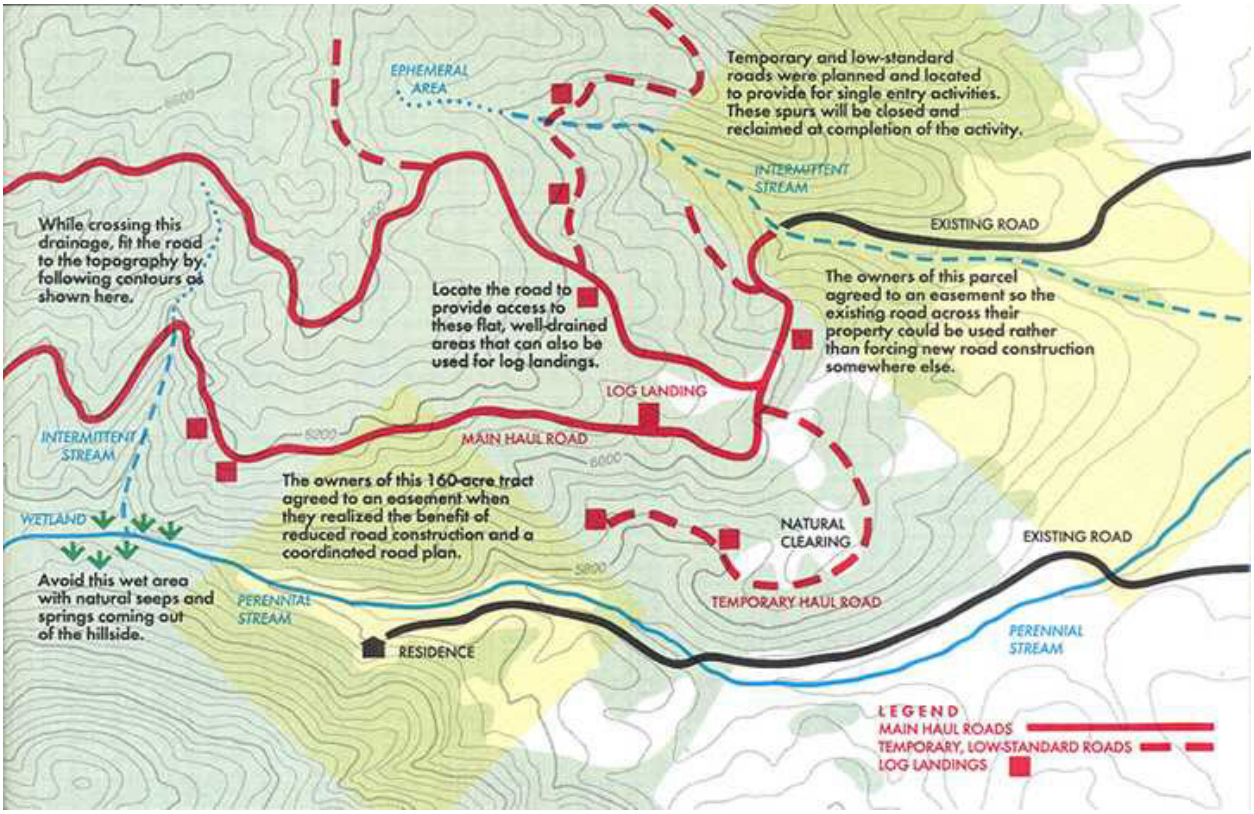


Figure 10

1. Pre-harvest Planning BMPs Quiz

(Answers can be found on page 47.)

1. What is the purpose of a preharvest plan?

- ☐ A. Identify potential problem areas.
- ☐ B. Reduce the potential for nonpoint source pollution.
- ☐ C. Maximize timber harvest.
- ☐ D. Identify Best Management Practices.
- ☐ E. A and B.
- ☐ F. A and C.
- ☐ G. A, B and D.
- ☐ H. None of the above

2. What information should be included in preharvest plan?

- ☐ A. A delineation of the harvest boundary.
- ☐ B. BMPs for only the timber harvest itself.
- ☐ C. Location of sensitive environmental areas.
- ☐ D. Employee information.
- ☐ E. B and C.
- ☐ F. A and C.
- ☐ G. A, B and D.
- ☐ H. None of the above.

3. What are some of the steps to take to minimize environmental impact?

- ☐ A. Avoid sensitive environmental areas when possible.
- ☐ B. Work when soils are saturated.
- ☐ C. Design road system to take advantage of topography.
- ☐ D. Obtain easements from adjacent landowners if this will result in a more efficient road system.
- ☐ E. A and C.
- ☐ F. B and C.
- ☐ G. A, C and D.
- ☐ H. All of the above.

2. Streamside Management Zones (SMZs)*

***Note:** BMPs outlined below are examples. Check with the appropriate state agency to determine applicable BMPs in your area.

Figure 11

Streamside management zones (SMZs) are buffer strips of a width specified in state BMPs, consisting of the existing native vegetation communities along the stream corridor. SMZs serve many important functions, and are of special importance in controlling and filtering sediment from silvicultural operations, sustaining wildlife and fish populations, and maintaining water quality (Figures 11 and 12). The SMZ not only acts as a buffer between land activities and sensitive aquatic ecosystems, but it also usually supports high biodiversity, valuable habitat, and multiple recreational uses. The vegetation in the SMZ serves as filter material to reduce pollutants entering the stream. Streamside forests are a source of large woody debris for fish habitat. The shade provided by streamside trees is important in maintaining the natural temperature of the water which impacts aquatic habitat. These areas also function as travel corridors, provide food and protection, and nesting sites for wildlife. These zones are also called protective strips, filter and shade strips, and buffers.

Figure 12

Limiting disturbances in and near SMZs can protect one of the most environmentally sensitive areas in the forest (Figure 13). The width of the SMZ should be based on factors such as:

- erosiveness of the soil;
- steepness of the bank slopes;
- proximity to municipal watersheds;
- protection of adjacent wetlands; and
- sensitivity of the fish and wildlife habitat and other critical areas.

To limit the disturbances in SMZs, consider the following practices:

- roads should not be constructed in SMZs except at designated stream or wetland crossings (Figure 14).
- operate vehicles only on roads

- do not side cast road construction material into SMZs
- do not handle, store, apply, or dispose of hazardous chemicals, fertilizers, or pesticides in SMZs
- do not deposit waste timber or slash in SMZs

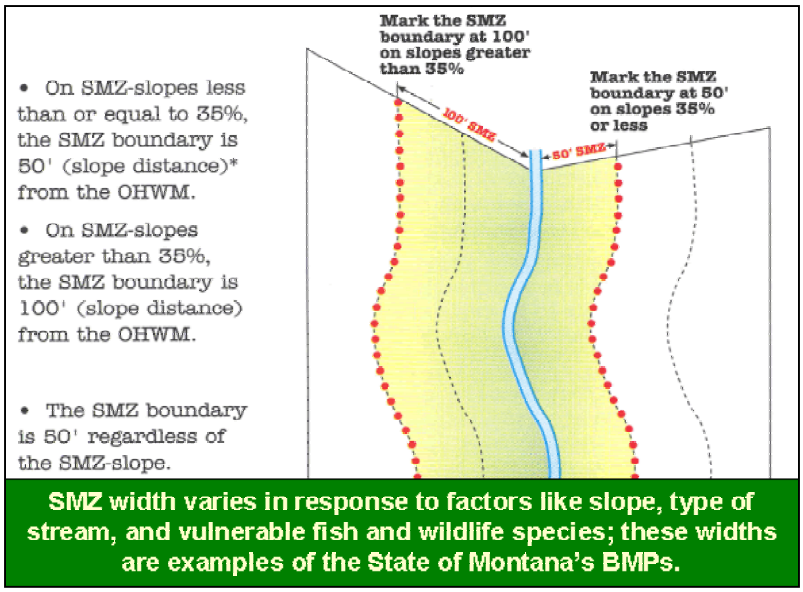


Figure 13
(OHWM = ordinary high water mark)

Timber harvesting in the SMZ should be done only selectively if at all, and with special care (Figure 15). Selective logging in the SMZ should consider the following practices:

- Retain the appropriate diversity and size of tree and shrub species.
- Protect and retain trees and shrubs and snags that are below harvest quality. These provide wildlife habitat and stabilize soil.
- Retain bank edge trees for stream channel stability and to shade stream.

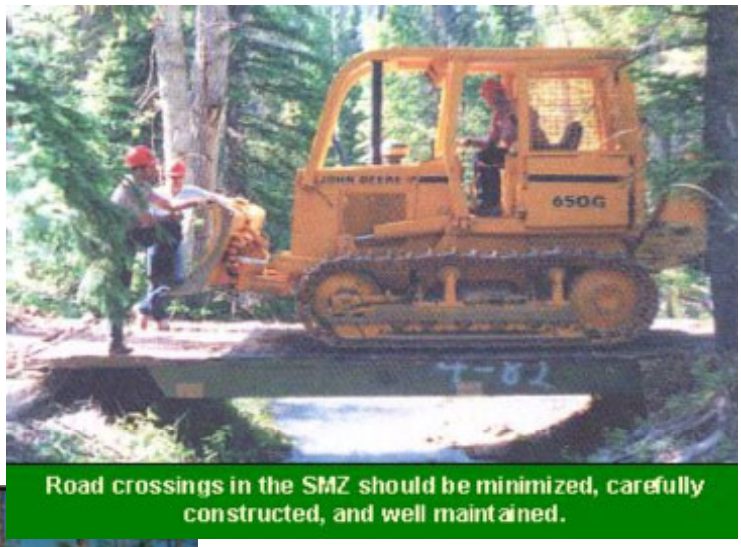


Figure 14

Figure 15

- Maintain sufficient ground cover to trap sediment.
- Immediately remove any logging debris which enters the stream channel.

2. Streamside Management Zones* (SMZs) Quiz

(Answers can be found on page 47.)

1. What is a streamside management zone?

- ☐ A. Ten feet or more of undisturbed forest on both sides of a stream.
- ☐ B. A buffer zone between land activities and the stream which acts as a filter for pollutants.
- ☐ C. A preferred area for location of roads.
- ☐ D. A and B.
- ☐ E. None of the above.

2. What are some of the harvesting precautions which should be taken in SMZs?

- ☐ A. Limit disturbances in the SMZs.
- ☐ B. Do not allow any timber harvesting in the SMZ.
- ☐ C. Place logging debris in stream channel for fish habitat.
- ☐ D. Keep all pesticides and fertilizers out of the SMZ.
- ☐ E. A and D.
- ☐ F. B and C.
- ☐ G. A, C and D.
- ☐ H. All of the above.

3. What are some of the factors to consider in selecting the size of the SMZ?

- ☐ A. Ground slope and soil stability.
- ☐ B. Location of wetlands and sensitive environmental areas.
- ☐ C. Volume of timber available for harvest.
- ☐ D. Time of the year of the harvest operation.
- ☐ E. A and C.
- ☐ F. B and C.
- ☐ G. A and B.
- ☐ H. All of the above.

*3. Forest Wetland Management**

***Note:** BMPs outlined below are examples. Check with the appropriate state agency to determine applicable BMPs in your area.

Forest wetlands (Figures 16 and 17) provide many beneficial functions such as sediment trapping, nutrient retention and removal, groundwater recharge, and exceptional wildlife habitat. Normal, ongoing forestry activities (including harvesting, road design and construction, site preparation and regeneration, and chemical management) must be planned and operated to adequately protect the beneficial functions of forest wetlands.

Figure 16

Figure 17

The Clean Water Act and state-level wetlands laws provide some regulatory protections (see www.epa.gov/owow/wetlands/regs/index.html) that may affect actions such as depositing fill. Nevertheless, use of Best Management Practices may make several forestry-related activities exempt from fill permit requirements (see section 232.3c (6) (i - xv) at www.epa.gov/owow/wetlands/40cfr/232.html#232.03). Foresters should identify the provisions that apply to their plans before taking action and consult their local authorities for advice.

The BMPs described for routine forestry activities are relevant to forested wetlands and, for certain activities, additional precautions are needed. For example:

- The streamside management zone should be extended to incorporate the wetlands nearby (Figure 18, overleaf).
- Ultrawide, high-flotation tires on logging trucks and skidders should be used to reduce soil compaction and erosion.
- Operations should be suspended or limited when soils become saturated.
- The natural contour of the site should be maintained and action should be taken to ensure that forestry activities do not immediately or gradually convert the wetland to dry land.
- Where roads are constructed, cross drainage should be provided to maintain natural surface and subsurface flow (Figure 19, overleaf).
- Construct road fills only when absolutely necessary. Gravel or crushed rock should be used as fill to provide for water movement.

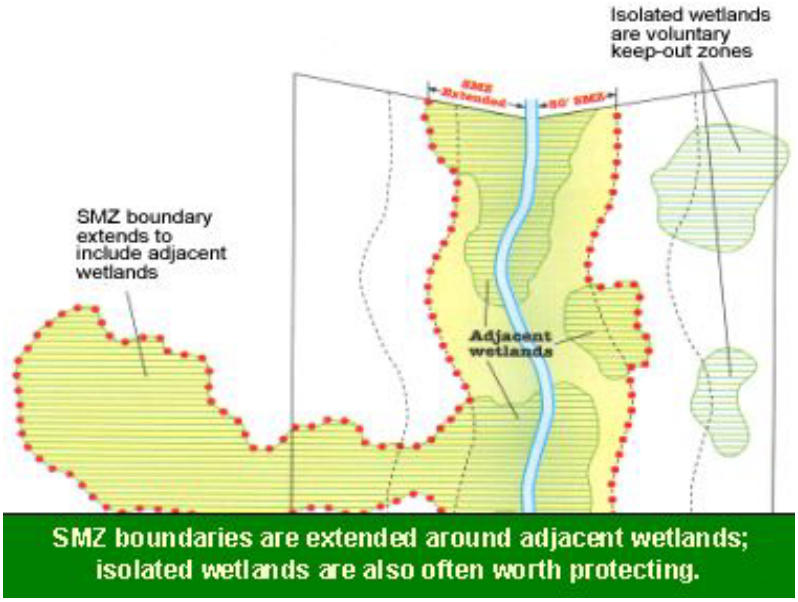


Figure 18

Figure 19

3. Forest Wetland Management Quiz

(Answers can be found on page 47.)

1. It is important to protect wetlands during timber harvest operations because these lands perform beneficial functions (habitat, filter pollutants).

- ☐ A. True.
- ☐ B. False.

2. What actions should be taken when harvest operations may impact wetlands?

- ☐ A. Incorporate wetlands into streamside management zones (SMZs).
- ☐ B. Drain wetlands so no special precautions are needed.
- ☐ C. Compact soils to reduce potential for erosion.
- ☐ D. Incorporate engineering solutions such as ultrawide, high-flotation tires to minimize compaction.
- ☐ E. A and C.
- ☐ F. A and D.
- ☐ G. A, B, and D.
- ☐ H. All of the above.

*4. Road Construction and Maintenance**

***Note:** BMPs outlined below are examples. Check with the appropriate state agency to determine applicable BMPs in your area.

Figure 20

Well-located, constructed, and maintained forest roads can minimize the major source of water pollution associated with silvicultural activities. A poorly designed road system (Figures 20 and 21) can result in significant impacts such as increased sediment load reaching the stream; landslide debris flows; degraded aquatic habitat and fish and wildlife migration barriers; stream bank and streambed damage; altered and concentrated surface runoff; and increased maintenance costs.

Some general principles to consider in the layout of the road system are:

- Plan harvesting activities to minimize the total number of miles of road length.
- Use existing roads wherever possible.
- Minimize the changes in the natural stability of the land - place roads on high ground; keep out of streamside management zones and wet areas; keep off the toe of banks and slopes.
- Where possible, the road should follow the natural contour of the land. This will avoid the need for extensive cut and fill.
- Minimize the number of wet meadow and stream crossings.
- Keep road gradient as low as possible. The steeper the grades, the greater the velocity of the runoff. If steep grades are needed for short distances, follow by stretches of lesser grades to reduce runoff velocity (Figure 22).
- Determine the appropriate standard of road needed for the type of equipment; volume of traffic; and length of use. Selection of the appropriate road surfacing material will minimize erosion and reduce maintenance costs.

Figure 21

Figure 22

Some general principles to consider in the construction of the road system are:

- Time the construction of the roads to minimize earth moving activities when soils are excessively wet and easily compacted and when fish are migrating and spawning and other critical times.
- Keep slope stabilization and erosion and sediment control work as current as possible with the road construction. This includes installing drainage features as part of the construction process and installing silt fences or windrows where needed to prevent sediment from entering streams (Figure 23).
- Place debris, overburden and other waste materials associated with construction in a location away from streams. Avoid placing these materials on unstable areas that may erode (Figure 24).
- Minimize soil erosion from road cuts and fills (Figure 25) through use of seeding, riprapping, mulching, or other methods to stabilize the soils and prevent weed invasion.

What's wrong with this picture? This road's embankments are not stabilized to limit erosion, and drainage is poor.

Figure 23

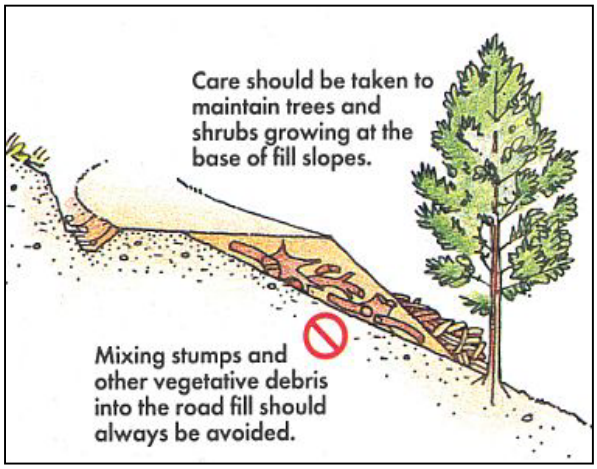
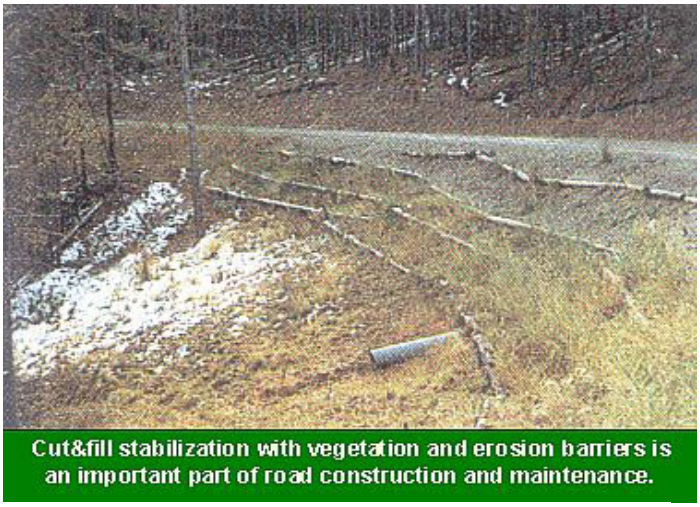


Figure 24

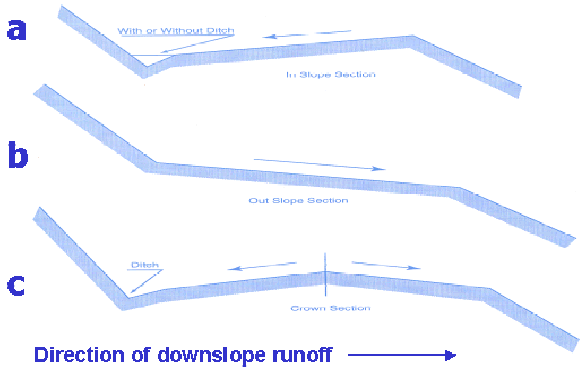


Cut&fill stabilization with vegetation and erosion barriers is an important part of road construction and maintenance.

Figure 25

Some general principles to consider in ensuring proper drainage from road surfaces are:

- Where possible, use outsloped roads to drain water directly onto forest floor. Note that outsloping may present safety concerns on areas such as sharp curves (Figure 26).
- If roadside drainage ditches are required, drain water from these ditches frequently to avoid flow concentrations.
- Drain water collected along the slope of the backfill for insloped and crowned roads by transporting across the road (Figure 27) through culverts or surface cross drains such as water bars (small earthen dams formed in the road to force water off the road surface, out of the side ditches and onto the forest floor) or dips (short road gradient changes or "steps" which check and divert runoff). Waterbars and relief culverts should cross the road bed at an angle of between 30 and 45 degrees in order to provide gradient to the culvert and reduce the maintenance burden (debris will accumulate as the angle approaches a perpendicular alignment to the road).



Road surfaces may be a) insloped, b) outsloped or c) crowned to drain water off to the forest floor; the choice depends on slope length and grade, drainage patterns and other factors.

Figure 26

Road surfaces and roadside ditches can unintentionally become stream beds. Culverts, water bars, and turn-outs (L to R) keep runoff more normally distributed in the forest.

Figure 27

- The spacing of the road cross drains (culverts, waterbars, dips) depends on the soil type, road gradient and amount of rainfall (Figure 28).
- Avoid placing drainage outlets on fill material since these materials are more readily eroded.
- Direct ditch waters onto undisturbed forest floor to allow water to infiltrate and sediment to settle out. Never drain road side ditches directly into streams.

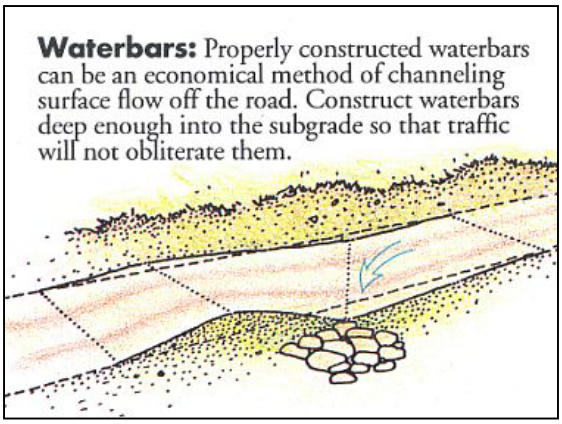


Figure 28

Some general principles to consider constructing stream crossings (Figure 29) are:

- Design crossing to allow for fish passage and to protect water quality.
- Time construction to protect fish habitat and water quality.
- Design crossing to handle peak runoff and flood waters.
- Stream crossings should be at right angles to the stream channel and should include erosion protection measures.
- Crossings should be designed to protect the approach to the stream at the stream banks and stream bottom.

Note that federal, state or local agencies may require permits for construction of stream crossings.

The choice of stream crossing method depends on the stream type and size; size of the watershed drainage area; construction cost and maintenance; amount of use; length of use; soil condition (Figure 30). Culverts, bridges, or fords may be used to allow logging equipment to cross ephemeral, intermittent or perennial streams.

Stream crossings include temporary and permanent bridges, fords, and culverts.

Figure 29

- Culverts are generally used when it is necessary to cross small streams . When installing culverts, the following practices should be considered:
  - Culverts should be oriented with the natural stream flow.

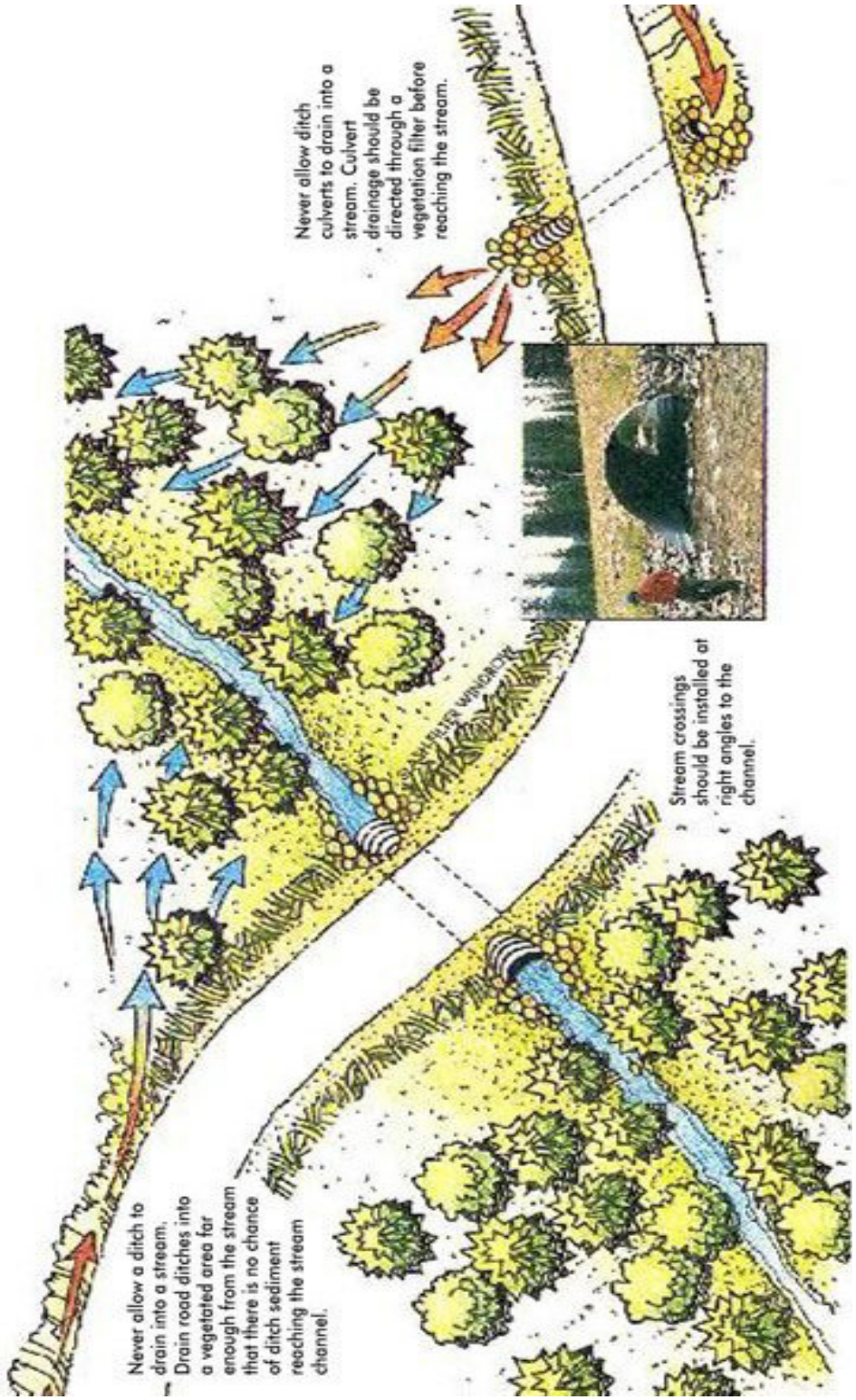

Never allow ditch culverts to drain into a stream. Culvert drainage should be directed through a vegetation filter before reaching the stream.
Stream crossings should be installed at right angles to the channel.
Never allow a ditch to drain into a stream. Drain road ditches into a vegetated area far enough from the stream that there is no chance of ditch sediment reaching the stream channel.

Figure 30

- Culverts must be designed and maintained to handle sediment and woody debris flow as well as stream flow.
- Culverts should be designed to allow fish passage (Figure 31).
- Erosion control measures, such as large boulders or riprap, should be installed to minimize sedimentation at culvert inflow and outfall.

Figure 31

- Bridges (Figure 32) are generally used when large streams are crossed. When constructing bridges, the following practices should be considered:
  - Bridges should be constructed with minimum disturbance to the stream bank, channel and SMZ.
  - Use portable, temporary bridges when possible. These are economical; can be installed with less impact on the environment than other alternatives; and can be easily removed upon completion of operations
  - Cross where the stream is relatively narrow with low banks and firm, rocky soil. The channel should be straight and uniform above, at, and below the crossing. Locate bridges so the stream and road alignment are perpendicular to one another and straight in all four directions.
  - Choose stream-crossing structures with the structural capacity to safely handle expected vehicle loads with the least disturbance to the watercourse. Consider stream size, storm frequency and flow rates, and intensity of use (permanent or temporary).

Analysis of site conditions and intended uses should precede the construction of temporary or permanent bridges.

Figure 32

- Fords (Figure 33) may be used if no practical alternative exists.
    - The use of fords should be limited to areas where the stream bed has a firm rock or gravel bottom. There are several options to harden the bottom of fords including gravel and concrete or wooden planks
    - The approaches to fords should be both low and stable enough to support traffic.
    - No fish should be present during low flow.
    - The water depth should be low enough to allow safe passage.

In general, timber harvesters should avoid impacts to wetlands and other aquatic resources to the maximum extent practicable. If a proposed road project would impact a wetland, it may require authorization under Section 404 of the Clean Water Act. In such cases, contact the Army Corps of Engineers local office to determine whether Section 404 applies to your project. Section 404 exempts discharges of dredged or fill material associated with forest road construction and maintenance, where such activities are conducted in accordance with specific Best Management Practices.

Temporary fords may be made safer at low water by installing portable concrete planks for later removal.

Figure 33

Some general principles to consider in constructing wetland crossings are:

- Use multiple culverts to preserve the existing hydrology
- For temporary roads, consider the use of support systems such as geotextiles and various wood and metal platform devices (Figure 34).
- Schedule the harvest during the drier seasons of the year or during time when the ground is frozen. Consider ceasing operations in areas where rutting exceeds 6 inches in depth.
- Do not skid (drag cut logs) through vernal ponds, spring seeps, or stream channels.
- Use brush or corduroy roads (rows of logs or limbs) to minimize soil compaction and rutting when skidding in wet areas.
- Consider chiseling to break up compacted road surface to reestablish soil porosity when hauling is completed.

Logging trucks can place and remove wooden mat roads in wetlands for temporary access. (photo by Maryland DNR)

Figure 34

Some general principles of road maintenance to consider are:

- Inspections to ensure water control measures are functioning properly are essential.
- To keep water flowing freely and quickly away from the road, culverts must be free of debris.
- Water bars and dips must be maintained as traffic wears them down.

- Road surface should be free of ruts to keep traffic moving safely. The road should be bladed and reshaped to conserve existing material; and to retain the original insloped, outsloped, or crowned design (Figure 35).
- Fill and side cast areas must be checked to make sure they aren't becoming saturated and unstable.

Road grading (left) and cleaning culverts (right) are long-term maintenance tasks that help minimize stream siltation from roads.

Figure 35

4. Road Construction and Management Quiz

(Answers can be found on page 47.)

1. What factors should be considered in designing the road system for a timber harvest?

- ☐ A. Locate roads as close to stream as possible since this is usually the lowest gradient.
- ☐ B. Follow natural contour of the land.
- ☐ C. Minimize the miles of roads needed.
- ☐ D. Minimize the number of stream crossings.
- ☐ E. C and D.
- ☐ F. B and C.
- ☐ G. B, C, and D.
- ☐ H. All of the above.

2. What are some general practices which can be followed to minimize the environmental impacts of the road construction?

- ☐ A. Schedule work to avoid times when soils are wet, when fish are migrating, and other sensitive times.
- ☐ B. Keep erosion control work, such as stabilizing slopes and installing drainage systems and silt fences, as current as possible with road construction.
- ☐ C. Keep all waste materials from road construction away from streams.
- ☐ D. A and C.
- ☐ E. A, B, and C.
- ☐ F. B and C.
- ☐ G. None of the above.

3. Outsloped road construction is preferred where possible because this allows water to drain directly from the road surface onto the forest floor avoiding the need for road side ditches, water bars, cross drain culverts, and other drainage systems to move the water from the road without impacting any streams.

- ☐ A. True.
- ☐ B. False.

4. What are some stream crossing design considerations?

☐ A. Crossing design and construction timing should consider fish passage and fish habitat protection.

☐ B. Crossing design should be able to handle a 10 year flood maximum.

☐ C. Culverts are generally used to cross small streams.

☐ D. Fords are generally used for streams which will be infrequently crossed.

☐ E. Bridges are generally used to cross large streams.

☐ F. A and B.

☐ G. C and E.

☐ H. A, C, and E.

☐ I. All of the above.

5. What kind of road maintenance operations should be performed?

☐ A. Make annual inspections to ensure drainage systems are operating properly.

☐ B. Reconstruct water bars and dips as traffic wears them down.

☐ C. Blade road as needed to retain original road inslope, outslope, or crown design.

☐ D. A and C.

☐ E. B and C.

☐ F. All of the above.

*5. Timber Harvesting**

***Note:** BMPs outlined below are examples. Check with the appropriate state agency to determine applicable BMPs in your area.

Timber harvesting consists of felling the tree, transporting (yarding) to a central accumulation point (landing), and transporting logs offsite along the main haul roads. Each of these activities can have minimal to severe impacts on water quality, depending in part on the level of planning and the implementation of best management practices (Figures 36 and 37). Of primary importance are the density and location of skid trails, type of yarding system selected, soil compaction and saturation, and amount of soil disturbance.

Figure 36

Figure 37

- Types of yarding systems include tractor/skidder, skyline, and helicopter logging (Figure 38).

Figure 38

- **Tractor/skidder systems** haul logs to a landing by tractor or skidder along skid trails (Figure 39). This is the least expensive and most common type of system, but it also can have the most impact on nearby waters if done carelessly. Impacts can be reduced through practices such as the following:

    - Skid trails should be carefully laid out to minimize the number of trails.
    - Skid trails should be clearly marked. Skid trails should not be located in streambeds, in SMZs, or on steep slopes.
    - Skidding should be upslope or on the topographic contour to disperse runoff.
    - Appropriate drainage control measures, such as water bars, should be installed on skid trails to protect water quality.

Figure 39

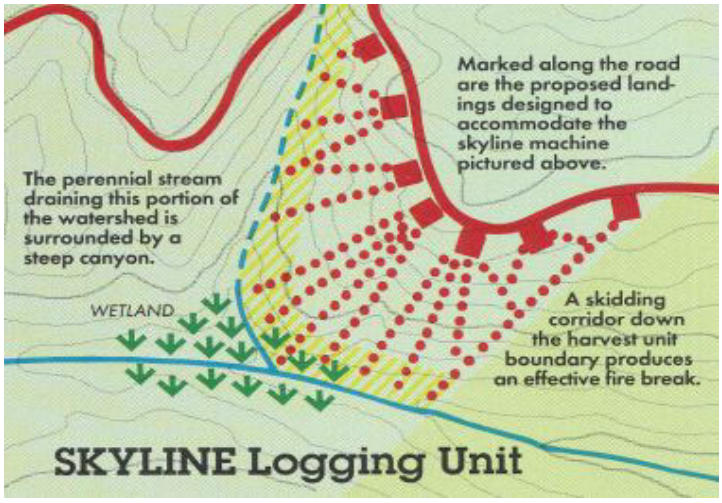


Figure 40

- **Skyline systems** move logs to the landing by aerial cables (Figure 40). This is used where there are long, steep slopes or where it is necessary to protect soils from excessive disturbance and to maintain integrity of sensitive areas.
- **Helicopters** move logs to the landing by helicopter (Figure 41). This method is used primarily in rugged terrain where good landing sites and roads are not very close to the harvest areas, or where there are exceptionally sensitive environmental features that may be affected by other yarding methods or new road construction. Landings for any of the above transport systems should be located in dry areas with slight slopes, well outside streamside management zones or wetlands. The number and size of landings should be planned along with the harvest road system considering the yarding system selected. There must be adequate drainage on approach trails to the landing and a mechanism to divert water away from the landing.

The ability to grow the next forest depends on protecting the soil. After completion of harvesting operations, landings and access roads must be stabilized. Regrade and revegetate the surface of landings and access roads so they are smooth, level, and free of ruts. Heavily compacted areas may require scarification or disking to promote water infiltration.

Helicopter logging may be practical when sensitive resources need to be avoided and few roads or landings are nearby.

Figure 41

5. Timber Harvesting Quiz

(Answers can be found on page 47.)

1. The three types of yarding systems are tractor/skidder, skyline, and helicopter. What factors should be considered in selecting which of these yarding systems will be used?

- ☐ A. The topography of the harvest site.
- ☐ B. The value of the timber.
- ☐ C. The environmentally sensitive areas within the harvest boundary.
- ☐ D. Potential for soil compaction or disturbance.
- ☐ E. A and D.
- ☐ F. B and C.
- ☐ G. A, C, and D.
- ☐ H. None of the above.

2. The landing should be located outside the SMZ in a dry area with a slight slopes to drain water from the site.

- ☐ A. True
- ☐ B. False

*6. Revegetation and Forest Regeneration**

***Note:** BMPs outlined below are examples. Check with the appropriate state agency to determine applicable BMPs in your area.

After an area is harvested, tree stumps, trees too small to harvest, and woody debris are left behind (Figures 42 and 43). This condition sometimes presents a potential fire hazard which can, in turn, lead to increased runoff and stream sedimentation. In addition, there are numerous roads, skid trails, and drainage structures which are no longer needed. If these are not properly closed or maintained, they are a source of sediment contamination. The immediate goal of site preparation is to get desired vegetation back on the site as soon as possible to control erosion, sedimentation, and nutrient loss. Through systematic planning and implementation of appropriate BMPs, we can minimize adverse impacts from past timber harvesting.

Figure 42

Site preparation can include:

- Removal of logging roads, landings, and drainage structures.
- Mechanical activities to chop, root rake, disk and blade the soil in the disturbed areas in preparation for planting.
- Prescribed fires to reduce logging residue and undesirable trees and vegetation (also see the next section of this module).

Figure 43

Each of these actions or a combination of these actions has the potential for increasing erosion and degrading water quality. Equipment and site preparation methods must consider the site topography, soil type, natural drainage, amount of rainfall, and kind of vegetation.

Some general principles of revegetation and reforestation to consider are (Figure 44):

- Establish a vegetative cover planting on erodible areas that were cultivated in the fall but will not be planted until spring.
- Stabilize steep slopes prior to planting.
- Use native grasses or other plant species to reseed bare-erodible areas; do not introduce invasive non-native plants under any circumstance (Figure 45).
- Windrow logging debris along contours, in gullies, and on skid trails to stabilize these areas.
- Remove unneeded logging roads and skid trails immediately. Do not wait for entire harvest operation to be completed.
- Smooth, grade and revegetate landings and, where appropriate, main haul roads.
- Remove temporary drainage structures and clean permanent drainage structures.

This clearcut is being managed to reforest itself naturally, but past clearcuts nearby were planted in even-aged stands.

Figure 44

Spreading slash along the slope contour and growing cover on inactive roads are two favored revegetation practices.

Figure 45

6. Revegetation and Forest Regeneration Quiz

(Answers can be found on page 47.)

1. A site preparation plan is necessary to ensure the harvest is conducted in an environmentally sound manner.

- ☐ A. True
- ☐ B. False

2. The site preparation plan should describe the steps which will be taken to get desired vegetation back on the site as soon as possible after the timber harvest.

- ☐ A True
- ☐ B. False

*7. Fire Management**

***Note:** BMPs outlined below are examples. Check with the appropriate state agency to determine applicable BMPs in your area.

Fire is an important tool in forest management and a natural occurrence that sometimes requires control or suppression. Practices for protecting water quality relate to two general categories of fire management: wildfire control and prescribed burning.

Figure 46

Prescribed burning reduces slash, competition for nutrients among seedlings, and fuel for wildfires. Where tree species are ecologically dependent on fire for regeneration, fire also serves as an essential forest management tool. Periodic, low-intensity prescribed fires usually have little effect on water quality, and revegetation of burned areas reduces sediment yield from prescribed burning and wildfires.

The intensity and severity of burning and the proportion of the watershed burned are the major influences on streamflow and water quality (Figures 46 and 47). Fires that burn intensely on steep slopes close to streams and that remove most of the forest floor and litter down to the mineral soil are most likely to affect water quality by increasing sediment and nutrient pollution in the water. Simultaneously, intense fires decrease soil nutrients and increase soil erosion.

Figure 47

The amount of erosion following a fire depends on:

- The amount of ground cover remaining on the soil
- The steepness of the slope (Figure 48)
- The time, amount, and intensity of rainfall
- The intensity of fire
- The erodibility of the soil
- How rapidly a site revegetates

Wildfire and prescribed fire change erosion rates on the burned area in two ways. First, fire eliminates vegetative soil cover (Figure 49). Second, chemical changes in the soil following fire create an increased resistance to water infiltration in the upper soil layer, and this increases surface runoff and sheet erosion. The magnitude of these effects depends on how hot a fire burns, and this in turn depends on numerous site characteristics. Erosion following fire is most severe where a fire has burned most intensely and the fire is followed by a strong storm, a year of moderately high rainfall, or a spring with a large volume of snowmelt. Wildfire control practices helpful to water quality include:

Most of this watershed was burned badly and its steep slopes are vulnerable to increased erosion.

Figure 48

This grassy slope is being burned to create part of a firebreak for controlling possible wildfires.

Figure 49

- Whenever possible avoid using fire-retardant chemicals in SMZs and over watercourses, and prevent their runoff into watercourses. Do not clean application equipment in watercourses or locations that drain into watercourses.
- Close water wells excavated for wildfire-suppression activities as soon as practical following fire control.

- During wildfire emergencies, firelines, road construction, and stream crossings are unrestricted by BMPs. However, install BMPs and begin remediation as soon as possible after the emergency is controlled.

Studies have shown that prescribed burning, if carefully planned and done using appropriate BMPs, can avoid significant effects on water quality. Prescribed fire BMPs include:

- Carefully plan burning to take into account weather, time of year, and fuel conditions so that these help achieve the desired results and minimize effects on water quality.
- Do not conduct intense prescribed fire for site preparation in the SMZ. Do not pile and burn for slash removal purposes in the SMZ, and avoid construction of firelines in the SMZ or immediately adjacent or parallel to the SMZ.
- Prescribe burns should be only as intense as necessary to achieve the desired objective (Figure 50). If possible, burn to maintain some of the duff or residual organic matter on the soil to prevent soil erosion.
- Avoid conditions that require extensive blading of fire lines by heavy equipment when prescribing burns. Use handlines, firebreaks, and hose lays to minimize blading of fire lines.
- Execute the burn with a trained crew and avoid intense burning (Figure 51).

Drip torches allow precise application of fire to small areas of flammable materials buildup in uneven terrain.

Figure 50

Prescribed burn safety requires burning only in specific weather conditions with fire crew and water onhand.

Figure 51

- Avoid burning on steep slopes in high-erosion-hazard areas or areas that have highly erodible soils.

Note that State, county, and local governments may have air pollution or smoke management requirements for **prescribed burns.**

Some general principles of fire management to follow for protecting water resources are:

- Intense prescribed fire should not cause excessive sedimentation due to the combined effect of removal of canopy species and the loss of soil-binding ability of subcanopy and herbaceous vegetation roots (Figure 52), especially in SMZs, in streamside vegetation for small ephemeral drainages, or on very steep slopes.
- Prescriptions for prescribed fire should protect against excessive erosion or sedimentation to the extent practicable.

Desirable trees, such as this small white pine, can survive prescribed burns. This photo was taken the day after a burn.

Figure 52

- All bladed firelines, for prescribed fire and wildfire, should be plowed on contour or stabilized with water bars and/or other appropriate techniques if needed to control excessive sedimentation or erosion of the fireline.
- Wildfire suppression and rehabilitation should consider possible nonpoint source pollution of watercourses, while recognizing the safety and operational priorities of fighting wildfires.

7. Fire Management Quiz

(Answers can be found on page 47.)

1. During a prescribed burn that is going according to plan, all actions are unrestricted by BMPs.

☐ A. True

☐ B. False

2. The potential negative impacts of fire on water resources come mostly from erosion, sedimentation, and nutrients.

☐ A. True

☐ B. False

3. Extensive blading of firelines has a negligible effect on erosion and water quality.

☐ A. True

☐ B. False

4. Prescribed burns usually have negligible effects on water resources.

☐ A. True

☐ B. False

*8. Forest Chemicals**

***Note:** BMPs outlined below are examples. Check with the appropriate state agency to determine applicable BMPs in your area.

Over the last several years, many chemical compounds including pesticides, fertilizers, and fire retardants have been used in forestry to increase production. These chemicals have the potential, if improperly used, to pollute soil and water and damage wildlife habitats (Figure 53).

Figure 53

To ensure safe use of chemicals, consider the following:

- Transportation, handling, storage, application and disposal of pesticides, fire retardants, and fertilizers must comply with applicable local, state and federal regulations (Figure 54).
- Monitor weather conditions such as rain, wind speed, temperature and humidity during application to prevent drift, volatilization, and surface water runoff.
- Do not apply chemicals in streamside management zones or wetlands.
- Note that fertilizers and fire retardants contain high amounts of both nitrogen and phosphorus and are easily transported overland and deposited in stream along with the sediment. These compounds can accelerate eutrophication (a process whereby water bodies are choked by overabundant plant life and algae due to higher levels of nutrients such as nitrogen and phosphorus).

Figure 54

- Oil and fuel for equipment and vehicles must also be carefully handled and disposed. Spills, leaks, empty containers, and filters are potential sources of soil and water contamination if improperly managed.
- Develop a spill contingency plan which identifies all actions to be taken in the event of a chemical spill including phone numbers for federal, state, and local agencies which must be notified.

8. Forest Chemicals Quiz

(Answers can be found on page 47.)

1. Chemicals, such as pesticides, fertilizers, and fire retardants, are used in forestry activities to increase production

- ☐ A. True
- ☐ B. False

2. What steps can be taken to ensure save use of chemicals in forestry activities?

- ☐ A. Develop a spill contingency plan.
- ☐ B. Do not use or store chemicals in the SMZ.
- ☐ C. Dispose of empty chemical containers by burying on site.
- ☐ D. Monitor weather conditions before and during chemical application.
- ☐ E. A, B, and D.
- ☐ F. B and D.
- ☐ G. A and C.
- ☐ H. All of the above.

Module Conclusion

If you have completed this module, you should now have basic awareness of the types of general activities involved in forestry, the kinds of adverse effects on aquatic systems that improper or careless forest practices might cause, and several general practices for minimizing these adverse effects (Figure 55). You had the opportunity to answer review questions after each of eight module sections. All the questions are reassembled on the following pages in a final self-test of your retention.

Figure 55

Appreciation is expressed to the States of Montana and Wyoming for the use of numerous graphics and photographs from their stream management and forest BMP publications, and for the use of their BMPs as examples in this module. Thanks also to reviewers Melissa DeSantis, Bill Kirchner, George Loeb, Sam Pett, Steve Ralph, Chris Solloway, Dov Weitman, and Alan Wright for their helpful comments.

Self Test on Forestry Best Management Practices in Watersheds

Choose the appropriate response to each question below. After you've completed the quiz, check your answers with the ones provided on the last page of this document. A passing grade is 18 of 25 correct, or 70%. Answers can be found on page 47.

Part I:

1. What is the purpose of a preharvest plan?

- ☐ A. Identify potential problem areas.
- ☐ B. Reduce the potential for nonpoint source pollution.
- ☐ C. Maximize timber harvest.
- ☐ D. Identify Best Management Practices.
- ☐ E. A and B.
- ☐ F. A and C.
- ☐ G. A, B and D.
- ☐ H. None of the above.

2. What information should be included in preharvest plan?

- ☐ A. A delineation of the harvest boundary.
- ☐ B. BMPs for only the timber harvest itself.
- ☐ C. Location of sensitive environmental areas.
- ☐ D. Employee information.
- ☐ E. B and C.
- ☐ F. A and C.
- ☐ G. A, B and D.
- ☐ H. None of the above.

3. What are some of the steps to take to minimize environmental impact?

- ☐ A. Avoid sensitive environmental areas when possible.
- ☐ B. Work when soils are saturated.
- ☐ C. Design road system to take advantage of topography.
- ☐ D. Obtain easements from adjacent landowners if this will result in a more efficient road system.
- ☐ E. A and C.
- ☐ F. B and C.
- ☐ G. A, C and D.
- ☐ H. All of the above.

4. What is a streamside management zone?

- ☐ A. Ten feet or more of undisturbed forest on both sides of a stream.
- ☐ B. A buffer zone between land activities and the stream which acts as a filter for pollutants.
- ☐ C. A preferred area for location of roads.
- ☐ D. A and B.
- ☐ E. None of the above.

5. What are some of the harvesting precautions which should be taken in SMZs?

- ☐ A. Limit disturbances in the SMZs.
- ☐ B. Do not allow any timber harvesting in the SMZ.
- ☐ C. Place logging debris in stream channel for fish habitat.
- ☐ D. Keep all pesticides and fertilizers out of the SMZ.
- ☐ E. A and D.
- ☐ F. B and C.
- ☐ G. A, C and D.
- ☐ H. All of the above.

6. What are some of the factors to consider in selecting the size of the SMZ?

- ☐ A. Ground slope and soil stability.
- ☐ B. Location of wetlands and sensitive environmental areas.
- ☐ C. Volume of timber available for harvest.
- ☐ D. Time of the year of the harvest operation.
- ☐ E. A and C.
- ☐ F. B and C.
- ☐ G. A and B.
- ☐ H. All of the above.

7. What actions should be taken when harvest operations may impact wetlands?

- ☐ A. Incorporate wetlands into streamside management zones (SMZs).
- ☐ B. Drain wetlands so no special precautions are needed.
- ☐ C. Compact soils to reduce potential for erosion.
- ☐ D. Incorporate engineering solutions such as ultrawide, high-flotation tires to minimize compaction.
- ☐ E. A and C.
- ☐ F. A and D.
- ☐ G. A, B, and D.
- ☐ H. All of the above.

8. What factors should be considered in designing the road system for a timber harvest?

- ☐ A. Locate roads as close to stream as possible since this is usually the lowest gradient.
- ☐ B. Follow natural contour of the land.
- ☐ C. Minimize the miles of roads needed.
- ☐ D. Minimize the number of stream crossings.
- ☐ E. C and D.
- ☐ F. B and C.
- ☐ G. B, C, and D.
- ☐ H. All of the above.

9. What are some general practices which can be followed to minimize the environmental impacts of the road construction?

- ☐ A. Schedule work to avoid times when soils are wet, when fish are migrating, and other sensitive times.
- ☐ B. Keep erosion control work, such as stabilizing slopes and installing drainage systems and silt fences, as current as possible with road construction.
- ☐ C. Keep all waste materials from road construction away from streams.
- ☐ D. A and C.
- ☐ E. A, B, and C.
- ☐ F. B and C.
- ☐ G. None of the above.

10. What are some stream crossing design considerations?

- ☐ A. Crossing design and construction timing should consider fish passage and fish habitat protection.
- ☐ B. Crossing design should be able to handle a 10 year flood maximum.
- ☐ C. Culverts are generally used to cross small streams.
- ☐ D. Fords are generally used for streams which will be infrequently crossed.
- ☐ E. Bridges are generally used to cross large streams.
- ☐ F. A and B.
- ☐ G. C and E.
- ☐ H. A, C, and E.
- ☐ I. All of the above.

11. What kind of road maintenance operations should be performed?

- ☐ A. Make annual inspections to ensure drainage systems are operating properly.
- ☐ B. Reconstruct water bars and dips as traffic wears them down.
- ☐ C. Blade road as needed to retain original road inslope, outslope, or crown design.
- ☐ D. A and C.
- ☐ E. B and C.
- ☐ F. All of the above.

12. The three types of yarding systems are tractor/skidder, skyline, and helicopter. What factors should be considered in selecting which of these yarding systems will be used?

- ☐ A. The topography of the harvest site.
- ☐ B. The value of the timber.
- ☐ C. The environmentally sensitive areas within the harvest boundary.
- ☐ D. Potential for soil compaction or disturbance.
- ☐ E. A and D.
- ☐ F. B and C.
- ☐ G. A, C, and D.
- ☐ H. None of the above.

13. What steps can be taken to ensure save use of chemicals in forestry activities?

- ☐ A. Develop a spill contingency plan.
- ☐ B. Do not use or store chemicals in the SMZ.
- ☐ C. Dispose of empty chemical containers by burying on site.
- ☐ D. Monitor weather conditions before and during chemical application.
- ☐ E. A, B, and D.
- ☐ F. B and D.
- ☐ G. A and C.
- ☐ H. All of the above.

Part 2

14. It is important to protect wetlands during timber harvest operations because these lands perform beneficial functions (habitat, filter pollutants).

☐ A. True.

☐ B. False.

15. Outsloped road construction is preferred where possible because this allows water to drain directly from the road surface onto the forest floor avoiding the need for road side ditches, water bars, cross drain culverts, and other drainage systems to move the water from the road without impacting any streams.

☐ A. True.

☐ B. False.

16. The landing should be located outside the SMZ in a dry area with a slight slopes to drain water from the site.

☐ A. True

☐ B. False

17. A site preparation plan is necessary to ensure the harvest is conducted in an environmentally sound manner.

☐ A. True

☐ B. False

18. The site preparation plan should describe the steps which will be taken to get desired vegetation back on the site as soon as possible after the timber harvest.

☐ A. True

☐ B. False

19. During a prescribed burn that is going according to plan, all actions are unrestricted by BMPs.

☐ A. True

☐ B. False

20. The potential negative impacts of fire on water resources come mostly from erosion, sedimentation, and nutrients.

☐ A. True

☐ B. False

21. Extensive blading of firelines has a negligible effect on erosion and water quality.

- ☐ A. True
- ☐ B. False

22. Prescribed burns usually have negligible effects on water resources.

- ☐ A. True
- ☐ B. False

23. Chemicals, such as pesticides, fertilizers, and fire retardants, are used in forestry activities to increase production

- ☐ A. True
- ☐ B. False

24. Temperature and humidity are weather factors which should be monitored when using forest chemicals.

- ☐ A. True
- ☐ B. False

25. The only problem forest chemicals can cause to water resources is toxic pollution.

- ☐ A. True
- ☐ B. False

Answers:

1. Pre Harvest BMPs (Page 9)

Q1: G Q2: F Q3: G

2. Streamside Management Zones (SMZs) (Page 12)

Q1: B Q2: E Q3: G

3. Forest Wetland Management (Page 15)

Q1: A Q2: F

4. Road Construction and Maintenance (Pages 22-25)

Q1: G Q2: E Q3: A Q4: H Q5: E

5. Timber Harvesting (Page 29)

Q1: G Q2: A

6. Revegetation and Forest Regeneration (Page 32)

Q1: B Q2: A

7. Fire Management (Page 37)

Q1: B Q2: A Q3: B Q4: A

8. Forest Chemicals (Page 39)

Q1: A Q2: E

Answers to Self Test on Forestry Best Management Practices in Watersheds (Pages 40-46)

Part I:

Q1: G	Q2: F	Q3: G	Q4: B	Q5: E	Q6: G	Q7: F	Q8: G
Q9: E	Q10: H	Q11: E	Q12: G	Q13: E			

Part II:

Q14: A	Q15: A	Q16: A	Q17: B	Q18: A	Q19: B	Q20: A	Q21: B
Q22: A	Q23: A	Q24: A	Q25: B				