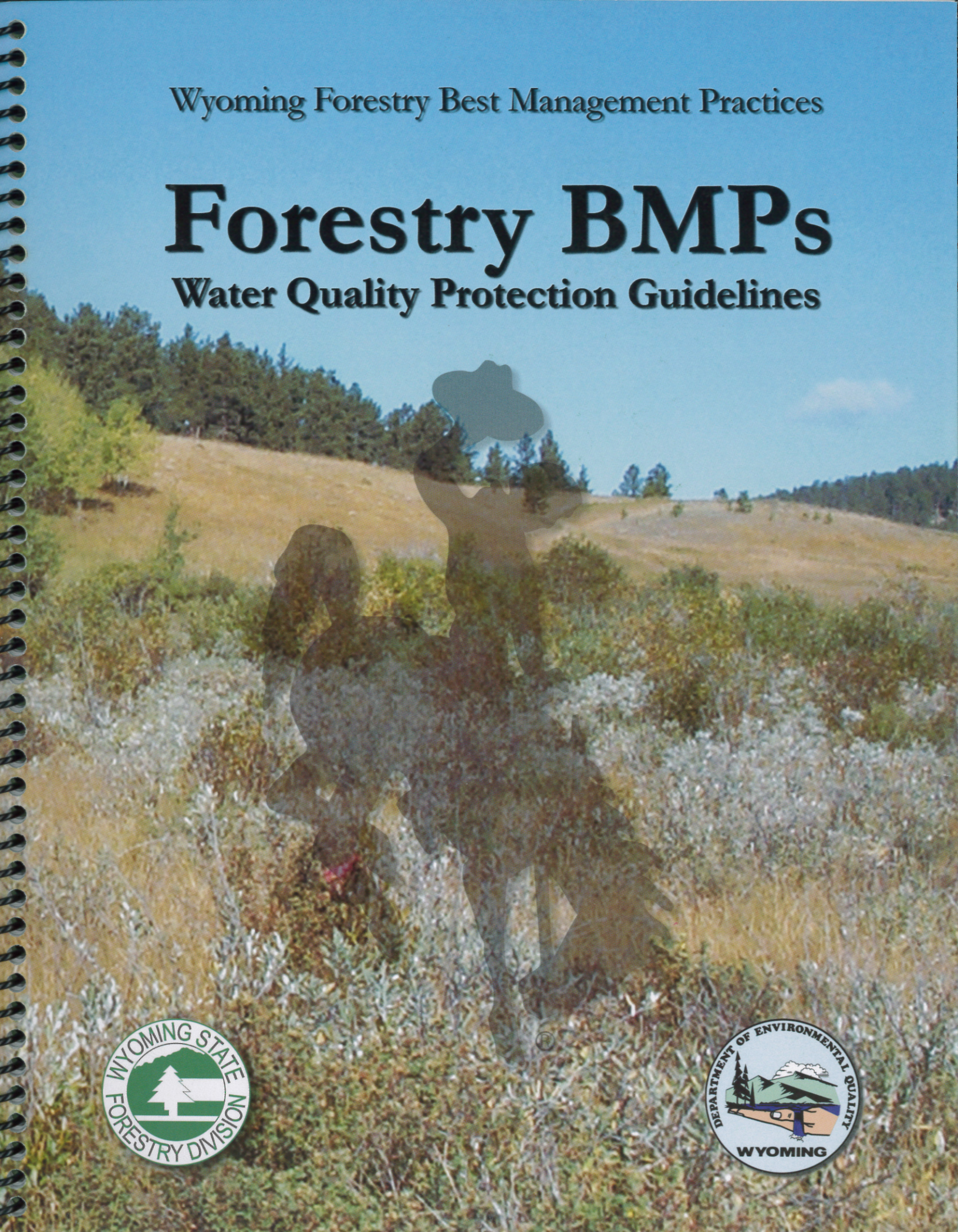
Wyoming Forestry Best Management Practices

Forestry BMPs

Water Quality Protection Guidelines



WYOMING STATE FORESTRY DIVISION

DEPARTMENT OF ENVIRONMENTAL QUALITY WYOMING

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A Watershed and its Parts

What is a Watershed?

A watershed is an area of sloping land surrounded by ridges and drained by a watercourse. Watersheds collect rainfall and snowmelt and deliver it to a single outlet. They range in size from a few acres to drainages that are thousands of square miles.

What are the Parts of a Watershed?

A watershed is a network of surface streams, underground water flows and other water bodies.

Surface streams that flow year-around are called **perennial** streams. Feeding perennial streams are **intermittent** streams, often dry except for spring and early summer flows. Some disappear underground only to reappear downstream.

Ephemeral areas deliver surface flow during spring runoff and rainstorms and feed intermittent and perennial streams. They rarely carry heavy water flows, but efforts should be made to minimize soil disturbance in these areas. Sediment from logging or road building can be carried by ephemeral, intermittent and perennial stream channels further down into the watershed.

Other parts of the watershed collection system include:

- Surface and subsurface water source areas. Their location is not always obvious, but understanding their function is important (pages 4-5).
- Riparian and wetland areas. Riparian and wetland areas are special places along streams, lakes and rivers. They include seeps, springs, vernal pools, wallows, marshes and bogs.

These areas require special protection when forest activities occur in or around them. Even during dry seasons of the year, riparian and wetland areas can be identified by the presence of certain plants (page 9).

PERENNIAL STREAM
Sediment from ephemeral areas can end up in perennial streams, causing problems for downstream users.

INTERMITTENT STREAM
Whether wet or dry, intermittent streams have gravel bottoms and identifiable banks. They connect ephemeral areas with perennial streams.

EPHEMERAL AREA
Torn-up ephemeral soils can be carried downhill during heavy rainfall or snowmelt.

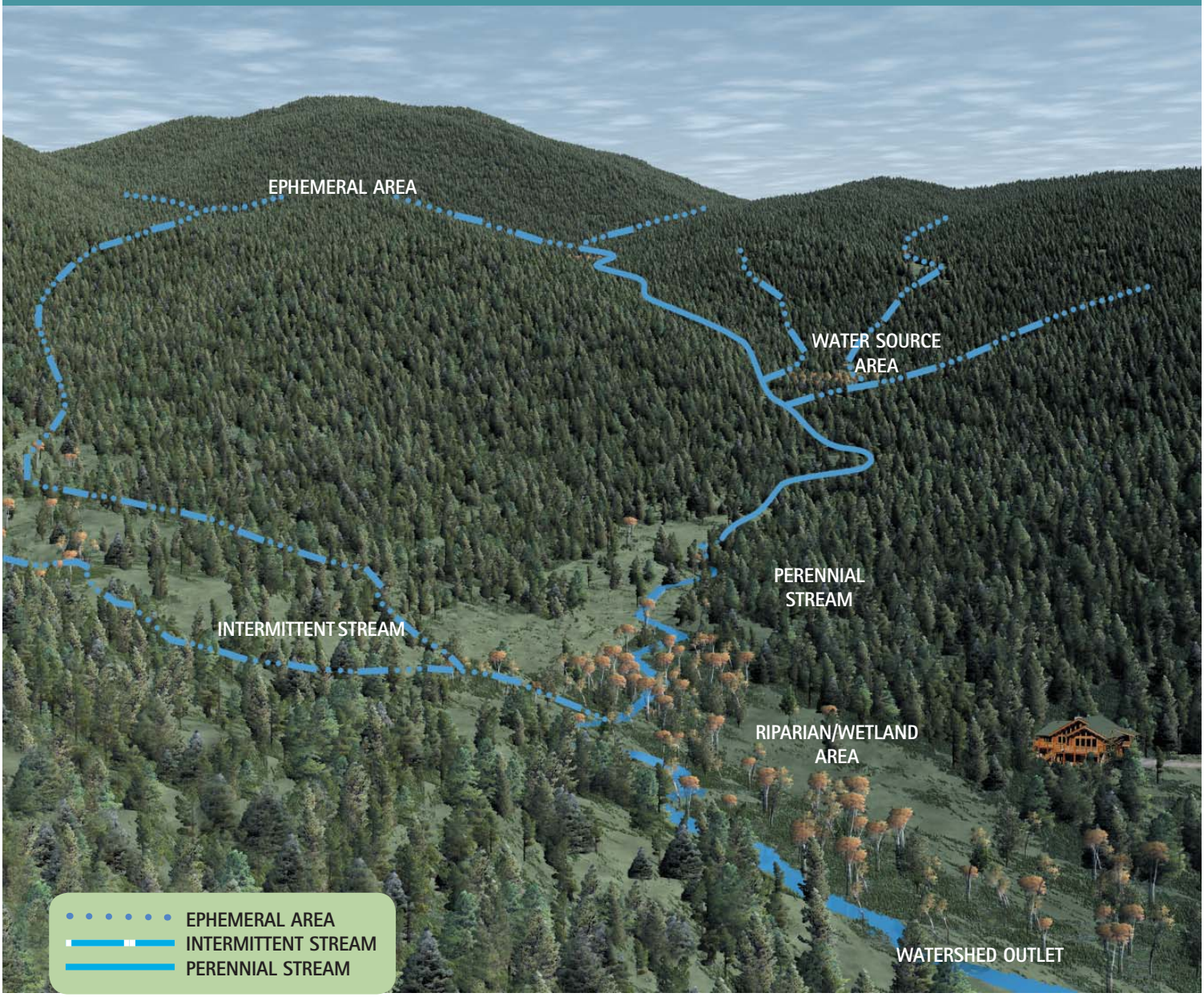
RIPARIAN/ WETLANDS
Springs, vernal pools, marshes and bogs all contribute to the watershed collection system and require protection.

Wallows are shallow pools used by elk during the mating season. Be sure to protect their surrounding trees and hiding cover.

Why are Watersheds Important?

- They collect, store and filter rain and snowmelt.
- They recharge groundwater aquifers.
- They provide water to towns and cities.
- They provide habitat for fish and wildlife.
- They connect uplands and headwaters with riparian and wetland areas.
- They provide clear, clean water to streams and lakes for everyone's recreation enjoyment, if properly managed.

A WATERSHED AND ITS PARTS



What Can Go Wrong in a Watershed?

Roadbuilding, timber harvesting and site preparation can affect the quality and quantity of water flowing through a watershed by creating sediment, changing water temperature or adding nutrients.

#18 Minimize the number of roads constructed in a watershed through comprehensive road planning, recognizing intermingled ownership and foreseeable future uses.

When improperly planned, located or constructed, logging roads, skid trails and landings can become man-made streams carrying sediment. If BMPs are not followed, sediment can make its way to the watershed outlet, creating problems downstream. Hazardous materials, like fuels and chemicals, can contaminate water and damage downstream life forms.

Damage to intermittent streambeds and banks can result in sediment being carried to perennial streams during high-water.

Ephemeral areas used as skid roads can become man-made streams, which erode and deliver sediment to the watershed.

Ignoring BMPs can result in damaged streams, unhappy downstream neighbors and fines.

How Water Gets To A Forest Stream

In non-forested watersheds it's not uncommon to see water flowing across the soil surface during storms. But surface water flow rarely happens in undisturbed forested watersheds.

Why?

There's a layer of organic litter or duff on the surface of forested watersheds, so even during intense storms, overland or surface flow is rare. While most rainfall on forested watersheds infiltrates the soil, there are small rills, rivulets and channels that can be found discharging water into headwater stream channels.

Science and observation has taught us that certain areas in a watershed contribute surface water flow to streams. They're called "water source areas," and they change in size, depending on rainstorm or snowmelt intensity. During low intensity storms, that portion of the watershed near the stream channel is the only part that contributes surface runoff. That part further away from the stream makes no surface contribution, but does contribute subsurface water. But as rainstorms and snowmelt increases, the size of water source areas expands. (See diagram on page 5.)

What This Means for Forestry Activities

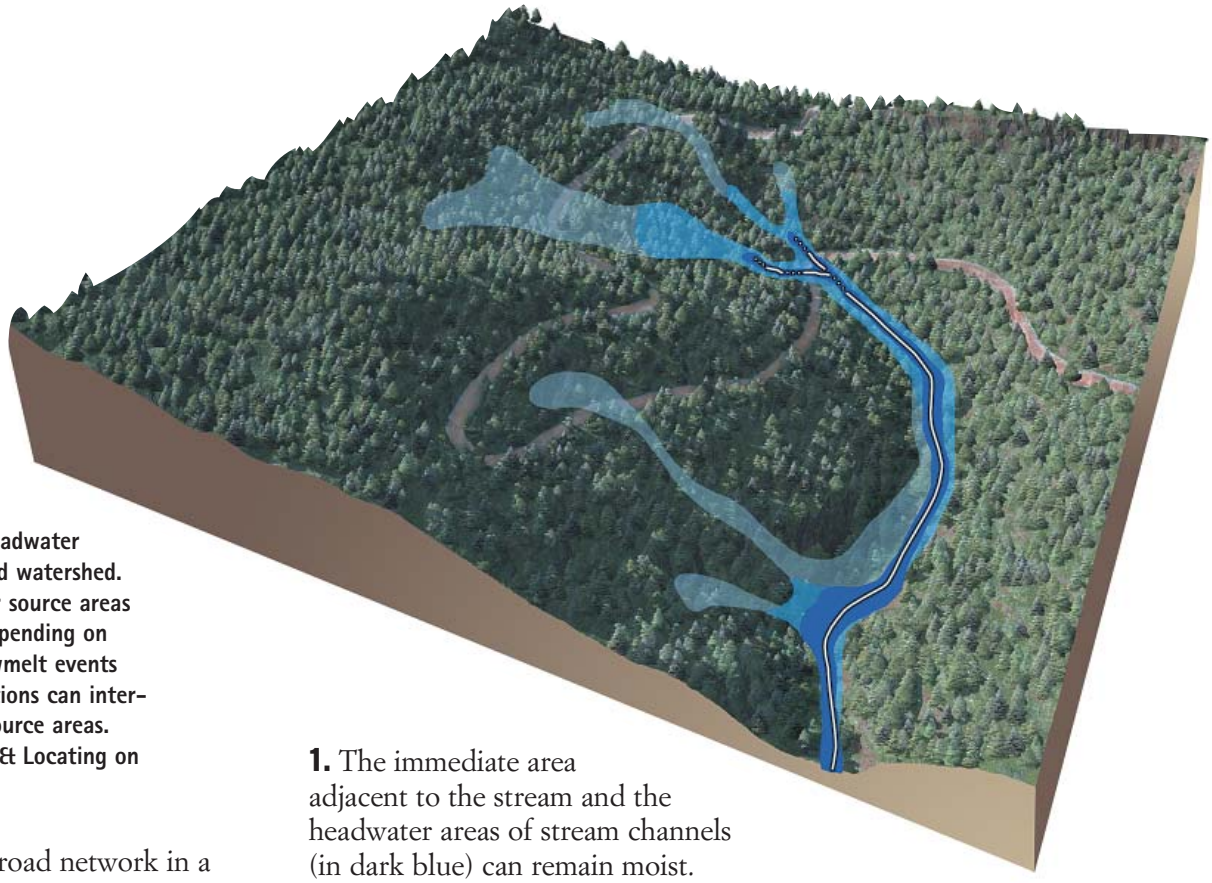
Knowing about surface and subsurface water source areas around streams and headwaters makes the following BMPs easier to understand.

#18 Avoid wet areas including moisture-laden or unstable toe slopes, seeps, wetlands, wet meadows and natural drainage channels.

#18 Design roads to minimize disruption of natural drainage patterns.

BMP Indicates State of Wyoming BMP

WATER SOURCE AREAS



This is an actual headwater stream in a forested watershed. It shows how water source areas swell and shrink depending on rainstorm and snowmelt events and how road locations can intercept these water source areas. See Road Planning & Locating on Pages 18–19

Installing a road network in a watershed may affect stream hydrology in several ways. Compacted road surfaces generate overland flow. Ditches and relief culverts concentrate runoff and change natural water flow pathways. Road location and cut slopes can interrupt water source areas. The result can be watershed streams that respond faster and have larger peak flows during snowmelt or rain events.

Recognizing water source areas on the ground is not always easy. Topographic maps and landforms can help. The identification of certain plants can be an additional clue (page 9).

1. The immediate area adjacent to the stream and the headwater areas of stream channels (in dark blue) can remain moist. These water source areas contribute surface water to the stream.

2. During heavier storms and periods of snowmelt, water source areas become larger (in medium blue). These bulb-shaped water source areas expand and contract with storm intensity and quantity of snowmelt. Their surface water flows beneath the layer of forest litter and duff and may not be obvious to the casual observer.

3. The subsurface water source areas (shown in light blue), carry water that has infiltrated into the soil. This water moves slowly to the channel and feeds the stream between storms and periods of snowmelt. Forest roads, like the one shown crossing the water source areas, can show evidence of contact with water (cut slope seepage; ditch water) at certain times of the year. Be sure that road design and drainage structures allow for adequate surface and subsurface water drainage.

Caution!

Misplaced and poorly designed roads can alter watershed hydrology or the natural flow of water. Road ditches can become man-made channels, directing water into stream channels faster than normal. The result can be flashy watershed response and potential downstream flooding. It is possible to relieve some of this problem by directing road ditches into vegetation filters (page 37), or providing more frequent ditch relief (pages 27 and 28), but the hydrology of heavily roaded watersheds can be permanently altered. It is very important to understand watershed drainage patterns and plan roads that minimize watershed impacts.

What are Riparian and Wetland (R/W) Areas?

R/Ws have seasonally moist, sometimes wet soils and high water tables where water-loving plants such as alder, willow and cottonwood grow. Certain shrubs, grasses and herbaceous plants like rushes and sedges can grow thick.

Where are they?

R/Ws occur along the shoreline of streams, lakes or ponds and around springs, marshes, bogs and seeps. Some take the shape of narrow bands hugging the edge of a stream.

Others stretch hundreds of feet beyond the water's edge, reaching out across broad floodplains.

Still others may be located in forested uplands, and are called "isolated" R/W areas (pages 12-13).

R/W areas are common along streams and rivers but are also found around "other bodies of water," see page 9.

An Early Description of R/Ws

Explorers Lewis and Clark described R/W areas and what they found in them. "The bank of the river (continues) back (from the river), is well watered and abounds in deer, elk and bear." 12th June 1804.

Before 1950, timber harvesting along streams and rivers was no different than upland harvesting. Forests were cut from ridge to stream edge.

Those early logging practices created problems, but over time many changes have been made in the way rivers are used. Today, R/W areas adjacent to streams are protected. Logging equipment stays a safe distance from the stream and some trees are left for shade to protect water temperature. These and other streamside precautions are recommended within Wyoming's Streamside Management Zone (SMZ) BMPs (page 12).

Douglas Creek, in the Medicine Bow Mountains, WY during the 1900s and today. Splashdams were built across narrow stretches of the river, and the riverbed was filled with logs. When filled to capacity, dynamite was used to blow the dam, sending water and logs crashing down the drainage to the sawmill. The effect on the watershed, the river and its adjacent R/W areas were staggering. The river bottom, banks and pools were scoured, and natural instream log structures were swept away. Yet Douglas Creek, today, is a very popular trout stream. Obviously rivers can recover from disturbance, but the leagcy of these huge disturbances are still evident as the stream recovers.

Are Riparian and Wetland Areas the Same?

Technically, no.

Wetlands also include riparian areas, floodplains, lowlands and shallow lakes and ponds. So, riparian areas are one type of wetland.

Many wetlands have the following characteristics:

1. Standing water, long enough each year to create oxygen-deficient soil.
2. These oxygen deficient soils are a permanent part of the wetland's soil profile.
3. Plants that require or tolerate oxygen-deficient soils grow during some part of the growing season.

Some riparian areas are found near running water such as rivers, streams and drainages with recognizable channels and floodplains. Other riparian areas may be the fringe of land around ponds, lakes and other water bodies. Clearly, riparian areas are the link between water environments and uplands.

What makes Riparian and Wetland Areas Unique?

Their mix of water, plant cover and food is rare compared to the rest of the watershed.

For some animals, the presence of water makes R/W areas their preferred or sole habitat. Most amphibians live on land and return to water to breed, spending much of their lives in R/W areas. Open water and a high water table combine to produce higher humidity, more shade and unique air movement.

Frequently, they support a greater number of individuals, as well as a greater number of species, when compared to other parts of the watershed.

Why are Riparian and Wetland Areas Important?

R/W plants and soils serve as a filter, trapping pollutants and keeping them from entering streams, lakes and other water bodies.

R/W organic litter and soil act like a sponge, collecting and holding water, reducing downstream floods, allowing water to gradually leak out, and replenishing streams and lakes.

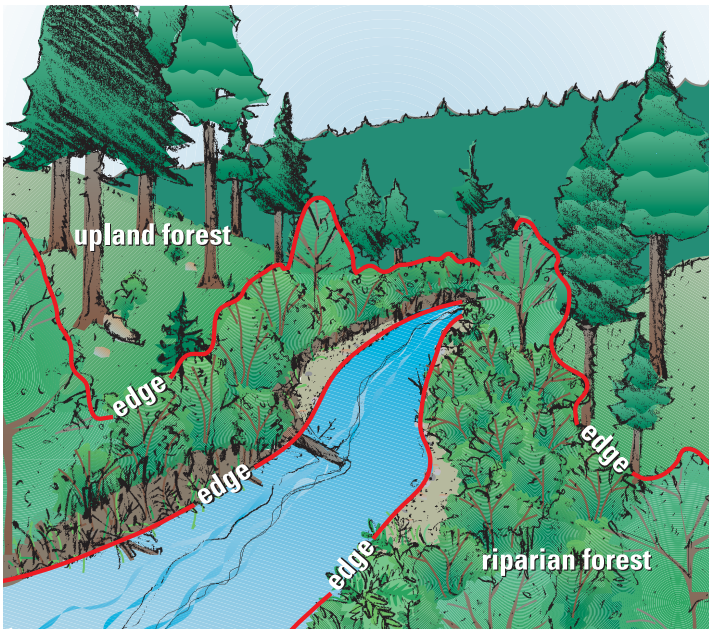
Many wildlife species rely on R/Ws for the necessities of life – food, water, protection from enemies and a place to rear young.

R/Ws are popular areas for recreation, hunting, fishing and camping.

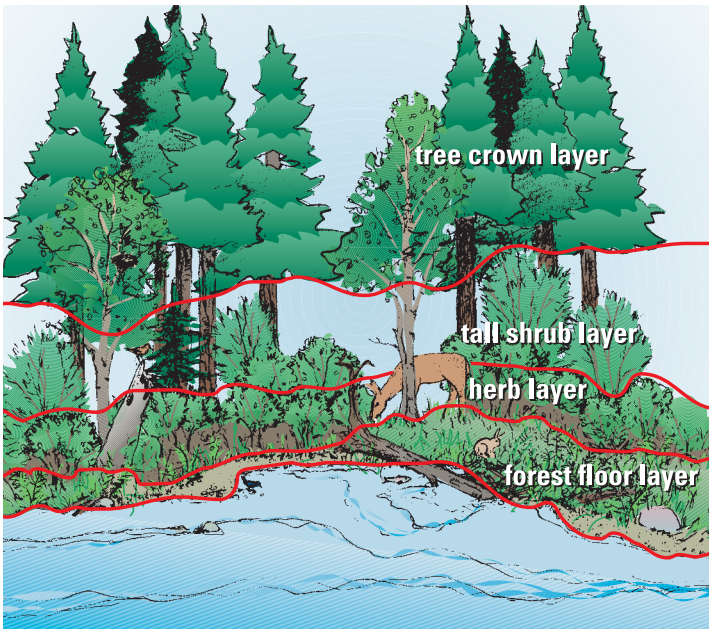
Edges and Layers in Riparian/Wetland Areas

An "edge" is where two different plant groups come together. In R/W areas there are two obvious edges. One occurs where R/W plants meet aquatic plants at the water's edge. The other is where R/W forest plants end and upland forest plants begin.

Edges give animals simultaneous access to more than one environment. They offer greater variety of plant cover and more abundant food sources. For some animals, edges can be hazardous; places where they venture to feed or rest and become prey for waiting predators.



Two edges in stream R/W areas.



The multi-layered, vertical and horizontal plant canopy offers a variety of nesting, resting, feeding and wildlife reproduction areas. The tree canopy layer shades the water, keeping it cold. This is important to cold water species like cutthroat trout.

An "Other Body of Water": A pond or pothole where poor drainage creates peat deposits, acidic water and floating aquatic plants such as pond lilies. Their water comes from precipitation and has standing water most of the year.

Other Bodies of Water (OBW). These are ponds and constructed features like irrigation ditches and reservoirs. OBWs may dry up rarely or briefly. They are distinguishable from wetlands by a clear bank and an area without plants except aquatic plants.

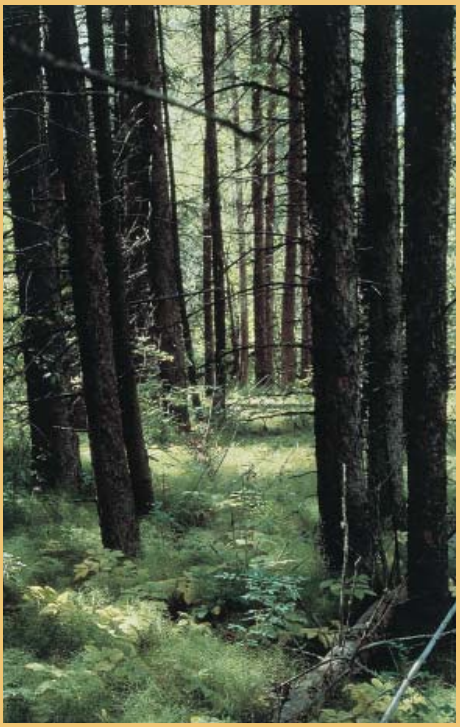
Identifying Forested Riparian and Wetland Areas

Specific plants can help locate and indicate the extent of a R/W area. Shown here are three common forested R/W areas identified by tree name and at least one understory plant. In each case, specific understory plants must be present. Remember, a R/W area does not always have standing water or wet soils, but can still be identified by its plants.

NARROWLEAF COTTONWOOD WITH COMMON CHOKECHERRY AND SNOWBERRY IN THE UNDERSTORY

ADJACENT TO THIS R/W FOREST OTHER TREE SPECIES that can be found are Douglas fir and ponderosa pine.

OTHER UNDERSTORY PLANTS that can be found in this R/W forest include Kentucky bluegrass and poison ivy.



SPRUCE WITH FIELD HORSETAIL AND/OR BLUEJOINT REEDGRASS UNDERSTORY.

IN THIS R/W FOREST, OTHER TREE SPECIES often found include subalpine fir and lodgepole pine found on drier, elevated soil mounds.

QUAKING ASPEN WITH BLUEJOINT REEDGRASS OR KENTUCKY BLUEGRASS UNDERSTORY.

BEAKED SEDGE AND AQUATIC SEDGE R/W TYPES ARE COMMON AS ARE WILLOW-DOMINATED R/W FORESTS

ADJACENT TO THESE R/W FORESTS, OTHER TREE SPECIES can include ponderosa pine, lodgepole pine, Douglas fir, cottonwood and quaking aspen.

OTHER UNDERSTORY PLANTS include bluejoint reedgrass and Kentucky bluegrass.

Bluejoint reedgrass, commonly grows three feet tall and has flat dull bluish-green leaves that are rough to touch. Its purplish-red seed head droops with age. Seed heads aren't always present when the plant grows in shade.

There are many willow and sedge R/W types in Wyoming. They are interspersed between conifer forests on the adjacent uplands and are excellent indicators of water source areas, where water is very close to the surface and equipment operation and rodbuilding should be avoided.

How Sediment Accumulates in a Watershed

What is Sediment?

Sediment is solid material, both mineral and organic, that is carried from its point of origin by water. Most people think sediment only comes from gullies, but important sources can include rain splash, rills and erosion from road surfaces, road cut and fill slopes and the banks of the stream itself.

How does Sediment Affect Water Quality?

Sedimentation is the process of depositing sediment. Sediment originates from mudslides, flooding and weathering erosion. Sediment deposits enrich soils for crops and create spawning beds for fish. However, water quality and stream health problems occur when sedimentation is excessive. Without carefully applying BMPs, forestry activities combined with natural erosion can cause excessive sedimentation.

What are Cumulative Effects?

Each of the soil erosion problems shown here creates sediment that can move into the network of streams in a watershed. All of them, natural and man-made, added together can have a serious damaging cumulative effect on a watershed.

Landowners and Loggers can Minimize Cumulative Effects

The job of ensuring clean water and stable soils in a watershed falls to landowners and loggers who construct roads, build stream crossings, harvest timber and prepare those locations for new forests. Every effort to reduce sediment will lower the cumulative impacts of sediment on water quality.

Naturally Caused Sediment

The force of rain splashing on bare soil can loosen and detach soil particles that can become sediment.

Landslides move tons of sediment and debris into rivers and streams.

Man-made Sources of Sediment

Water runoff formed these long narrow chutes or rills, running downslope on the surface of this road cut slope. It is a source of sediment.

This improperly placed culvert with no ditch plug has resulted in sediment.

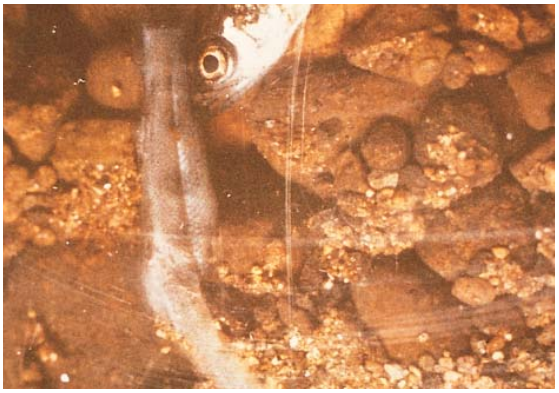
This plugged crossdrain culvert and washed-out catch basin can be a source of sediment.

The Result of Excess Sediment in Streams

Excess Sediment in streams can result in:

- Death of fish eggs and fry.
- Filling-in of spawning beds.
- Reduced aquatic insects and less fish food.
- Reduced growth of underwater plants.
- Increased costs for water filtration.

Dead fry that couldn't wriggle their way free from a sediment encased stream bottom.



Sac fry growing in oxygen-enriched water, hiding from predators among rocks and boulders on the bottom of a stream.

Trout Life Cycle

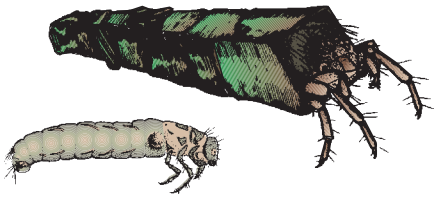
Trout and other fish reproduce by burying their eggs in clear stream-bottom gravels, where cold, aerated water circulates around them. When too much sediment settles to the bottom, it fills the gaps between gravel rocks, suffocating the developing sac fry.

The Effect of Sediment on Fish Food

A large number and variety of invertebrates live in streams, ready and waiting for the smorgasbord of falling organic debris. Among this army are shredders, collectors, grazers and scrapers.

Sediment affects aquatic insects and plants which are eaten by fish, which are then eaten by birds.

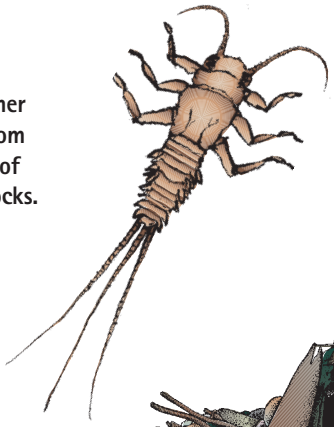
Sediment interferes with aquatic insects and the growth of underwater plants that these insects depend on for food. Whether shredders, scrapers, grazers or collectors, aquatic insects depend on clean, well oxygenated and sediment-free water to survive. Many of them feed on plant food floating downstream. Sediment also interferes with their breathing gills and their ability to gather food particles from the water as it passes through their filter feeding mechanisms. Aquatic insects are a food source for other aquatic animals and fish, so anything that affects the insects also disrupts the rest of the food chain. Damage to fish and other aquatic life can be minimized by protecting soil from erosion.



Shredders attach their cases to the upper surfaces of rocks. They tear away the soft parts of leaves and needles until only a skeleton of veins is left.

Grazers feed on the slippery layer of diatoms and algae found on rocks, protected from predators by their domed cases.

Scrapers gather their food from the surfaces of leaves and rocks.



Collector/Gatherers build a shelter from bits of sand, gravel and twigs, held together with silk. Hiding deep in the net, the insect comes out only to feed on food particles strained from the water.

Streamside Management Zone Definitions

In Wyoming, some of the most important BMPs are those that deal with Streamside Management Zones, or SMZs.

The Streamside Management Zone or SMZ means the stream, lake or other body of water and an adjacent area of varying width where management practices that might affect wildlife habitat or water quality, fish or other aquatic resources need to be modified. The SMZ encompasses a strip at least 50 feet wide on each side of a stream, lake or other body of water, measured from the ordinary highwater mark, and extending beyond the high water mark to include wetlands and areas that provide additional protection in zones with steep slopes or erosive soils.

"Stream" means a natural channel with defined bed and banks, that confines and conducts continuously or intermittently flowing water.

"Wetlands" mean those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include marshes, swamps, bogs and similar areas (pages 6-9).

"Adjacent wetlands" are wetlands within or adjoining the SMZ boundary.

"Isolated wetlands" are wetlands that lie within the area of operation (timber harvest), outside of the SMZ boundary.

What is a stream?

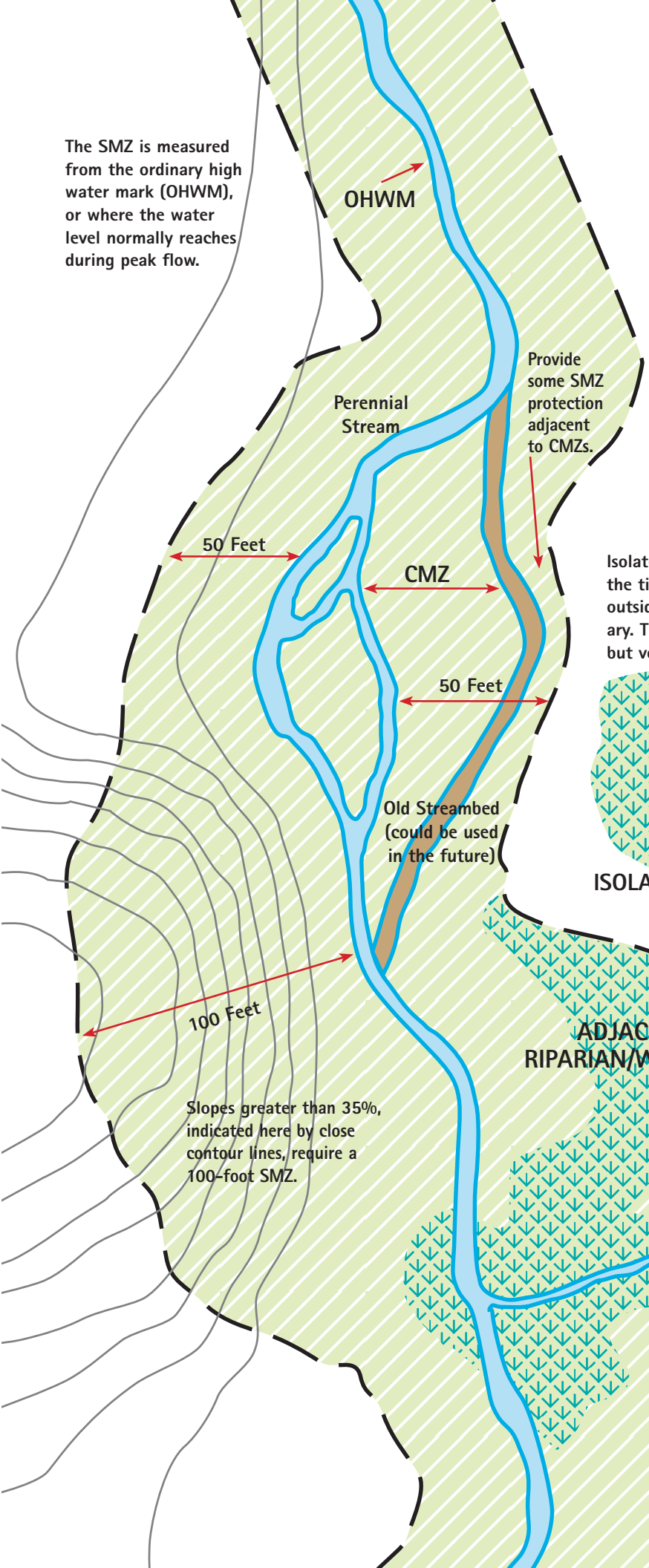
A stream can be identified in one of two ways. A stream must have a sandy or gravel bottom—the result of flowing water. Or a stream must have definite banks that restrict water. When no definite bank is apparent, watch for evidence of where sand or gravel stops and soil begins at the edge of a stream.

Is this a stream?

No. There's no rocky bottom or identifiable banks. But it is an ephemeral area, part of the watershed collection system, that may carry water during wet periods. Disturbing these soils can create sediment. Whenever possible, avoid these areas when logging.

Clearly mark the SMZ boundary for equipment operators. Use plastic flagging, paint or signs at frequent intervals.

Steep slopes like this require a 100-foot SMZ.



What About Streams that Migrate from Side to Side?

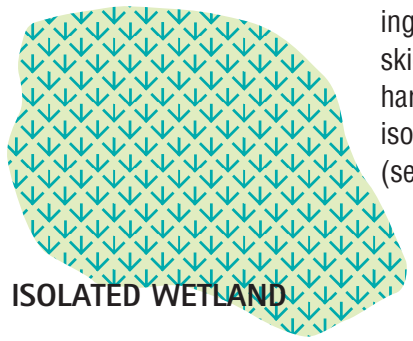
Channel Migration Zones (CMZs) are areas along a stream where terraces or floodplains are likely to be occupied by the stream channel at some time in the future.

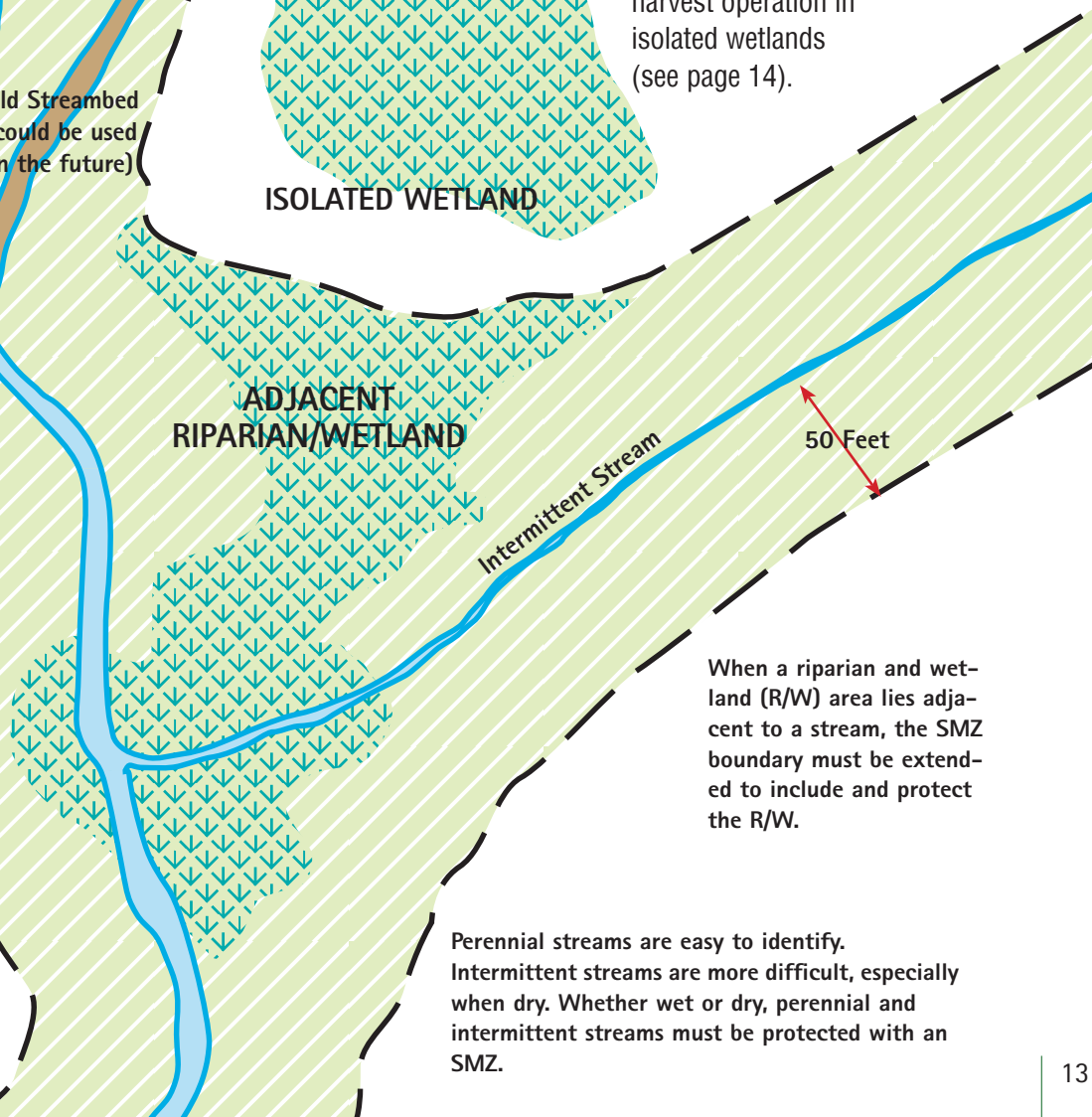
The Problem

Simply applying the 50-foot SMZ in CMZs could fail to account for future channel movement and would not provide stream shading or the need for fallen large woody debris (LWD).

#10 Avoid operation of wheeled or tracked equipment within isolated wetlands, except when the ground is frozen.

#7 Use directional felling or alternative skidding systems for harvest operation in isolated wetlands (see page 14).





When a riparian and wetland (R/W) area lies adjacent to a stream, the SMZ boundary must be extended to include and protect the R/W.

Perennial streams are easy to identify. Intermittent streams are more difficult, especially when dry. Whether wet or dry, perennial and intermittent streams must be protected with an SMZ.

When Harvesting In and Around the SMZ

The SMZ is not a "keep out" zone, but due to its values, timber harvesting in and around the SMZ requires special care.

**** Wheeled or tracked equipment should be kept out of the SMZ and logging operations modified to protect the vegetation and ground cover in the SMZ.

#3 Wyoming BMPs specify a minimum 50' SMZ, which is extended to a 100' minimum when slope perpendicular to the stream is greater than 35%.

**** Some larger trees should be retained in the SMZ, to provide shade that helps to moderate stream temperature and to provide a source of large woody debris, to enhance stream channel diversity.

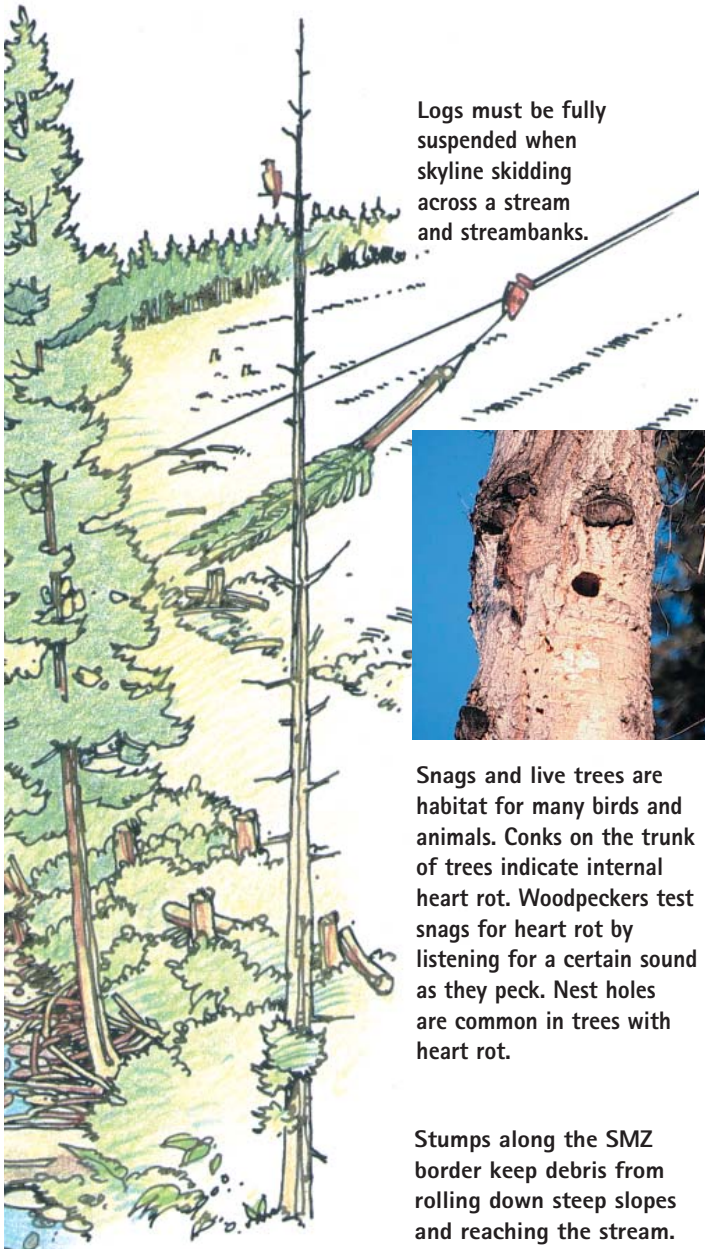
The trees left after harvest are important to a healthy SMZ. The probability of a tree falling into a stream depends on its height and distance from the stream. Research indicates that approximately 1/3 of the trees within one tree height of the stream will fall into the stream and that 80% of Large Woody Debris originates within 2/3 tree heights of the stream channel.

Wyoming BMPs encourage broadening the SMZ to allow for the retention of taller trees, which provide for more shade and large woody debris recruitment.

Streambank trees and shrubs are important. They anchor the bank, shade the stream, provide food, and supply cover for fish and habitat for birds and other wildlife.

Ground vegetation is the filter that keeps sediment from reaching the stream. If torn up during harvesting, it cannot do its job. Skidder and tractor operators must stay out of SMZs.

Directional falling and/or mechanical feller-bunchers allow removal of some SMZ trees without damaging the SMZ.



Logs must be fully suspended when skyline skidding across a stream and streambanks.

Snags and live trees are habitat for many birds and animals. Conks on the trunk of trees indicate internal heart rot. Woodpeckers test snags for heart rot by listening for a certain sound as they peck. Nest holes are common in trees with heart rot.

Stumps along the SMZ border keep debris from rolling down steep slopes and reaching the stream.

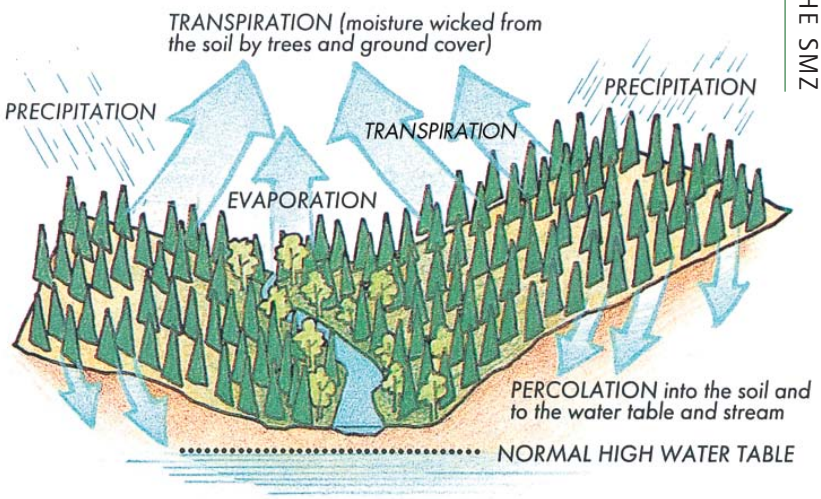
Keep slash out of streams and other water bodies. Rotting slash uses up oxygen, needed by fish and other aquatic animals. Move harvested tree limbs and tops to locations well above the stream high-water mark.

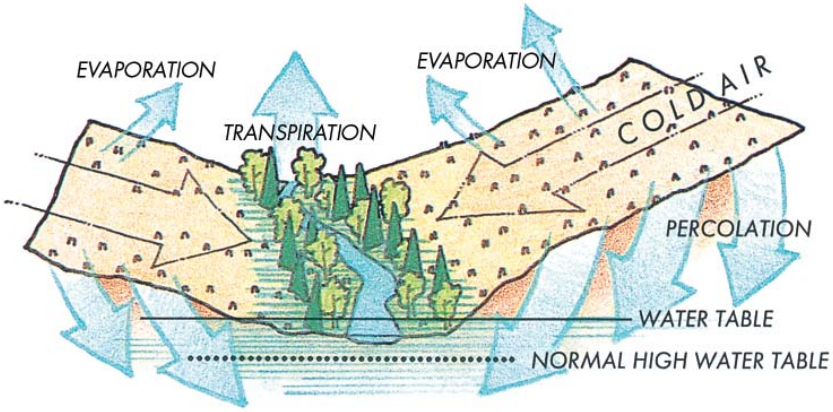
Trees leaning toward the stream are important. Large diameter, fallen tree stems with attached rootwads are most likely to remain permanent in a stream channel. These woody "anchors" promote the development of persistent pools, control sediment and create fish habitat.

Conifer Regeneration Tips In and Around SMZ's

Be aware that in some types of soil and drainages, clearcuts adjacent to SMZs can cause marked increases in the water table, cold-air ponding and grass/shrub competition. All of these conditions can inhibit conifer regeneration.

Trees act as a buffer. Except for times of extreme precipitation and runoff, trees help maintain the normal water table along streams. They act like wicks, pumping water from the soil and releasing it into the air through leaves and needles (transpiration). Some soil moisture, of course, seeps underground, slowly draining into the stream channel.





After adjacent hillside trees are harvested and many of the "wicks" have been removed, transpiration is reduced, and more underground water is available, at least until vegetation recovers. Removing trees can lead to cold-air ponding, a condition that extends winter's cold temperatures into early spring and interferes with natural conifer regeneration. Removing adjacent hillside trees can also raise the streamside water table, making soils too wet for conifer regeneration. Wetter soils often result in grass and shrub invasion, making conifer regeneration more difficult. Conifer regeneration with preferred species can be a challenge. Artificially hand-planting tree seedlings can increase success rates.

Forest Road Service Levels

Roads are essential for forest management. But of all the forest development, harvest and management practices, roads are the number one source of sediment. Roads produce 90 percent of all sediment from forest activities.

When properly constructed and maintained on gentle and moderate slopes with stable topography, roads have a low potential for contributing sediment.

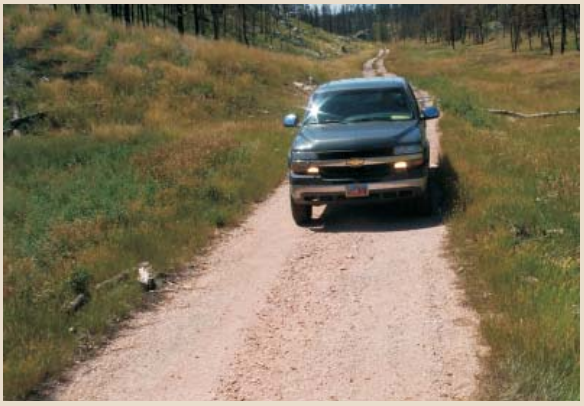
However, if not well-planned, constructed and maintained, roads located next to streams, on steep slopes or on unstable topography have a high potential to produce sediment for a long time. Roads on steep slopes cost more to build and generally have greater environmental impact.

Road Design

Forest roads are built to different standards depending on the service they are designed to provide. General categories range from high to medium to low service level. Standards include traffic load, surfacing, width, steepness, sight distances and vehicle speed. Most forest landowners want roads as narrow as possible to reduce construction and maintenance costs. A 12-foot minimum travelway is needed for log truck traffic. Roads used as log landings will need wider sections to allow for traffic to pass. High service level forest roads are those that can accommodate two-lane traffic, usually have a gravel driving surface and can accommodate longer distance visibility. While beneficial, high service level roads require more space and disturb more soil during construction. Medium and low service level roads are more common.

#18 Design roads to the minimum standard necessary to accommodate anticipated use and equipment.

High service level roads accommodate two-lane traffic, public use and usually have a gravel driving surface. They are capable of year-round use and large truck traffic.



Single lane, medium service level roads like this, with occasional pull-outs for oncoming traffic, are common in the forest. To reduce the impact of roads always build the narrowest road that will serve the need. A 12-foot-wide running surface is usually needed for log truck traffic.

Temporary low service level roads are designed for short-term minimal use during timber harvesting. Low service level roads involve clearing vegetation and minimal construction. They can be built, used and reclaimed when rainfall and erosion potential is minimal.

Restoration of temporary roads includes pulling up roadside berms, ripping compacted surfaces, restoring natural drainage and reseeding with appropriate grasses (see pages 34–35 for more on road restoration).

Road Use Management

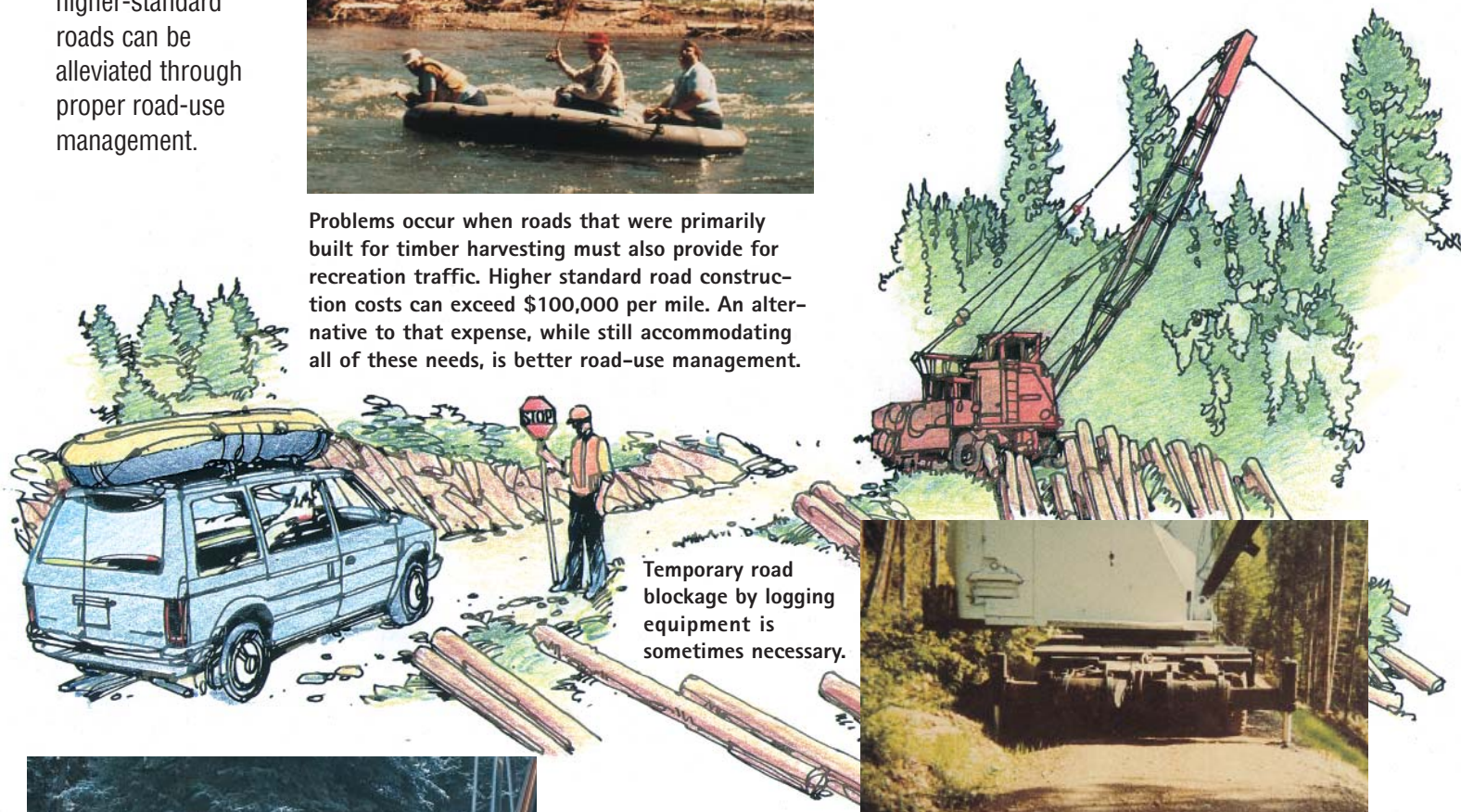
#19 Design roads and drainage facilities to prevent potential water-quality problems from road construction.

This road is too close to the stream. There's not an adequate filtration zone to trap road sediment and keep it from entering the stream.

#19 The need for higher-standard roads can be alleviated through proper road-use management.

Forest management roads provide access to favorite recreation areas.

Problems occur when roads that were primarily built for timber harvesting must also provide for recreation traffic. Higher standard road construction costs can exceed $100,000 per mile. An alternative to that expense, while still accommodating all of these needs, is better road-use management.



Temporary road blockage by logging equipment is sometimes necessary.

Access through locked gates is one method of road-use management. Seasonal weather conditions may also require restricted access.

When access requires crossing moist areas with a poor road base, cross only when the ground is frozen or dry, otherwise a rutted, poorly drained road results.

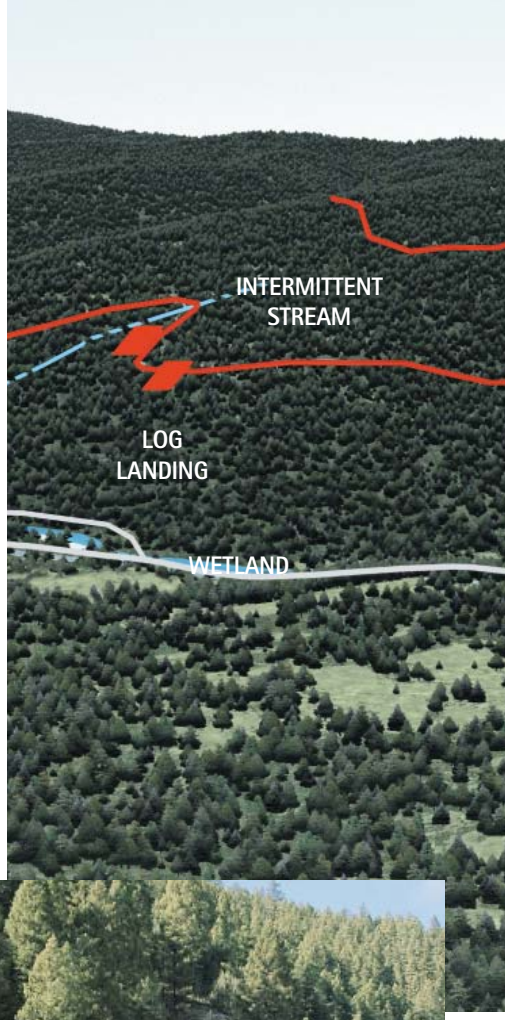
Planning and Locating

#18 Minimize the number of roads constructed in a watershed through comprehensive road planning, recognizing intermingled ownership and foreseeable future uses. Use existing roads where practical, unless use of such roads would cause or aggravate an erosion problem.

#18 Review available information and consult with professionals as necessary to help identify erodible soils and unstable areas and to locate appropriate road-surface materials. Topographic maps are available from the U.S. Geological Survey. The USDA Natural Resources Conservation Service (NRCS) can provide soil information.

#18 Locate roads on stable geology, including well-drained soils and rock formations that tend to dip into the slope. Avoid slumps and slide-prone areas characterized by steep slopes, highly weathered bedrock, clay beds, concave slopes, hummocky topography, and rock layers that dip parallel to the slope. Avoid wet areas including moisture-laden or unstable toe slopes, seeps, wetlands, wet meadows and natural drainage channels.

Hillsides like this are evidence of excessive roading. Cooperation and planning among adjacent landowners within a watershed can reduce roads and road sediment.



#18 Fit the road to the topography by locating roads on natural benches and following natural contours.

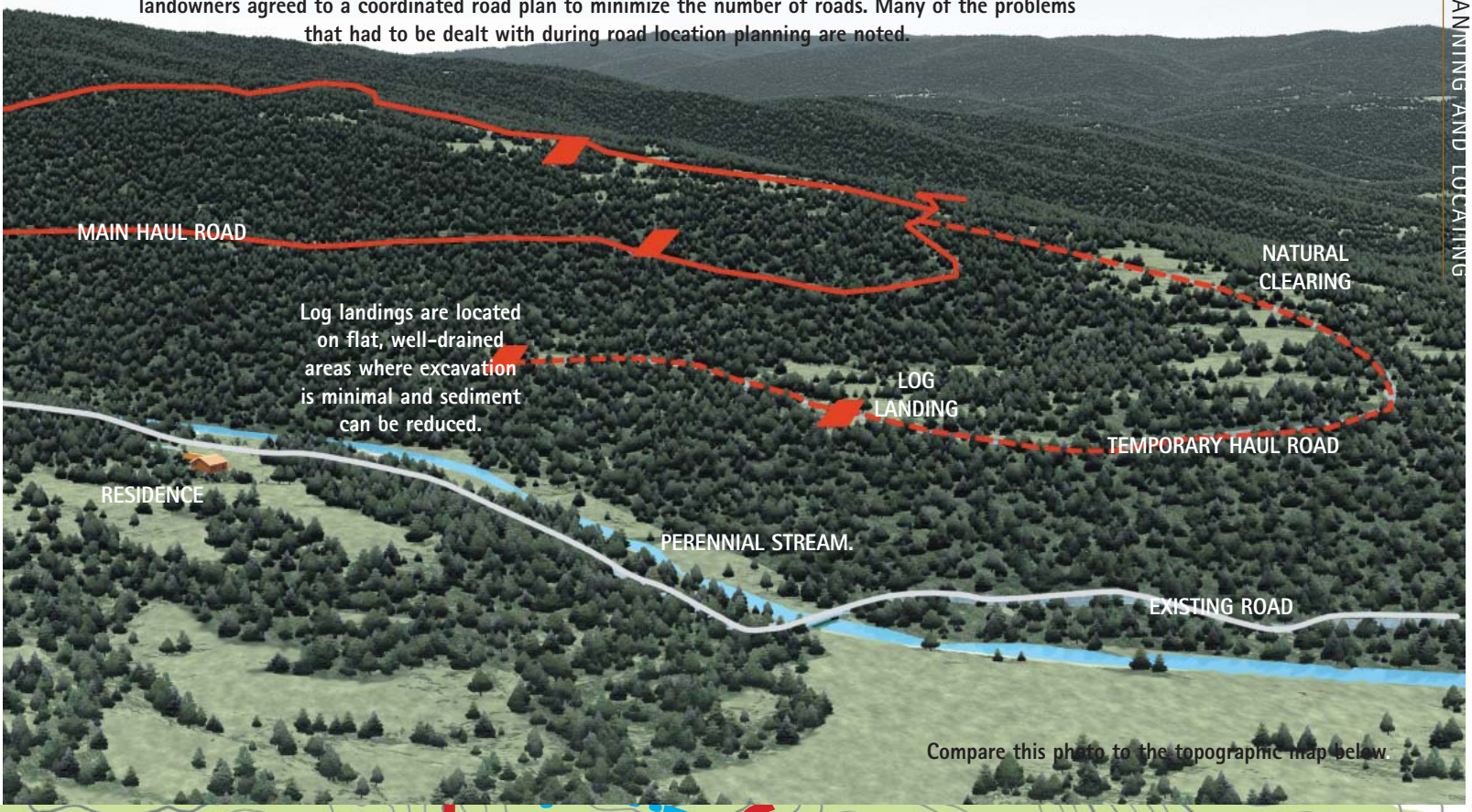
Avoid long, steep road grades and narrow canyons, like this one.

Rock layers that slant with, rather than into, the slope are a clue to potentially unstable bedrock conditions.

Roads dictate the location of log landings where logs are sorted and loaded on trucks. When roads use natural benches and flat areas, log landing excavation and sediment is reduced.

#11 Locate roads to provide access to suitable (relatively flat and well-drained) log landing areas to reduce soil disturbance.

The road system planned for this mixed ownership forest is detailed on the topographic map below. All landowners agreed to a coordinated road plan to minimize the number of roads. Many of the problems that had to be dealt with during road location planning are noted.



Compare this photo to the topographic map below.

Road Construction

The Basics of a Constructed Road

Once a route is identified, the road is marked on the ground with survey stakes or plastic flagging.

1. Road construction begins with cutting merchantable trees within the road right-of-way. This timber faller is cutting logs into appropriate lengths for later sale.

2. This is the finished road shown in photo 1. Described next are the steps of construction.

3. An excavator clears the right-of-way. Its clamshell bucket digs soil and picks up objects. The excavator cab and hydraulic arm can rotate 360 degrees while the machine sits in place. This motion allows the operator to move and stack logs on both edges of the road. After the road is constructed these logs are hauled to a sawmill.

4. Stumps and root wads are shaken to remove soil and placed in a disposal area outside the roadway. Small trees, brush and other woody debris are lifted and piled on the downslope edge of the new road to provide erosion control. Never bury this material in the road.

5. The excavator's primary job is to clear vegetation and obstacles. It moves only enough earth to build its own running surface. A rough road shape is now visible. The remaining construction can be completed with a bulldozer. However, excavators can be used to dig cuts and fills and may do substantial earthwork on steep slopes.

6. Here's the finished road in photo 5. It has a 14-foot driving surface. Vegetation was cleared to 30-40 feet depending on the slope. Steeper slopes require more clearing width than level slopes.

7. There is a lot of work between photos 5 and 6. A bulldozer follows the excavator. This D7 has a 12-foot, U-shaped blade that prevents excavated material from spilling off the blade edges. Bulldozers begin by digging into the cutslope side of the road and drift the material to the outside edge as they build the fillslope of the road.

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8. Here the operator is moving soil to be used as fill to build up this low spot and support the planned road curve.

9. With each pass of the dozer, the grade is lowered and fill is built up.

10. When the curve and its 35-foot turnout are finished the dozer moves on to the next road segment.

11. Cross drain culverts are installed before the final smoothing of the road surface.

12. The final step is to smooth, shape and ditch the road with a motor grader, allowing water to drain off and away from the road.

13. High service level forest road construction involves additional steps. A compactor may follow the bulldozer to compact and stabilize the new roadbed. Compacting increases the density of the road surface for improved support for heavy vehicles and to resist erosion.

14. High service level roads are often surfaced with non-native material. Surfacing material, excavated from a gravel pit, is trucked to the new road. Separate layers of material may be used on the road surface to improve drainage and provide a more stable road surface. Each layer is compacted. Water trucks may be used to wet the material and improve compaction. Chemicals can be added to road gravel to control dust and harden the surface.

15. After construction all roadsides are seeded with the appropriate grass seed mixture. Grass on exposed soil reduces erosion and limits weeds.

16. Both cutslopes and fillslopes can and should be revegetated.

Rules of Thumb for Road Grades

- Try to keep road grades less than 8 percent.
- Try to avoid road grades greater than 12 percent for distances over 300 feet.
- When necessary, short steep pitches under 300 feet long are acceptable.

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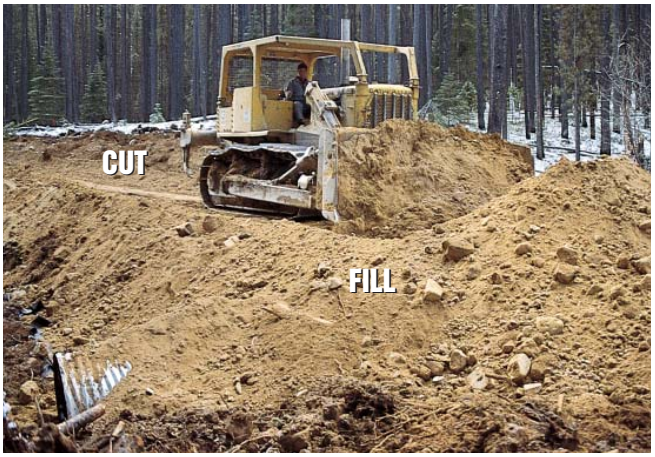
#25 Keep slope stabilization, erosion and sediment-control work current with road construction. Install drainage features as part of the construction process, ensuring that drainage features are fully functional.

More on Cuts and Fills

Most forest roads are built by excavating a road surface. The design of a road and its layout on-the-ground indicates to machine operators the proper cut slopes and cut slope steepness. A bulldozer or excavator, starts at the top of the cut slope, excavating and sidecasting material until the desired road grade and width are obtained. Soil taken from cuts is often pushed or "drifted" in front of the blade to areas where fill is needed. Road fill is used to cover culverts and build up flat areas. Since fill must support the weight of traffic, it needs to be spread and compacted in layers in order to develop strength.

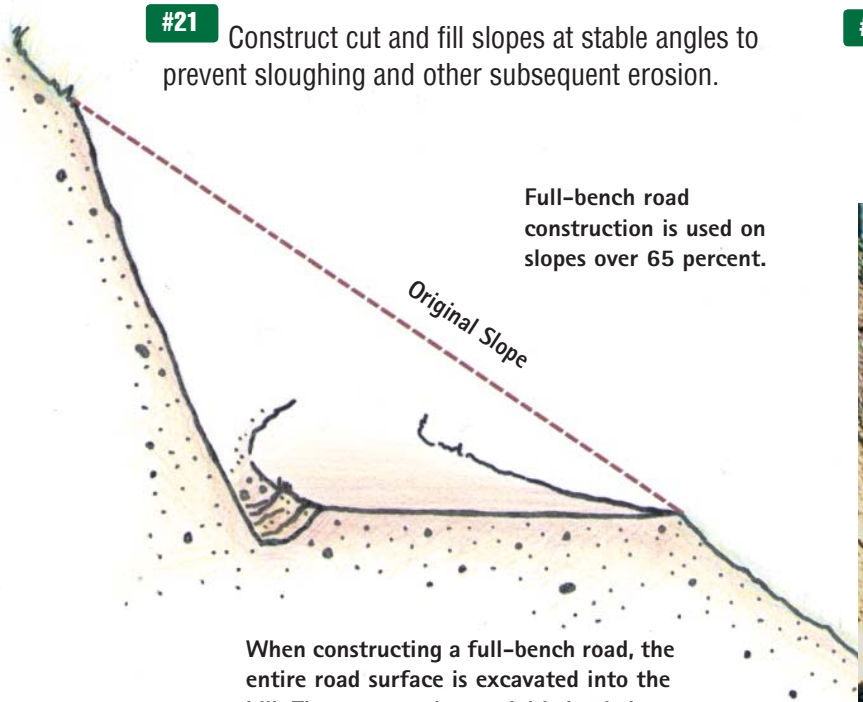
During the process of cut-and-fill, never let sidecast or waste material enter streams and never place it on unstable areas where it might erode.



Cut-and-fill road construction is common for gentle terrain.

#21 Construct cut and fill slopes at stable angles to prevent sloughing and other subsequent erosion.

#21 Design roads to balance cuts and fills or use full bench construction (no fill slope) where stable fill construction is not possible.



Full-bench road construction is used on slopes over 65 percent.

When constructing a full-bench road, the entire road surface is excavated into the hill. The excavated material is hauled to an area needing fill or to a disposal area.

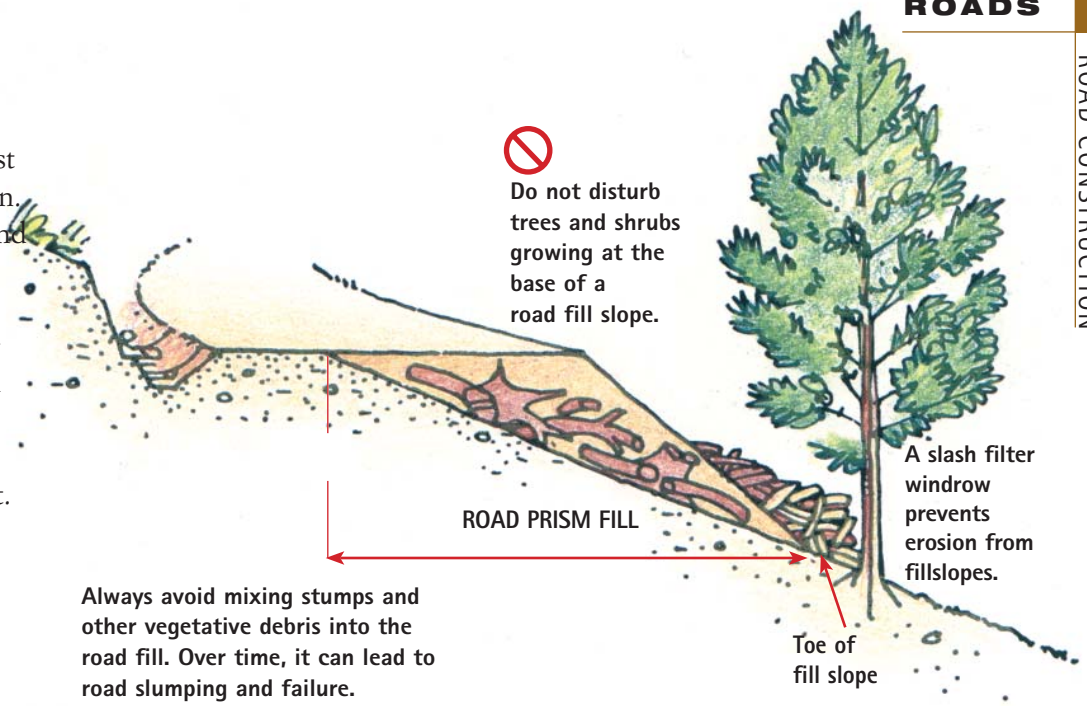
#26 Place debris, overburden and other waste materials associated with construction and maintenance activities in a location to avoid entry into streams. Include these waste areas in soil stabilization planning for the road.

Root wads, slash and vegetative debris during road construction are disposed of in burn bays. To prevent contamination, locate burn bays away from water sources.

You Need to Know

Most road erosion occurs in the first two or three years after construction. When cut and fill slopes stabilize and revegetate, erosion rates decrease. After this initial period, and with proper maintenance, erosion in later years comes primarily from the road travelway. Without a rock surface, water erosion on a bare soil travelway continues to generate sediment. Control techniques for travelway erosion are described on pages 29-30.

#22 Complete or stabilize road sections within the same operating season.



Always avoid mixing stumps and other vegetative debris into the road fill. Over time, it can lead to road slumping and failure.

#32 Avoid incorporating potentially unstable woody debris in the fill portion of the road prism. Where possible, leave existing rooted trees or shrubs at the toe of the fill slope to stabilize the fill.

#20 Minimize earth-moving activities when soils appear excessively wet. Do not disturb roadside vegetation more than necessary to maintain slope stability and to serve traffic needs.

Slash Filter Windrows

#26 At the toe of potentially erodible fill slopes, particularly near stream channels, pile slash in a row parallel to the road to trap sediment. When done concurrently with road construction, this is one method that can effectively control sediment movement, and it can also provide an economical way of disposing of roadway slash. Limit the height, width and length of "slash filter windrows" so wildlife movement is not impeded. Sediment fabric fences or other methods may be used if effective.

Spreading slash along the right-of-way is one way to cover bare soil and reduce erosion.

Slash-filter windrows are compacted logging slash, installed along the base of fill slopes during road construction. Built by excavators, these 3x3 foot barriers are very effective at slowing surface runoff and keeping sediment from entering streams.

Sediment fabric fences are another technique for reducing sediment movement. They slow surface water and trap sediment.

Geotextiles and Their Uses

Geotextiles are synthetic permeable fabrics used to reduce rutting, stabilize the ground and increase the load-carrying capacity of unpaved roads.

They are used to separate rock surfacing materials from subgrade soils while allowing for water passage.

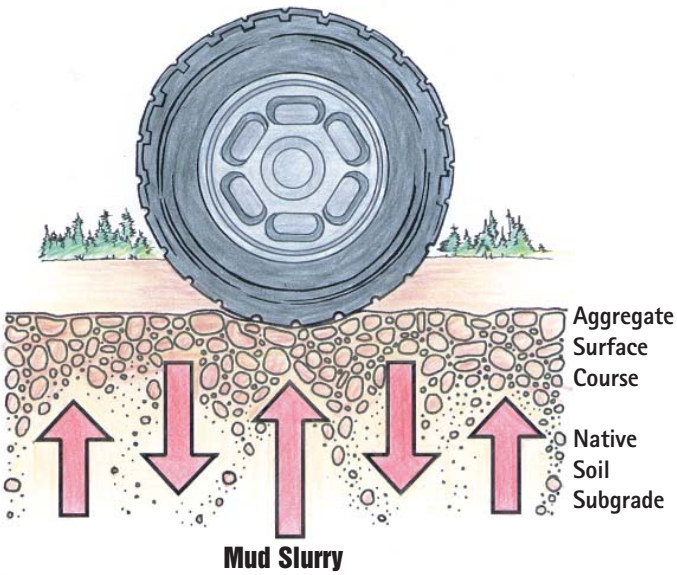
Geotextiles can reduce the amount of rock surfacing needed and reduce road costs.

#19 Consider road surfacing to minimize erosion.

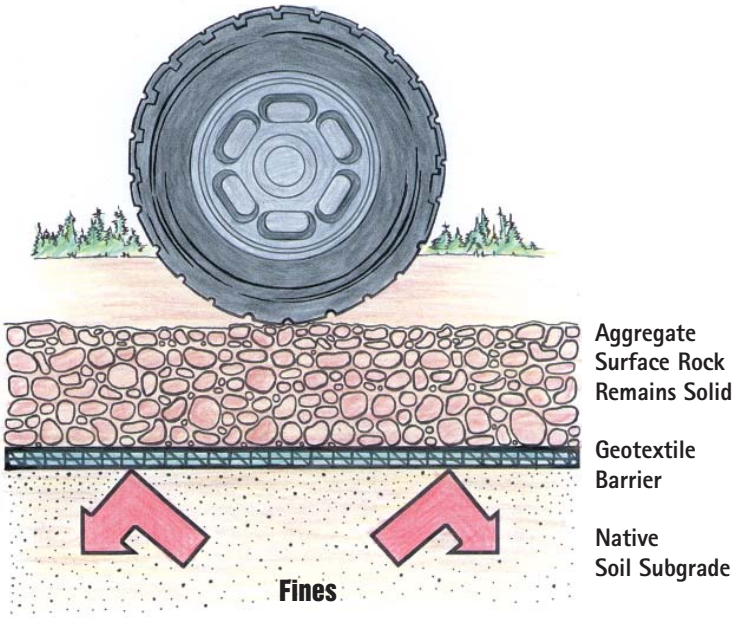
Geotextiles are used to reinforce subgrades by spreading the load over a larger area. This reduces the chance of settling and failure. It also allows road construction over wet areas, reducing the need to remove unsuitable roadbed material.

Road surfacing can double the cost of a road. However, gravel roads can provide all-weather access, reduce road maintenance costs and ensure water-quality protection, because the soil is covered with a weather-resistant surface. Rock is applied in two layers. The base layer can be 6-18 inches of larger rock, capable of supporting heavy loads. The running surface is a 2- to 4-inch layer of smaller rock. Use of geotextile can significantly reduce these thicknesses.

Geotextiles can keep weak subgrade soils from moving into the road base rocklayer, reducing its weight-carrying effectiveness.



Roadway without Geotextile
Mud slurry mixes with surface aggregate.



Roadway with Geotextile
Fines are stopped by Geotextile

Road Improvements

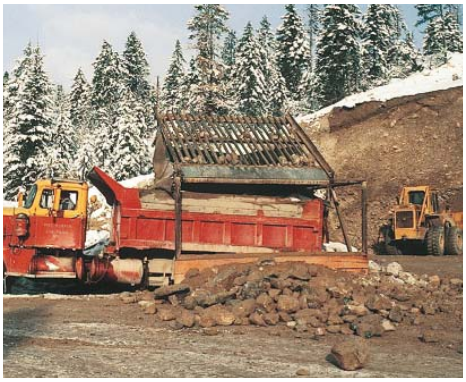
Over time, it's often necessary to add culverts for improved drainage. Anticipate the need to add more culverts and avoid drainage problems.

Deep, wide road fills like this can be stabilized with log terraces. After installation, the entire road fill is seeded with grass cover.

Road improvements, such as cutting back an inside slope and removing vegetation crowding the roadway, can improve vehicle safety and visibility.

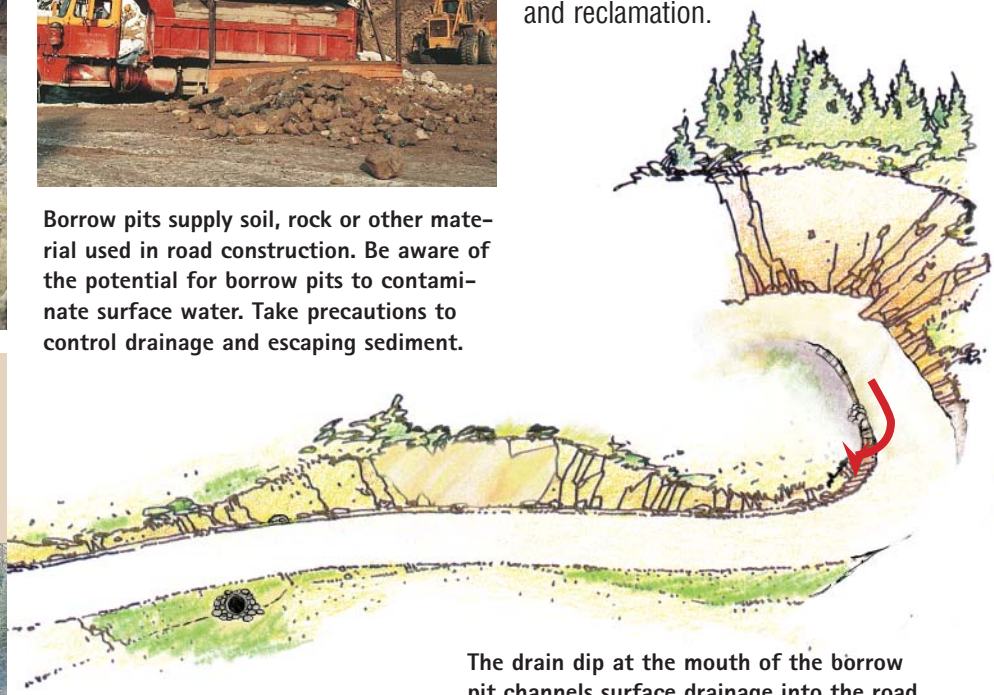
#21 Stabilize erodible, exposed soils by seeding, compacting, riprapping, benching, mulching or other suitable means prior to fall or spring runoff.

Geotextile material can also be used to hold embankment soil in place, allowing vegetation to grow. It's applied at culvert inlets and outlets to protect slopes adjacent to flowing water.



#31 Minimize sediment production from borrow pits and gravel sources through proper location, development and reclamation.

Borrow pits supply soil, rock or other material used in road construction. Be aware of the potential for borrow pits to contaminate surface water. Take precautions to control drainage and escaping sediment.



The drain dip at the mouth of the borrow pit channels surface drainage into the road ditch and away to a safe location.

Reopening Existing Roads

Use existing roads if possible to reduce new construction. Sometimes existing roads are so poorly designed they cannot or should not be re-used.

#18 When using existing roads, reconstruct only to the extent necessary to provide adequate drainage and safety; avoid disturbing stable road surfaces. Consider abandoning existing roads when their use would aggravate erosion.

Reopening a closed road can be a big job. In addition to removal of overgrown vegetation, culverts, ditches and the original surface grade may need reconstruction. Carefully consider how it can be done to minimize sediment.

Controlling Drainage from Road Surfaces

When compared to natural sediment, road sediment includes other contaminants. It's more fine grained and carries oils. That's why control techniques that reduce road sediment are so important for healthy streams.

Drainage Techniques that Work:
Ditch grade
Ditch relief culvert
Drain dip
Open top pipe culvert
Open top wood culvert
Water bar

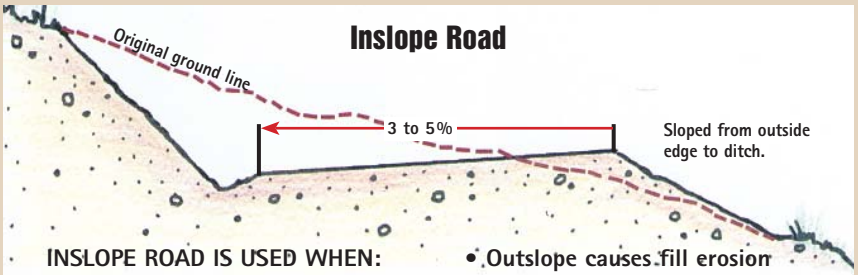
#23 Provide adequate drainage from the surface of all permanent and temporary roads. Use outsloped, insloped or crowned roads, and install proper drainage features. Space road-drainage features so peak drainage flow on the road surface or in ditches will not exceed capacity.

#18 Outsloped roads provide means of dispersing water in a low-energy flow from the road surface. Outsloped roads are appropriate when fill slopes are stable, drainage will not flow directly into stream channels, and transportation safety can be met.

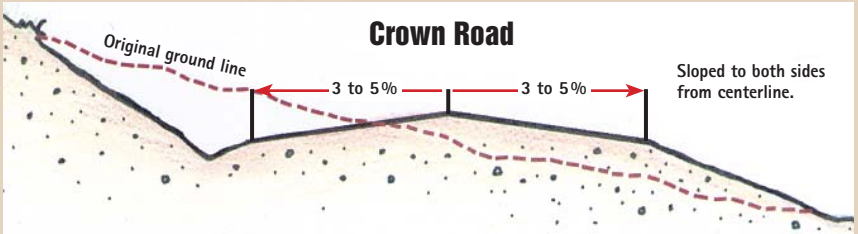
#18 For insloped roads, plan ditch gradients steep enough, generally greater than 2% but less than 8%, to prevent sediment deposition and ditch erosion. The steeper gradients may be suitable for more stable soils; use the lower gradients for less stable soils.

Roadway surfaces are normally crowned or sloped to remove surface water. Well-designed forest roads have changing road grades, adequate ditches and ditch relief culverts that control drainage and ensure water quality.

OUTSLOPE ROAD IS USED WHEN:
- Road grade is gentle or flat (< 7%)
- Ditch or cutslope is unstable
- Surface can be kept smooth
- Road is closed
- Rutting can be controlled
- Road use is seasonal and traffic is light



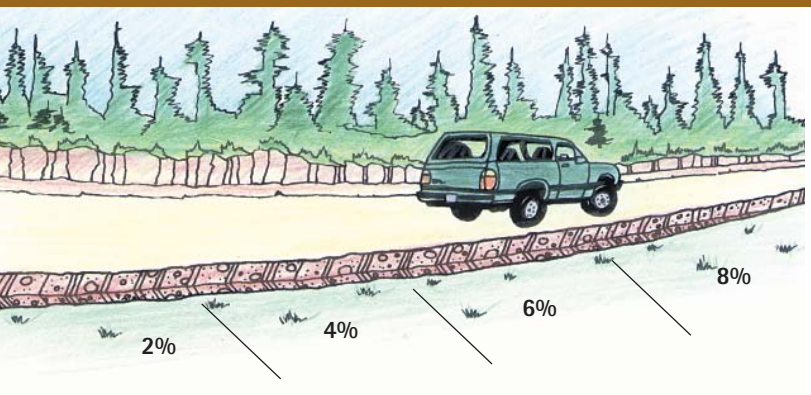
INSLOPE ROAD IS USED WHEN:
- Road grade is steep (>8%)
- Surface drainage is carried to a ditch or surface drain
- Outslope causes fill erosion
- Outslope is ineffective due to ruts
- Slippery or icy road conditions are prevalent



CROWN ROAD IS USED WHEN:
- Two traffic lanes are required
- Regular maintenance of ditches, crown and cross drains is possible
- Single lane road on steep grade
- Slippery or icy road conditions are prevalent
- Road grade is flat (crown fill)

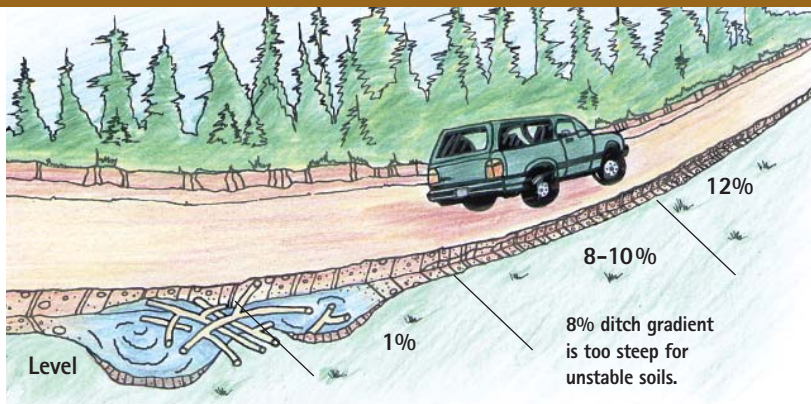
Ditch Grades

THE RIGHT AMOUNT OF DITCH GRADE



2-6% ditch gradients are steep enough to keep water moving to relief culverts without excessive sediments.

TOO STEEP OR NOT STEEP ENOUGH



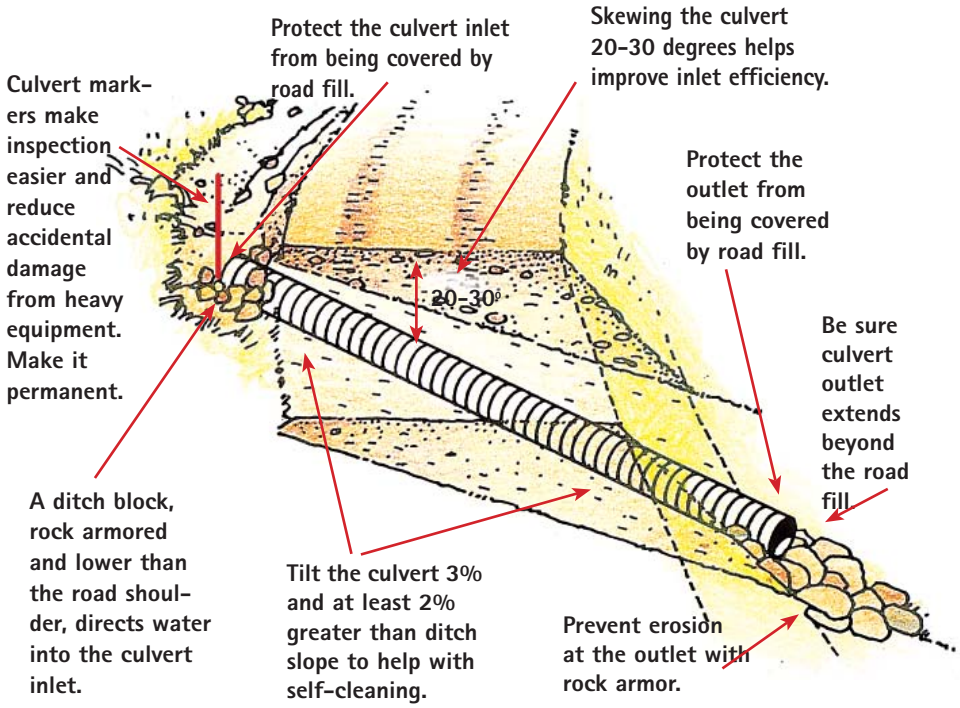
Ditch gradients steeper than 8% give water too much momentum and carry sediment and debris for great distances. Where the ditch levels off, debris drops, clogging ditches and carrying sediment into streams.

Ditch Relief Culvert

- Ditch relief culverts transfer water from the ditch on the uphill side of the road, under the road, releasing it onto a stable area on the downhill side.
- They prevent water from crossing the road surface and softening the road bed.
- Ditched roads with ditch relief culverts are wider and more costly, but they also allow for faster speeds and greater safety.

Drop inlet installed at a ditch relief culvert inlet slows water, helps settle out sediment and protects the culvert from plugging.

Rock-armored catch basins prevent water from eroding and undercutting the culvert inlet and flowing under the culvert.



#23 For ditch relief culverts, construct catch basins with stable side slopes. Protect the inflow end of crossdrain culverts from plugging and armor if in erodible soil. Skew ditch relief culverts 20 to 30 degrees toward the inflow from the ditch to help maintain proper function.

#23 Prevent downslope movement of sediment by using sediment catch basins, drop inlets, changes in road grade, headwalls or recessed cut slopes.

#23 Where possible, install culverts at the gradient of the original ground slope; otherwise, armor outlets with rock or anchor downspouts to carry water safely across the fill slope.

#23 Provide energy dissipators (rock piles, slash, log chunks, etc.) where necessary to reduce erosion at the outlet of drainage features. Crossdrains, culverts, waterbars, dips and other drainage structures should not discharge onto erodible soils or fill slopes without outfall protection.

Ditch Relief Culvert Installation

Ensure proper tilt of culvert. At least five inches in every ten feet.

Seat the culvert on the natural slope. Bedding material should be free of rock or debris that might puncture the pipe or carry water around the culvert.

Cover with soil, using at least one foot or one-third the culvert diameter, whichever is greater. Avoid punctures from large rocks.

Compact soil at least halfway to prevent water seepage around sides. Be sure outlet extends beyond any fill and empties onto an apron of rock, gravel, brush or logs.

Drain Dip

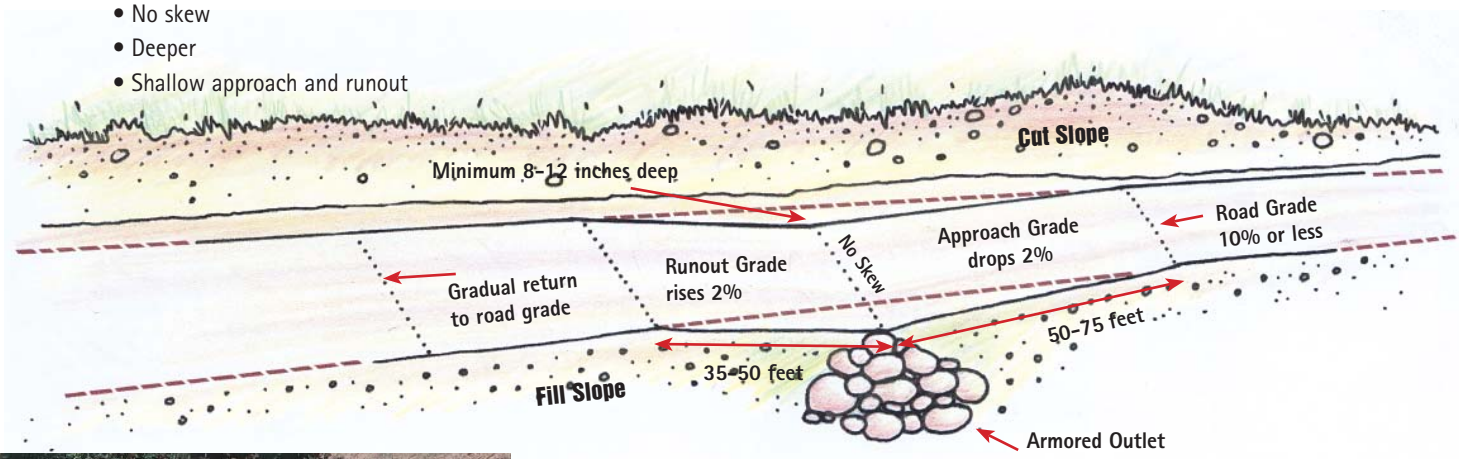
- Used on ditched or unditched active roads.
- Preferred alternative to the traffic obstruction of a waterbar.
- It is a gentle roll in the road surface, sloped to carry water from inside to outside, onto natural ground.
- The approach, depth and runout provide drainage without being a driving hazard.
- Effective on roads with grades up to 10 percent.
- Difficult to construct on steeper roads and difficult for log trucks to pass. For steeper road grades consider an open top pipe culvert.

The drain dip bottom is sloped to carry water from inside to outside of road surface, onto natural ground.

High Service Level Drain Dip

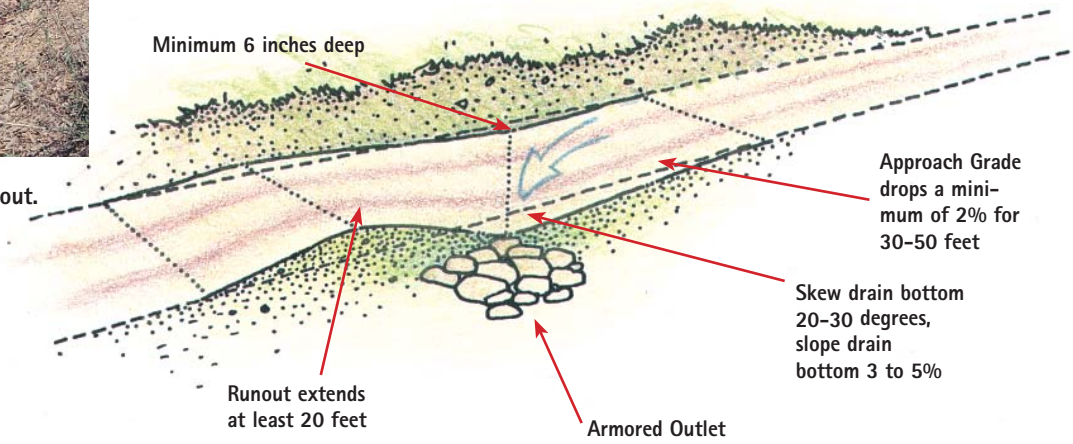
(Higher speed, lower clearance)

- Longer length
- No skew
- Deeper
- Shallow approach and runout



Use at least 50 feet for approach and runout. More on steeper road grades.

#23 Properly constructed drain dips can be an economical method of road surface drainage. Construct drain dips deep enough into the subgrade so that traffic will not obliterate them.



Low Service Level Drain Dip

(Lower speed, higher clearance)

- Shorter length
- Skewed
- Less depth
- Steeper approach and runout

Open Top Pipe Culvert

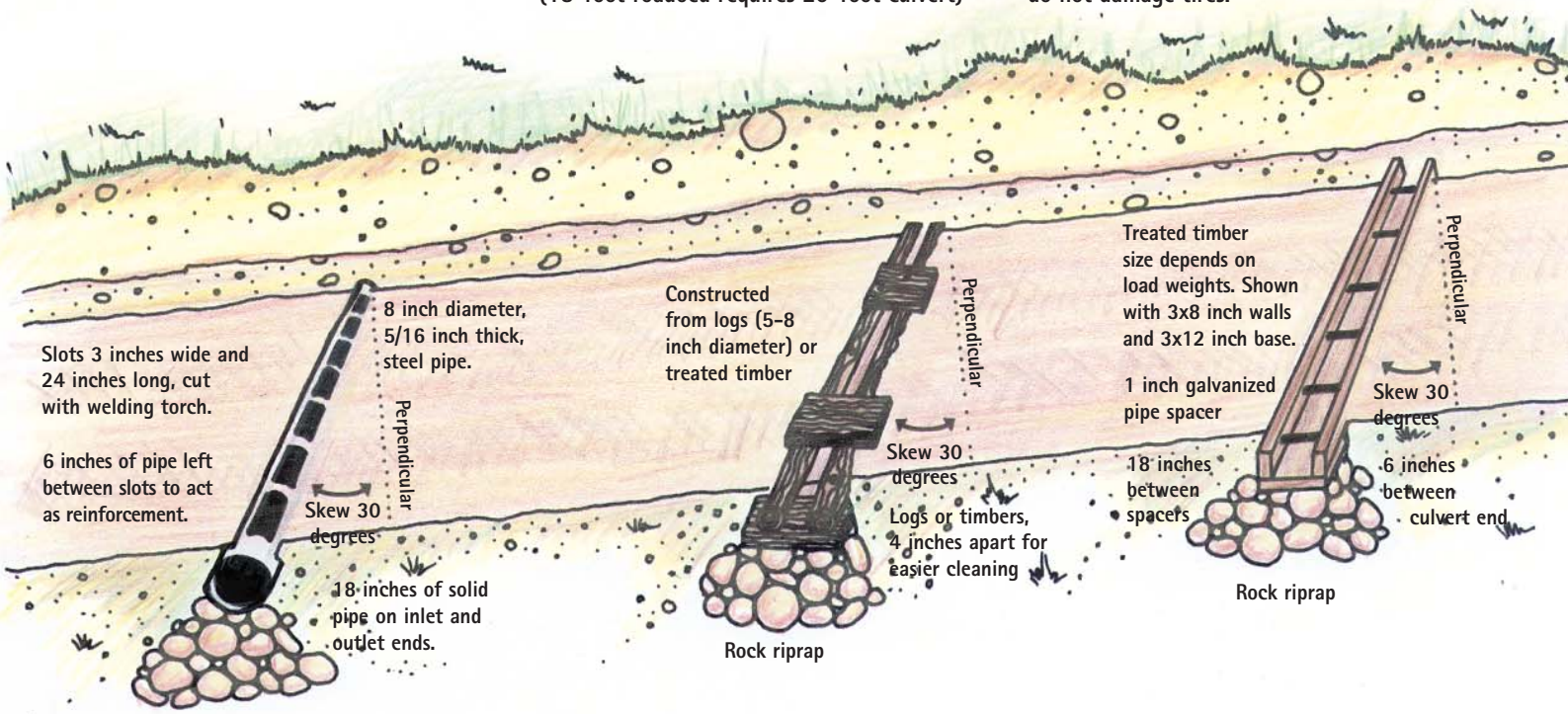
- Alternative to drain dip on roads with greater than 10% grade.
- Used to control surface water on unditched roads.
- Water cannot run past them as long as they are maintained.
- Constructed from both steel and wood (see below).
- Steel is more resistant to damage and relatively permanent.
- Can be dented by repeated trips by bulldozer cleats.
- Road grader operators should lift blade when passing.

A backhoe is the best choice for open top pipe culvert installation.

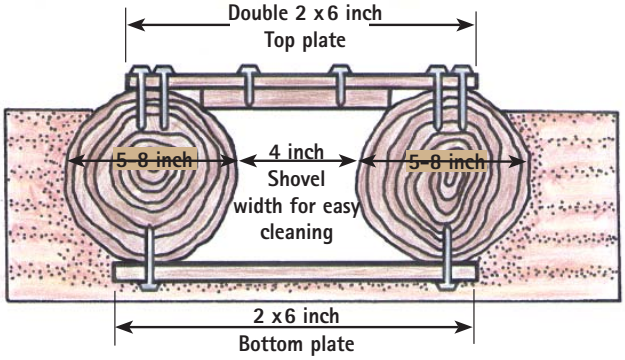
Pipe bed must have a grade of 8%.

Skew pipe 30-45 degrees for self-cleaning. (15-foot roadbed requires 20-foot culvert)

Slots are wide enough for cleaning but do not damage tires.

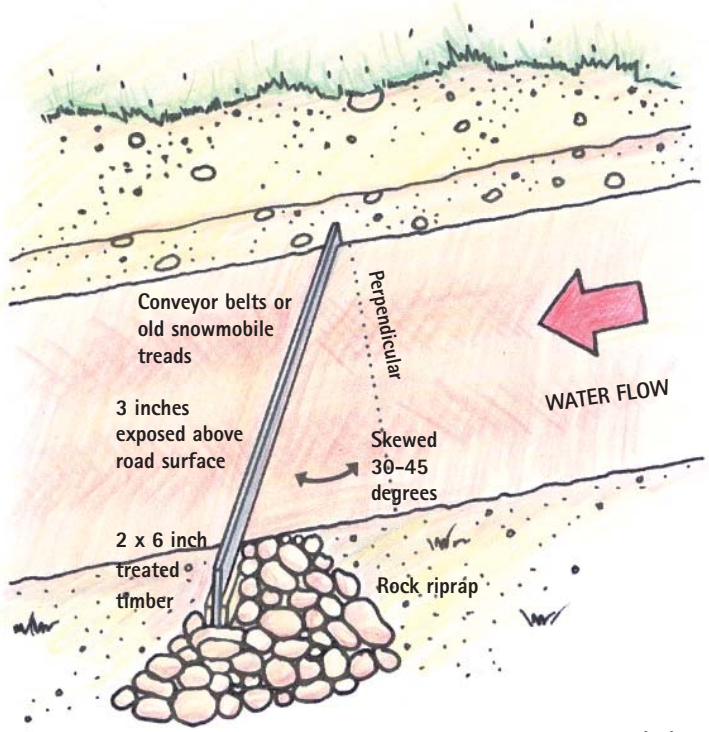


Because water is discharged above the road fill, protect fill with rock riprap.



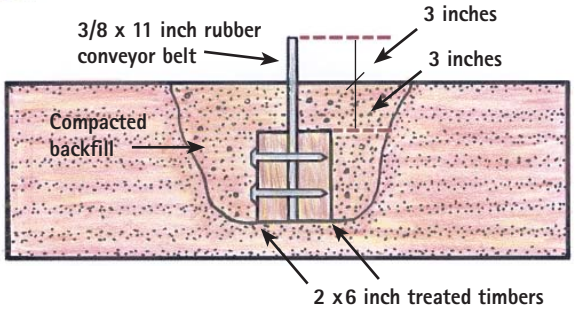
Open Top Wood Culvert

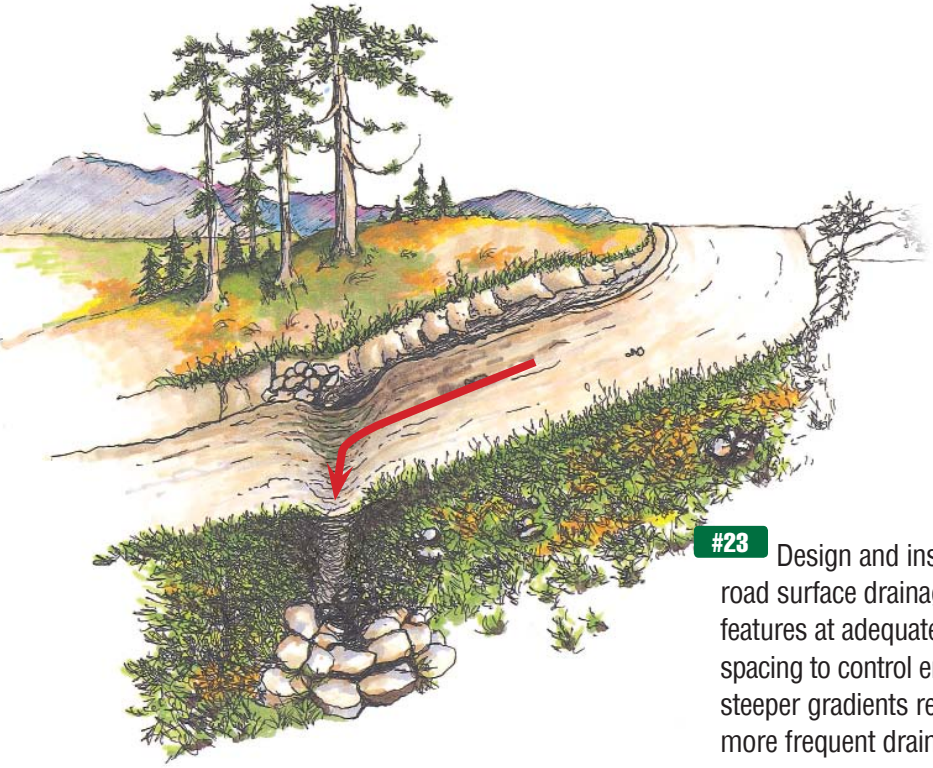
- Used on steep, lower standard, unditched roads.
- Less expensive and work well if kept repaired.
- Require frequent cleaning to remain effective.
- Easily damaged by logging equipment.



Rubber Water Diverter

- Another surface water control alternative.
- For steep, unditched roads.
- Rubber belt fastened between timbers and buried in the road.
- Easily damaged by track machines and snowplows.
- Expect frequent replacement on regular traffic roads.

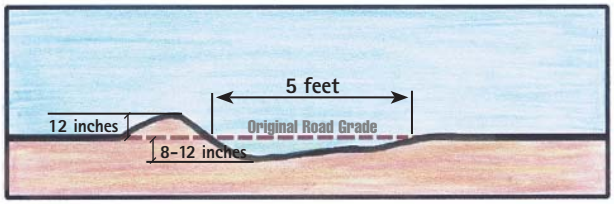




#23 Design and install road surface drainage features at adequate spacing to control erosion; steeper gradients require more frequent drainage features.

Water Bar

- Small earth dam or hump built into the road surface.
- Used to divert road surface water to where it will not cause erosion.
- Used on inactive roads and skidtrails.
- Can be constructed with a shovel, but mechanical equipment is most common.
- Spacing recommendations should be based on soil type, topography, road dimensions, road aspect and climate.



Suggested Water Bar Intervals for Different Soils *(Intervals in feet)*

ROADS AND LANDINGS			
SLOPE GRADE	GRANITIC OR SANDY	CLAY OR LOAM	SHALE OR GRAVEL
2–5%	400'	500'	600'
6–12%	200'	250'	300'
SKID TRAILS			
SLOPE GRADE	GRANITIC OR SANDY	CLAY OR LOAM	SHALE OR GRAVEL
5–10%	250'	300'	400'
11–12%	150'	200'	300'
over 25%	75'	100'	150'

Road Grading

Roads are one of the most important and costly features constructed on forest land. Maintenance is required to ensure road usefulness and value. Ignoring or delaying maintenance often leads to repair damage more costly than original road construction.

Road Maintenance Activities

- Road grading
- Culvert and ditch cleaning
- Cut and fill slope inspection
- Dust control
- Snow removal

Road Grading

- Purpose is to maintain road surfaces, either crown, inslope or outslope.
- Maintain road surface cross-drain structures.
- Corrects road surface damage resulting from vehicle traffic and freeze-thaw cycles that reduce drainage effectiveness.
- Timely road grading and road use restrictions during wet periods can protect drainage on unimproved roads.

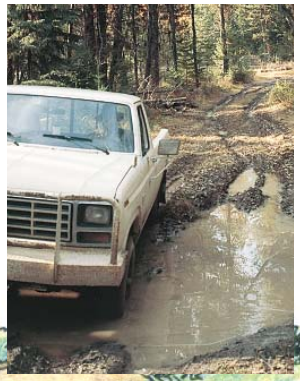
#16 Grade road surfaces only as often as necessary to maintain a stable running surface and adequate surface drainage.

Road Grading Precautions:

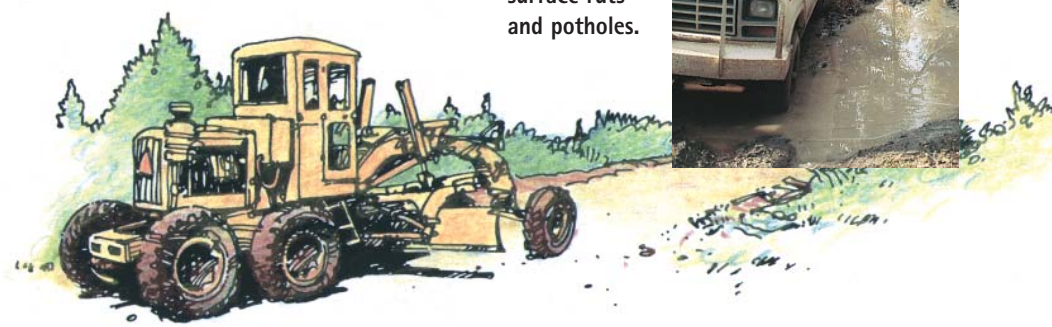
- Grading should be done when roads are neither dusty nor muddy. Moist roads are more easily shaped and compacted by grading machinery.
- Watch for steep sections or curves where added wear and rutting takes place.

#16 Avoid cutting the toe of cut slopes when grading roads, pulling ditches or plowing snow.

Roads receive heavy use during logging. Be aware of early signs of damage. Serious damage to road surfaces starts with excess water. Standing water is a sure sign of road-drainage problems. Ruts indicate that road strength is deteriorating.



Road grading repairs the drainage by smoothing surface ruts and potholes.



Avoid grading sections of road that don't need it. This only creates an unnecessary sediment source from the disturbed surface. Raise the blade where grading is not needed!

Grader damage to inside ditch toe slopes exposes an easily erodible surface and is a source of sediment. What was an outsloped road is now insloped and road drainage will be severely impaired

Slow, controlled grader operation is key to reducing culvert inlet and outlet damage. Reduce damage by keeping graders on the road running surface. Never sidecast gravel over culvert inlets or outlets.

If grading produces excess material, feather it out or haul it away. Never sidecast material into streams. Avoid leaving a berm that channels water down the road unless it is routed into an effective vegetation filter zone (page 37) which spreads it out and removes sediment.

Road Maintenance

Culvert and Ditch Cleaning

- More culverts fail from inlet debris than from any other cause.
- Debris reduces flow velocity at the culvert inlet, causing sediment to drop and making the culvert non-functional.
- Culvert inlet debris can cause water to overtop the embankment, in turn causing embankment erosion and/or flooding of land upstream from the culvert.

Without crossdrains, water can soak into the road, causing surface softening and rutting.

This undersized cross-drain culvert resulted in a breached ditch block and sediment flowing directly into the stream.

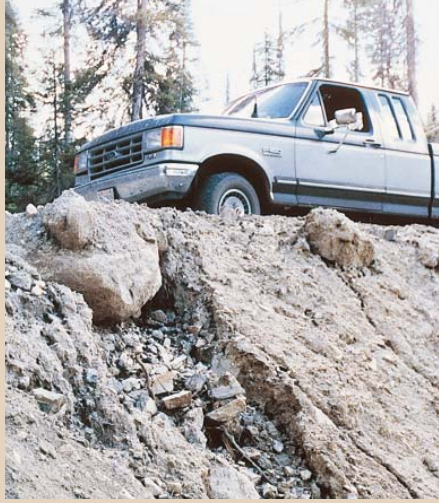
Hand, shovel and chainsaw work are usually all that culvert maintenance requires. But don't delay! Delay in cleaning a blocked culvert or ditch can result in a damaged road that requires costly reconstruction.

Preventive maintenance can reduce culvert plugging and the need for culvert cleaning. In recently logged areas, like this one, remove floatable debris from drainage ditches and seed the disturbed area with a grass seed mixture - see page 60.

This road ditch has blown out, leaving the crossdrain too high to move water under the road to a safe drainage area. The cause was an unstable ditch block.

#16 Maintain erosion-control features through periodic inspection and maintenance, including cleaning dips and crossdrains, repairing ditches, marking culvert inlets to aid in location, and clearing debris from culverts.

Watch for damaged culverts that need replacement. Repair work should be completed during dry weather.



Poor road surface drainage caused this fill slope erosion.

Soil sloughing off a road cut.

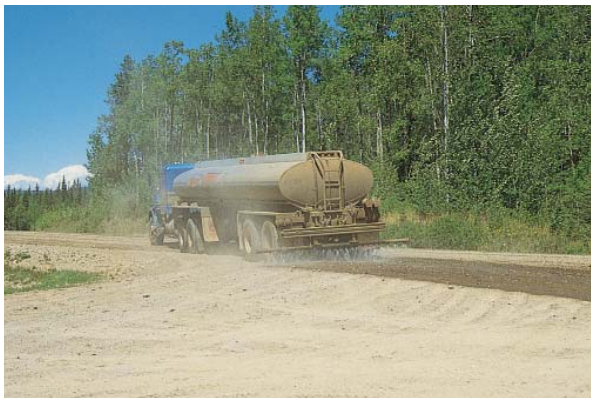
Cut and Fill Slopes

- In steep terrain, ditch walls and cut-and-fill slopes can slump.
- Debris collects in ditches, and vegetation may block water flow.
- Ditch inspection should be done during storm events when problems are most obvious. Watch for blockage and overflow problems.
- Clean promptly. Move soil and debris to a location where they will not create additional erosion problems.
- Be aware that these problems may be symptoms, indicating need for larger ditches or more culverts.
- Vegetating cut and fill slopes will reduce erosion.
- Ditchline erosion may indicate a need for more or larger culverts or ditch stabilization such as compacting or armoring with rock (see ditch gradients page 26).

#26 Haul all excess material removed by maintenance operations to safe disposal sites and stabilize these sites to prevent erosion. Avoid sidecasting in locations where erosion will carry materials into a stream.

Dust Control

- Road dust is a driving hazard and a source of sediment to water bodies.
- Significant amounts of road surface can be lost as dust.
- Road surfaces can be protected with the use of water, chemicals or oil.
- Dust abatement chemicals can decrease rutting.
- Abatement chemicals can be pollutants, and caution should be used in their application near streams or drainages.

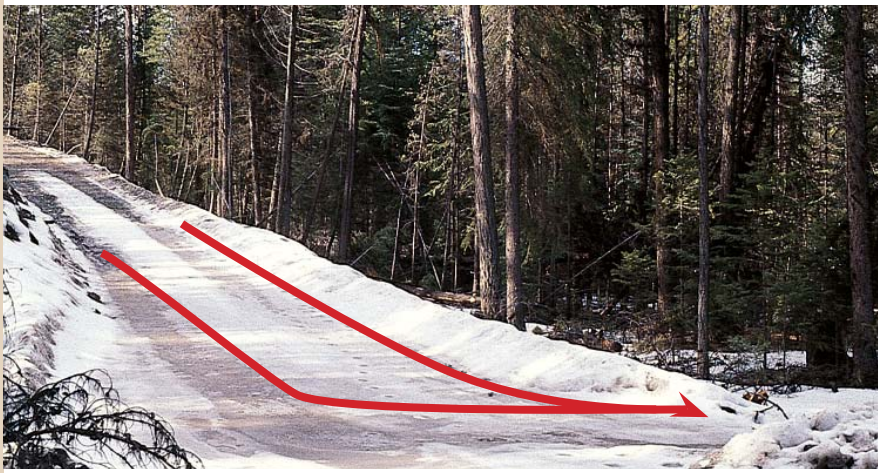


Chemicals used to control dust should be applied according to the manufacturer's specifications.

Snow Removal

#16 When plowing snow, provide breaks in the snow berm to allow road drainage.

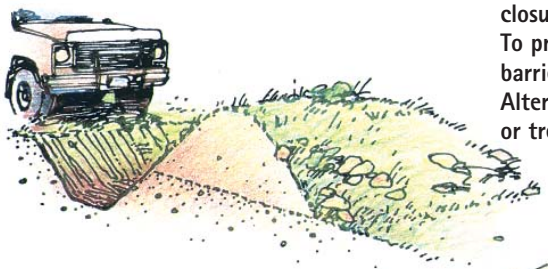
Snow berm breaks allow for spring drainage without damaging the road surface. They also serve as escape corridors for wildlife.

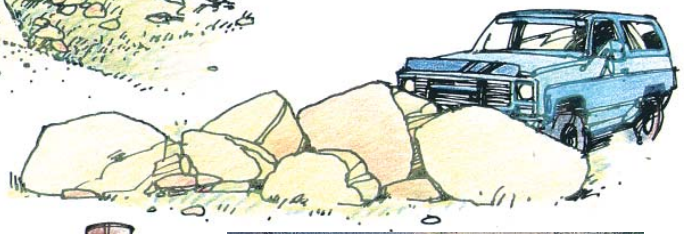


Closing Roads to Protect Water Quality

Forest roads remain part of the landscape long after harvest, site preparation and reforestation are completed. If access is no longer needed, steps should be taken to either temporarily close, permanently close or obliterate roads.

Temporary road closure is easiest. Permanent closure, or storing a road for future use, involves specific actions described on page 35. In contrast, road obliteration, used in some situations, is also described.





It may be necessary to physically block road access. Gates provide temporary closure along with quick access if needed. To prevent vandalism, gates and other barriers need to be well anchored. Alternatives to gates include large berms or trenches, logs, stumps or rock boulders.

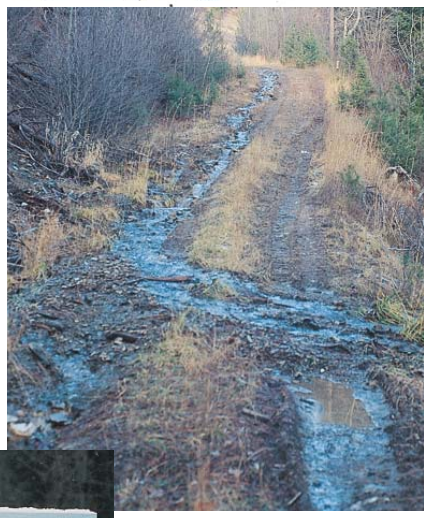
#19 Consider gates, barricades or signs to limit use of roads during spring break up or other wet periods.

Temporary Road Closure

#19 Avoid using roads during wet periods if such use would likely damage the road drainage features.

#16 Upon completion of seasonal operations, ensure that drainage features are fully functional. The road surface should be crowned, outsloped, insloped or waterbarred. Remove berms from the outside edge.

Traffic control is an effective way to reduce road maintenance costs and provide protection of other forest resources. Traffic control can include: full road closure, temporary or seasonal closure, or road open but restricted to only light use. Whatever traffic control option is selected, all require regular maintenance inspections.

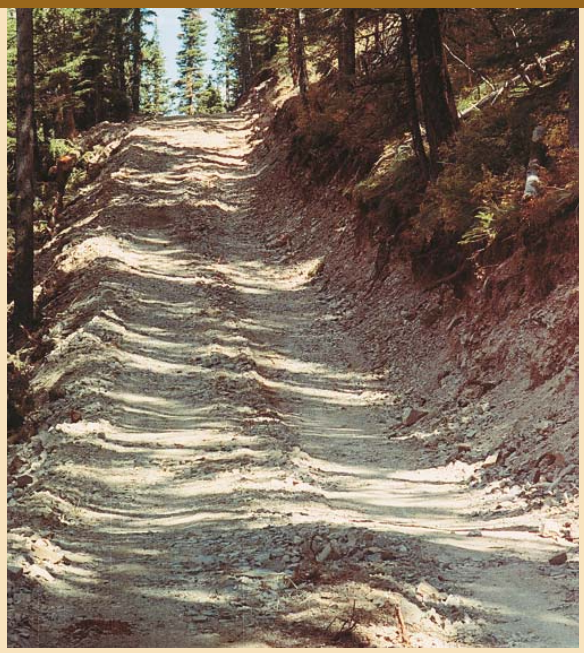


Don't let closed roadways become streams. When roads become channels for drainage, major sediment pollution can result. Outslope the surface of closed roads and periodically inspect to avoid this problem.

Road Obliteration

- Road obliteration is the unbuilding or dismantling of a road and return to its revegetated condition.
- When should obliteration be considered?
  - When the road no longer serves a useful purpose.
  - When there's a need to eliminate or discourage access.
  - To reduce watershed peak flows that are the result of roads.
  - To reduce erosion and sedimentation.
  - To correct unstable road cuts and fills.
  - To break up compacted soil and water concentration areas.
  - To improve the visual quality of road corridors.
- Where is road obliteration used?

It may be necessary only on certain road segments, such as, recontouring a road junction and its initial stretch of road. Other segments may be stable and can be revegetated as is.



Road segment before obliteration.

Permanent Road Closure

- Permanent closure is more than just blocking the road off from traffic.
- Permanent closure may solve costly road maintenance, but it requires the most preparation.
- Remember, water still runs on closed roads.
- Road revegetation is the only way to reduce runoff, erosion and sediment from permanently abandoned roads.

#16 Leave abandoned roads in a condition that provides adequate drainage without further maintenance. Close these roads to traffic; reseed and/or scarify; and, if necessary, recontour and provide waterbars or drain dips.

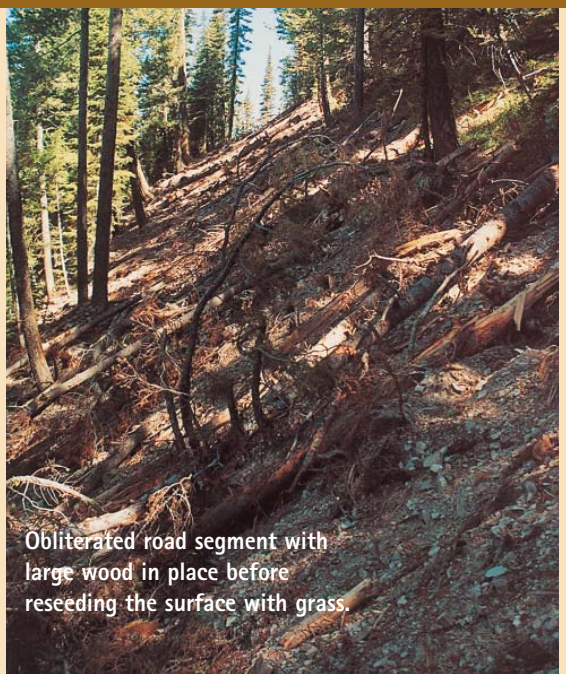
Removing culverts can prevent erosion problems, and waterbars may be a solution. Space waterbars more closely in areas that are more likely to erode. When removing culverts, stockpile earth from the removal in a safe place where it can be recovered and won't erode. Reshape banks to a stable slope.

It may be necessary to rip or decompact both the road subgrade and its surfacing material before seeding can be successful.

It is necessary to restore all drainage features to their natural condition. This includes reseeding both the road surface and cut and fill slopes.

Bridges present special road closure problems. Unless there are regular inspections of bridge abutments and other structural components, it may be best to remove all bridge structures.

Excavator dismantling the road corridor.



Obliterated road segment with large wood in place before reseeding the surface with grass.

Choosing and Designing a Stream Crossing

Stream crossing structures include culverts, arches, bridges and fords. Each is designed to maintain natural water flow and provide a safe vehicle crossing. Choosing the wrong stream crossing structure can result in damage to both the immediate site and downstream water uses.

Your Choice of Stream Crossing Depends On:

- Stream size. Bridges are best for streams more than 10 feet wide and those with high-gradients.
- Is it a fish-bearing stream? Arches and bridges protect the natural streambed with less impact on fish.
- Construction and maintenance costs. Crossing structures ranked in order of increasing cost are: ford, round culvert, squash culvert, bottomless arch and bridge.
- Future years of use. Culverts provide a smoother ride and better access than fords.
- Soil foundation conditions. Bedrock crossings may require a bottomless arch, bridge or ford.
- Available equipment and materials. Culverts require a backhoe or excavator, portable compactor, bedding gravel, armoring material and sediment filter.

Bridges often require a crane, concrete truck access for abutments, pile driver, and a high service level road for steel or pre-stressed concrete delivery.

Fords require armoring of approaches and stream bottom and possibly geotextile and excavation equipment.

- Permits may be required for perennial stream crossings or when the filling of wetlands is necessary. Some crossings, especially bridges, require a qualified engineer. Hydrologic and fisheries requirements may dictate a specific structure style.

Legal and Planning and Construction Requirements

#30

#2 Close coordination with Wyoming Department of Environmental Quality (DEQ) and Wyoming Game & Fish Department will help with fish passage issues and the potential need for Army Corps of Engineers 404 Permits, if in-channel excavation is necessary.

#15 Plan construction methods to protect the channel and streambanks during construction

Design Considerations

#18 Design stream crossings for adequate passage of fish (if present), minimum impact on water quality. Consider oversized pipe when debris loading may pose problems. Ensure sizing provides adequate length to allow for depth of road fill.

Planning for a stream crossing must include flood calculations. When ignored, the potential for water-quality damage is enormous. The costs of this culvert repair will far exceed the costs of a properly planned installation.

#18 Minimize the number of stream crossings and choose stable stream crossing sites.

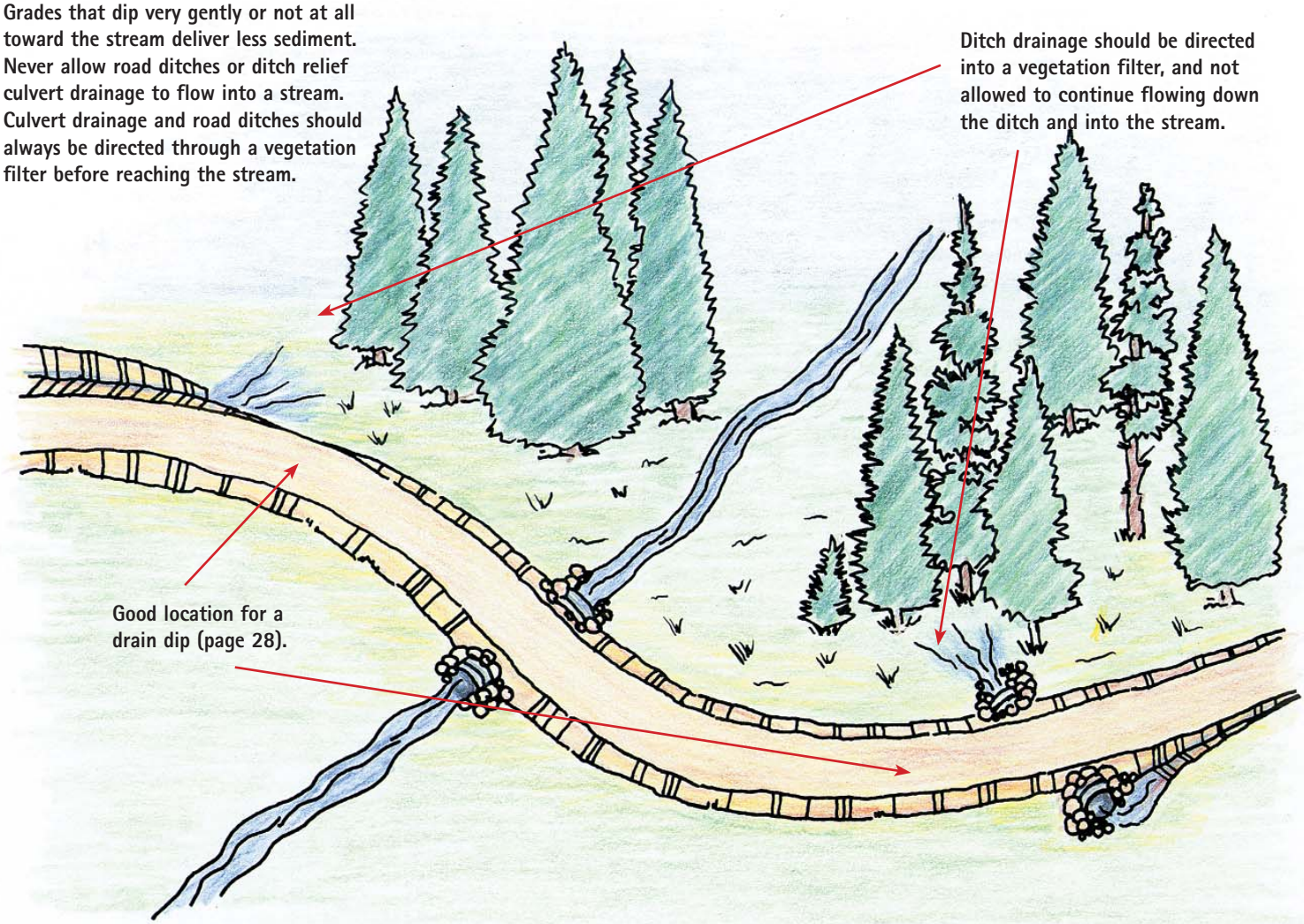
Vegetation Filter Zones

Road drainage at stream crossings needs to be robust and drainage features must have adequate filtration zones, to allow drainage water to infiltrate and not directly enter the stream.

#23 Route road drainage through adequate filtration zones or other sediment settling structures to ensure sediment doesn't reach surface water. Install road-drainage features above stream crossings to route discharge into filtration zones before entering a stream.

The Problem: Allowing ditch drainage to flow directly into a stream is one of the most common road-drainage problems. This ditch water is on a direct route to the stream. Never let this happen.

The Solution: Always route ditch drainage through a filter of undisturbed vegetation so sediment can be removed before water reaches the stream.



Stream Culvert Installation

#27 Minimize stream-channel disturbances and related sediment problems during construction of road and installation of stream-crossing structures. Do not place erodible material into stream channels. Remove stockpiled material from high-water zones. Locate temporary construction bypass roads in locations where the stream course will have minimal disturbance. Time construction activities to protect fisheries and water quality.

#30 When using culverts to cross small streams, install those culverts to conform to the natural stream bed and slope on all perennial streams and on intermittent streams that support fish or that provide seasonal fish passage. Ensure fish movement is not impeded. Place culverts slightly below normal stream grade to avoid culvert outfall barriers. Do not alter stream channels upstream from culverts, unless necessary to protect fill or to prevent culvert blockage.

#30 Install culverts to prevent erosion of fill. Compact the fill material to prevent seepage and failure. Armor the inlet and/or outlet with rock or other suitable material where feasible.

#28 Consider dewatering stream-crossing sites during culvert installation. This can be done with a temporary diversion channel or a sandbag dam with a pump diversion.

1

Construction of culvert stream crossings has the greatest potential to cause immediate sediment pollution. Installing culverts is more than just placing a pipe in a stream. Complete the work promptly, at a time when the least damage will occur.

2

The temporary channel in the foreground carries stream water. The dewatered stream channel is being cleared for culvert installation. The channel foundation and trench walls must be free of logs, stumps, limbs or rocks that could damage the pipe.

Once the ends are secured by backfill, the center of the culvert is covered.

5

9

After checking to be sure the new culvert is working, close the dewatering channel.

10

The road approach to the new culvert is the next phase of construction.

3

The culvert bed must conform with the natural streambed. The bed should be either rock-free soil or gravel. Bedding should provide even distribution of the load over the length of the pipe. Countersink the culvert to allow stream gravel to deposit in culvert bottom (see detailed diagram, page 40).

4

Secure each end of the culvert with backfill. Pour backfill material over the top of the pipe. This allows finer soil particles to flow around and under the culvert sides. Larger particles roll to the outside. Fine soil particles, close to the culvert, compact more easily.

6

Tamping fill material throughout the entire backfill process is important. The base and sidewall material should be compacted first. This reduces any chance of water seepage into the fill.

7

Armor the culvert inlet and outlet. Rocks, logs or grass seeding can be used to protect these locations against erosion. Check the area upstream and downstream from the culvert. Clear upstream area of woody debris that might plug the culvert.

8

After the new culvert is opened to water, watch for the need for more rock armor. Be sure that a minimum of one foot of compacted soil covers the top of the culvert.

11

Layers of fill are pushed into place and carefully compacted to build up and maintain a consistent road grade.

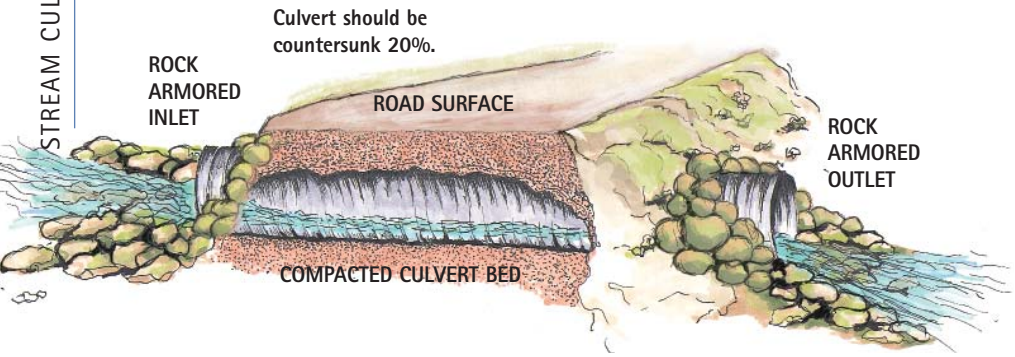
12

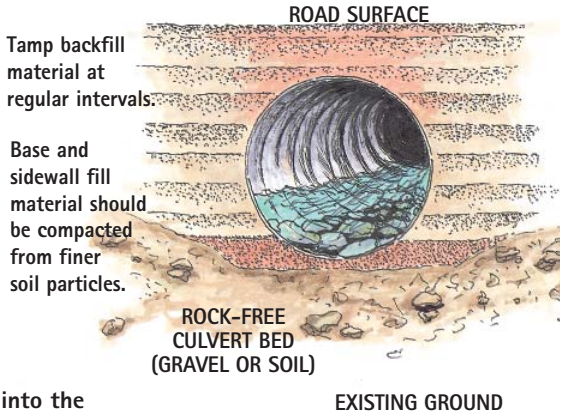
As a final precaution against sediment entering the stream, a slash-filter windrow is constructed around the culvert outlet.

Stream Culvert Installation Details

#30 Use culverts with a suitable diameter for permanent stream crossings and make sure they will accomodate peak flows and allow for fish passage. Consult with Wyoming Game and Fish for specific fish-friendly designs

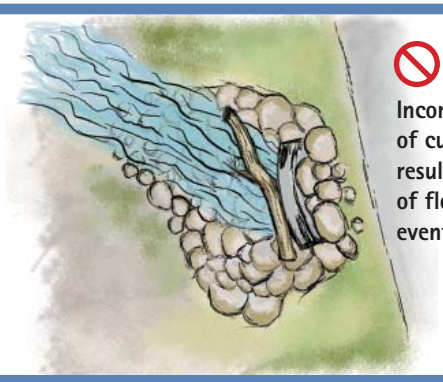
#30 Maintain a 1-foot minimum cover for culverts 15 to 36 inches in diameter, and a cover of one-third diameter for larger culverts to prevent crushing by traffic.



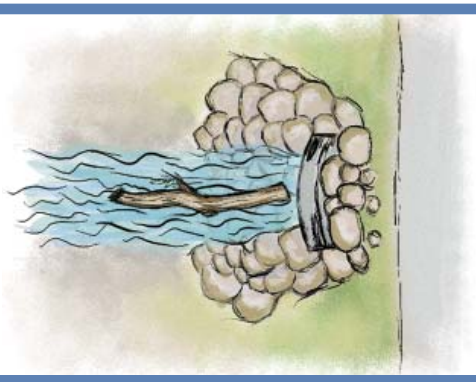


Culvert slope should be less than 2% to provide fish passage.

At least 20% of the culvert should be countersunk. This partial burial of the culvert into the streambed reduces water velocity in the culvert and allows gravel to deposit in the bottom.



Incorrect alignment of culvert with stream results in accumulation of floating debris and eventual inlet plugging.

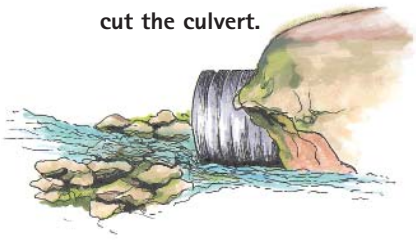


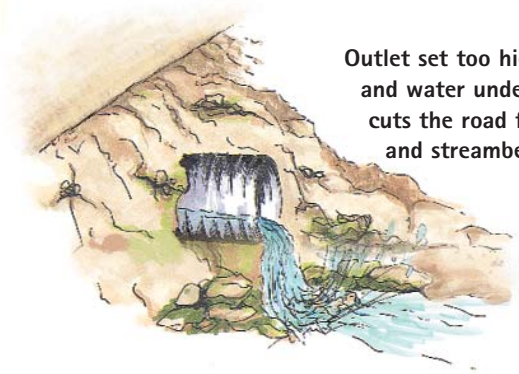
Incorrect Culvert Alignment | **Correct Culvert Alignment**

Common Culvert Installation Problems

Culvert alignment is critical for proper culvert function. Culverts set at an angle to the channel can cause bank erosion. Skewed culverts can develop debris problems. Culvert alignment must fit the natural stream channel. Place culverts slightly below the natural streambed so water can drop slightly as it enters.

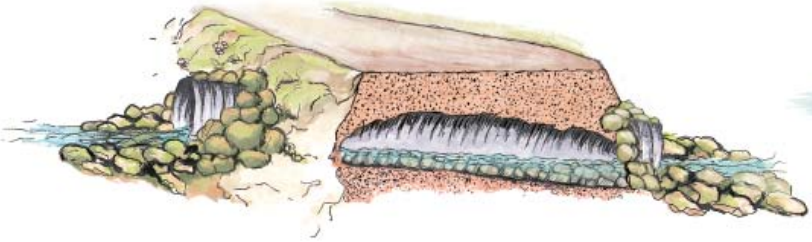
Inlet is not deep enough, allowing water to undercut the culvert.



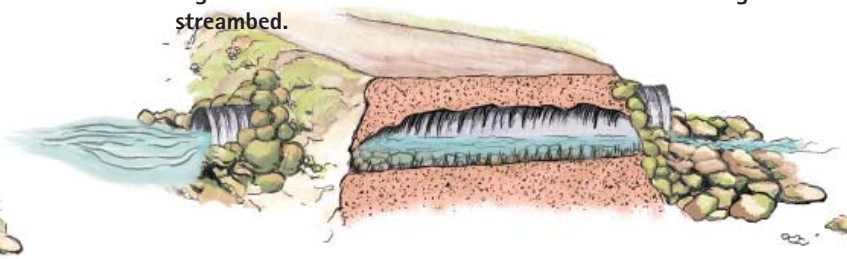


Outlet set too high and water undercuts the road fill and streambed.

Culverts installed at greater than stream grade can result in the outlet becoming buried, and flow is restricted, or steepening the stream grade makes it difficult for fish to pass upstream.



Culverts installed at less than stream grade result in the inlet becoming buried, and flow is restricted, ponding occurs at inlet and raised outlet results in scouring streambed.



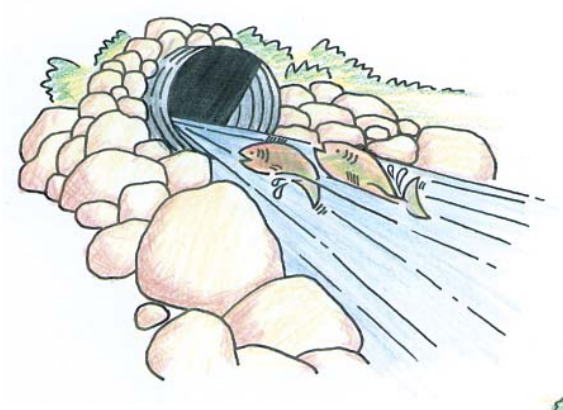
Stream Crossings and Fish

The Problem of Culverts and Fish

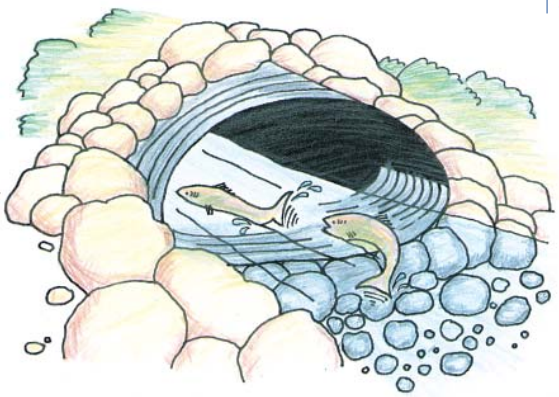
- Culverts can be a problem when used on fish-bearing streams.
- Fish move upstream to spawn, search for favorable water temperatures and find food during aquatic insect hatches.
- Culverts can accelerate existing stream flow and make it impossible for fish to migrate upstream.

Make It Easier for Fish

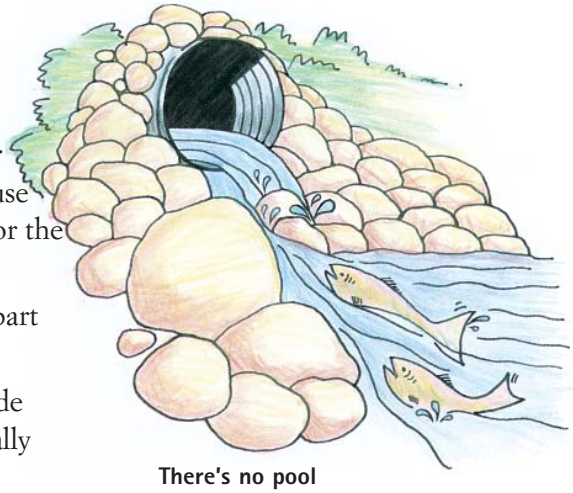
- Don't force fish to jump to enter or pass through a culvert.
- Keep culvert openings free of debris.
- Be sure there's no change in channel slope at the culvert site.
- Minimize culvert length and use culverts of adequate diameter for the stream width.
- Locate culverts on a straight part of the stream.
- Set culverts below stream grade so streambed gravels can naturally accumulate inside.
- Corrugated culverts help fish by providing a low flow zone next to the wall where passage is easier.
- Provide resting pools.



Fish may not be able to swim fast enough to overcome culvert water velocity that develops in round culverts with low cross-sectional flow area. Rule of thumb: water moving through a culvert faster than a brisk walking pace is potentially a fish passage barrier.

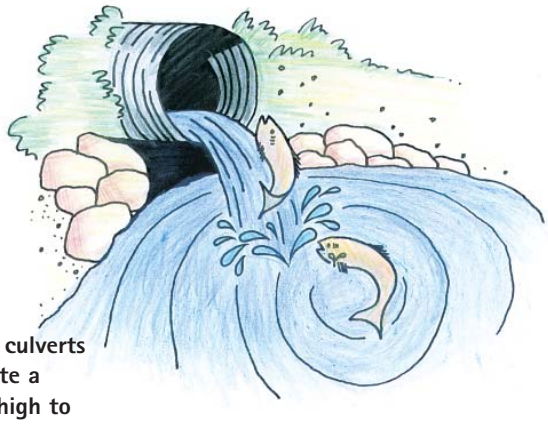


Water may be too shallow for fish to swim. This is sometimes a problem created by squash pipes that are used when road clearance over the pipe is limited. Shallow water leaves fish partially submerged and unable to get maximum thrust from tail and body movements.



There's no pool below the inlet for fish to rest in or jump from.

#30 Ensure fish movement is not impeded.



Hanging culverts can create a fall too high to jump.

Step pools at culvert outlets can sometimes correct the problem of hanging culverts by allowing fish to rest before attempting passage.

What's Best for Fish Passage?

Ranked from most optimum.

1. Bridges
2. Bottomless arches
3. Countersunk corrugated pipe
4. Corrugated pipe with a slope less than 0.5 percent.
5. Corrugated pipe, with baffles or sills, on grades between 0.5 and 5.0 percent. Sills are v-shaped, miniature dams that increase flow depth during low flows and decrease water velocity through the culvert.

Consult with Wyoming Game & Fish for assistance with fish friendly stream crossing culvert design.

Bottomless arches leave the streambed intact, making it easier for fish to pass. Natural streambed roughness creates pockets of low water velocity where fish can move comfortably. Bedrock or concrete footings are required.

Bridge Crossings

Tips when Considering Permanent Bridges

- Size bridges to accommodate stream channel width and flood risk.
- Bridges and bridge approaches should be constructed to minimize soil or other material from reaching the stream.
- Whenever possible, retain existing vegetation and organic material around stream crossings. It is the most effective erosion control.
- Abutments and wingwalls should prevent material from spilling into the stream.

Bridges are best for large streams and those plagued with floatable debris problems. Bridges and arches have the least impact on fish.

Keep road drainage under control. Sediment is being carried around this bridge abutment and draining directly into the stream.

#29 Advantages of Portable Bridges

- Handy for stream crossings on temporary low-standard roads.
- Useful when short-term access to forest land is cut off by a stream.
- Quick, economical and can be installed with minimal impact.
- The crossing can be restored to its original condition.

A portable railroad flatcar provides access across streams with minimal disturbance to streambanks or bed. Select locations with firm soil banks, level grade and minimal vegetation clearing.

Along with its portability, this bridge is strong enough for all harvesting activities.

This 20-foot portable bridge was hauled into place on a flatbed truck, stretched across the stream and set into place in one day. The bridge cribbing is 10-foot timbers laid on the ground four feet from the bank.

A small bulldozer built the road approaches to the bridge. Over a three-week period, the bridge carried approximately 25 truckloads of logs.

When harvest was completed, the temporary bridge was removed and the crossing site rehabilitated. Temporary bridges can be reused many times and, if carefully installed and removed, can leave the stream in the same condition as it was before.

Ford Crossings

What is a Ford?

A ford is a stream crossing option for low service level roads that are private, gated and have infrequent use. Access control is important to avoid damage to the ford approaches when they are vulnerable to erosion. Fords seldom have year-long access.

Fords are the least desirable stream crossing because of the continued disturbance to the streambed.

#29 Avoid unimproved stream crossings. When a culvert or bridge is not feasible, locate drive-throughs on a stable, rocky portion of the stream channel.

Limited traffic on this improved ford crossing has both minimal impact on the streambed and on sediment production.

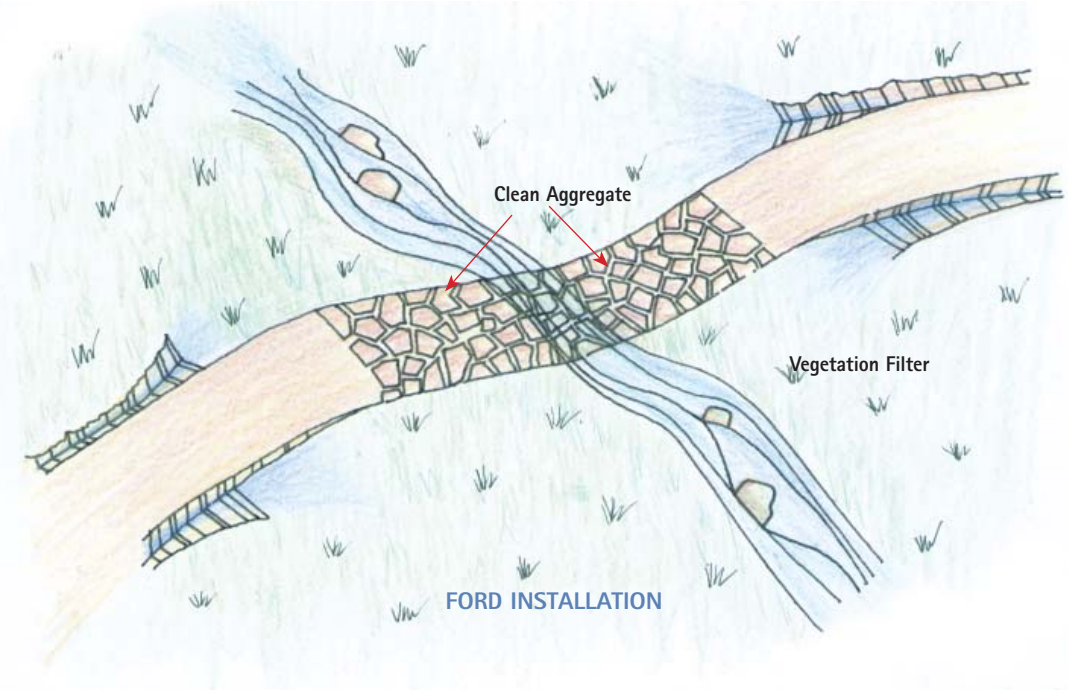
Concrete planks, fastened together and stretched across the streambed, provide an "improved" ford crossing.

Where should a Ford be Located?

A bedrock stream bottom is ideal for a ford location. Otherwise, the bottom should be armored with suitable rock or concrete planks (pictured above).

The size and shape of instream rock can indicate the minimum size of armor rock required to resist downstream movement. It should be bigger than what you see in your stream bottom. Angular rock is preferred, because it resists movement by interlocking. Do not restrict fish passage.

Gently sloping, stable streambank approaches are preferred. Approaches should be rocked to minimize erosion when driving in and out of the ford. Where practical, approaches should be at right angles to the stream. Approaches should dip into and out of the stream, creating a concave shape that ensures the stream cannot be diverted out of its natural channel and down the road.



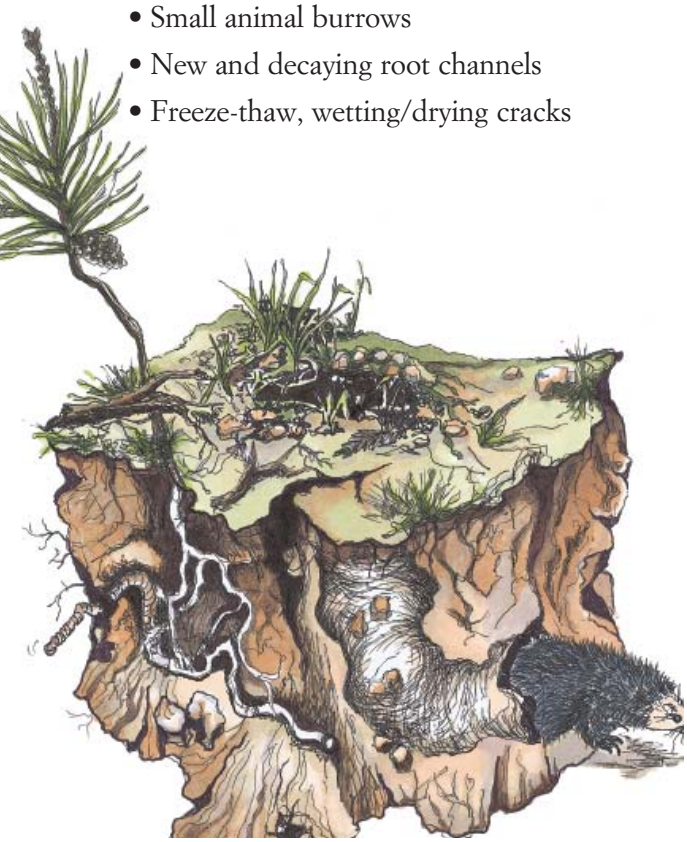
Forest Soil

What is Forest Soil Made of?

- Openings, called pore space, filled with oxygen and water
- Nutrients used by plants and animals
- Clumps of soil called aggregates
- Mineral particles
- Plant and animal matter, both living and dead

Soil Pore Space is the Result of:

- Tiny cracks and crevices between soil aggregates
- Earthworm passageways
- Small animal burrows
- New and decaying root channels
- Freeze-thaw, wetting/drying cracks



Why is Pore Space so Important?

- Rain, snowmelt water and air enter the soil through pore space.
- Soil gasses escape into the atmosphere from soil pores.
- Tree roots grow through pore space, using water, oxygen and nutrients.

Take a Look at Forest Soil ...

1. Pick up a handful of forest soil. Clear away the litter and decomposing layer and scoop up the mineral soil. Try not to squeeze it.

Look closely and notice that half or more is solid material, the rest is pore space.

The pore space is filled with a combination of air and water depending on how moist the soil is.

2. Now squeeze that handful of soil. Because it's wet, it will form a lump in your hand. Dry soils do not form a lump.

3. What was once a handful of moist soil is now compacted.

- The solid particles of soil have been squeezed together.
- The pore space is reduced.
- If you try to pick up soil from a skidder track, you'll find it has also been compacted.

4. Now try to pick up a handful of soil that has been rutted or compacted. You'll probably have a harder time prying loose a handful. Why?

Different soil types have different textures. Fine textured soils are susceptible to compaction, while coarse textured soils are not so easily compacted.

Use this basic test to determine the susceptibility to soil compaction.

Soil Erosion and Compaction

#6 Tractor skid where compaction, displacement and erosion will be minimized. Avoid tractor or wheeled skidding on unstable wet or easily compacted soils.

What is Soil Compaction and Rutting?

Compaction is the compression or squeezing of soil to the point that pore space is reduced.

Rutting, or displacement, refers to the depressions left in soil from heavy equipment.

Compaction and displacement reduce the infiltration capacity of the soil and increase surface runoff during rain and snowmelt events.

Soil Erosion can occur when ground vegetation is disturbed during timber harvest and the surface of the soil has been displaced or compacted. Surface runoff erodes soil particles, which can be moved downslope and into streams.

The Degree of Soil Compaction, Displacement and Erosion Depends on:

- Type of soil. Compaction and displacement can occur on all types of soil. However, fine textured soils are generally more susceptible than coarse textured gravel soils.
- Soil moisture. Compaction increases with soil wetness, but it occurs when soils are well below saturation.
- The amount of force and vibration applied to soil.
- The number of passes made over the soil.
- The condition of existing ground vegetation.
- The season of operation and weather conditions.

What Influences the Potential for Erosion?

Different soils have different properties and a combination of parent material and subsequent soil particle size, shape and the way the particles are bonded together influences the risk of erosion. The type of harvest and the equipment used will influence how much soil disturbance and erosion will occur.

Use the Soil Risk Matrix below to help you evaluate the soil erosion potential relative to the type of timber harvest and harvesting equipment you are planning to use (see pages 47-53).

Soil Type		Clearcut			Partial Cut		
Slope	Soil Erosion Index	Skid	Forward	Cable	Skid	Forward	Cable
0-10%	High	2	2	N/A	2	1	N/A
	Medium	2	1	N/A	1	1	N/A
	Low	1	1	N/A	1	1	N/A
10-20%	High	3	2	1	2	2	1
	Medium	3	1	1	2	1	1
	Low	2	1	1	2	1	1
20-30%	High	4	2	1	3	2	1
	Medium	3	2	1	3	1	1
	Low	2	1	1	2	1	1
30-40%	High	4	3	2	4	3	2
	Medium	4	2	1	3	2	1
	Low	3	1	1	2	1	1
40% +	High	5	4	2	5	4	2
	Medium	5	4	2	4	3	2
	Low	3	2	1	3	2	1

Erosion Risk Matrix Legend:

1=Low Risk 2-3= Moderate Risk 4-5= High Risk

Soil Erosion Index from Parent Material (adapted from Pfister & Sherwood):

High	Moderate	Low
Granitics	Schist	Argillite/Quartzite
Alluvium	Soft/Hard Sediments	Metamorphic
Lacustrine	Basic Igneous	

Higher soil erosion risk dictates that more extensive skid trail drainage BMPs will be needed to limit erosion and sediment delivery.

Harvest Systems

Timber Harvest Planning

#6 Plan timber harvest in consideration of your management objectives and the following:

1. Soils and erosion hazard identification

2. Rainfall

3. Topography

4. Silvicultural objectives

5. Critical components (aspect, water courses, landform, etc.)

6. Habitat types

7. Potential effects on water quality and beneficial water uses

8. Watershed condition and cumulative effects of multiple timber management activities on water yield and sediment production

9. Wildlife habitat

Which Harvesting System?

There are Five Different Timber Harvesting Systems:

1. Cut-to-length harvesting
2. Whole tree harvesting
3. Hand logging
4. Cable logging
5. Helicopter logging

Harvest site terrain influences the choice of a logging system. On gentle terrain, tree processors and forwarders, tractors and skidders, and even horses can be a logical choice. On steep terrain, cable harvesting equipment is used. Each logging system is described in the following pages.

#7 Use the logging system that best fits the topography, soil type, and season, while minimizing soil disturbance and economically accomplishing silvicultural objectives.

#6 Use the economically feasible yarding system that will minimize road densities.

#17 Use the logging system which integrates the appropriate slash treatment methods to protect water quality on the site.

A timber harvest plan must consider the long-term effects of harvesting on all forest resources. Before any timber harvest, ask the following questions:

QUESTION: When combined with other harvests and road construction in the watershed, will there be a detrimental effect on water yield and increase in sediment?

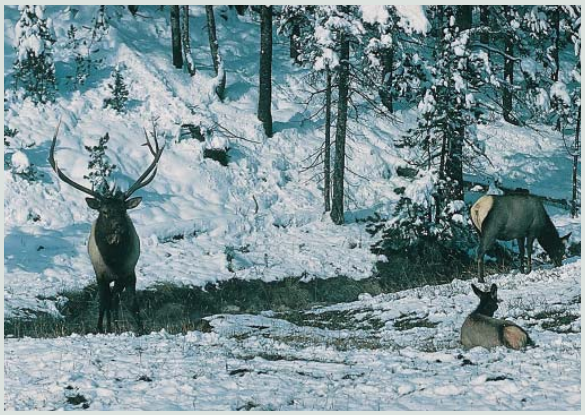
Are there soils present with a high potential for compaction and/or erosion?

Do I understand the topography – slopes, drainages, streams and other physical features?

Are there riparian and wetland plants indicating areas that require special attention? (See page 9)

QUESTION: How will the harvest affect wildlife habitat? For example, will the alteration of elk habitat displace elk use of the area?

What accommodations have been made to protect wildlife habitat?



QUESTION: What kind of forest will be grown after the harvest, and how quickly will the site be reforested?

What kind of slash treatment and site preparation will be necessary? (See pages 54-55)

Cut-To-Length Harvesting

The processor severs, delimbs and cuts trees into logs that are sorted and stacked in the forest. The forwarder picks up the logs in the forest and transports them to trucks.

Advantages
- Leaves slash (tree branches and tops) in the forest.
- Minimizes the need for access roads and log landings.

Topography Considerations
- Mostly limited to terrain with less than 40 percent slopes.

Soil Considerations
- Preferred system where soils are susceptible to compaction.
- Minimizes soil disturbance by confining machines to designated trails.
- Slash stays in the forest and acts as fertilizer.

Forest Stand Considerations
- Efficient method for commercial thinning.
- Moves short logs out of the forest rather than long logs - good for tight tree spacing.
- Useful for reducing wildfire hazard.

Equipment Used
- Tree processor
- Forwarder

Slash Disposal
- Slash is handled efficiently by the carpet of slash left by the processor.
- Usually complies with slash hazard requirements without additional treatment.

Reforestation Considerations
- Preferred in stands where additional tree seedlings are not wanted.

Economic Considerations
- Fewer roads may reduce overall harvest costs.
- This machinery is expensive and availability may be limited, but rising fuel costs make these fuel efficient machines a more attractive option.

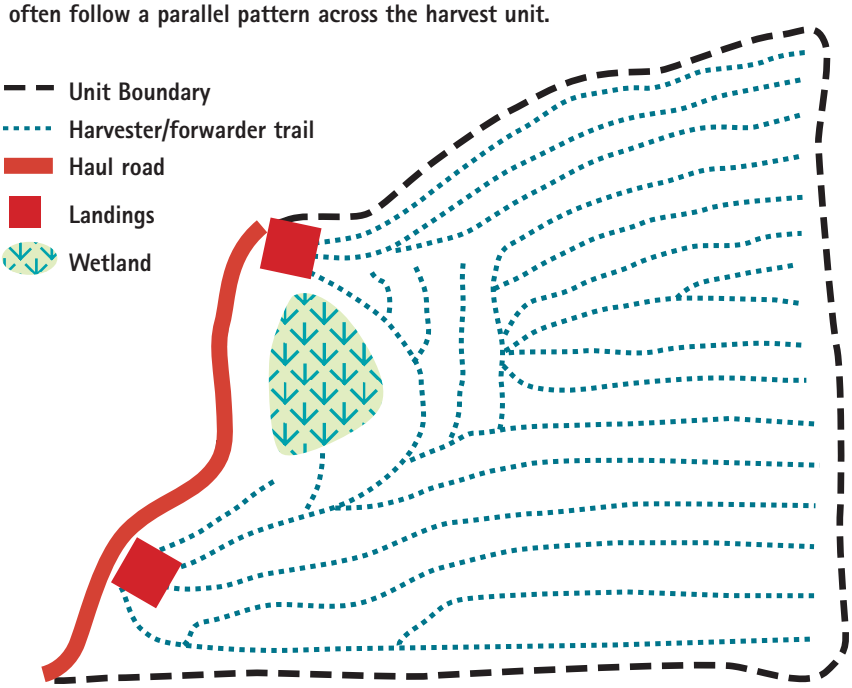
Single grip processors reach out 30-40 feet, cut a tree, strip the limbs, cut the stem into computer programmed lengths, and lay the logs on the ground, all in less than one minute. These machines travel on the carpet of tree tops and limbs they leave.

Forwarders follow behind the harvester, using the same slash carpet, picking up logs and delivering them to the landing. They can economically travel long distances, reducing the need for haul roads.

Logs can be offloaded from the forwarder directly to log trucks.

Typical Harvest Layout

Designated harvester/forwarder trails are approximately 60 feet apart and often follow a parallel pattern across the harvest unit.



Whole Tree Harvesting

A feller-buncher cuts and piles small bundles of trees. A tractor drags the tree bundles to the landing with limbs and tops attached to the stem.

Advantages

• Slash (tree tops, limbs or rotted portions of logs) is brought to the landing or roadside where it is piled and burned.

Topography Considerations

• Can be used on slopes up to 50 percent.

• Haul roads are usually at the bottom of the logging area.

Soil Considerations

• Potentially more soil disturbance than cut-to-length harvesting.

• A greater portion of the area is covered by machines as they cut, stack, gather and drag whole trees to the landing or roadside.

• Skid trails can become trenched and compacted from repeated use.

Forest Stand Considerations

• Efficient method for stand conversion without clearcut

Equipment Used

• Feller buncher

• Crawler tractor or skidder with grapple

• Stroke-boom or dangle-head delimber

• Log loader

Slash Disposal

• Slash piles are conveniently burned at a later time.

• Sometimes slash is returned to the forest and distributed (see page 55).

Reforestation Considerations

• Dragging tree bundles leaves a seedbed for natural seeding.

Economic Considerations

• Operating on steeper ground raises the harvest cost.

• Longer skid distances increase costs.

• Bunching trees reduces costs for handling small diameter trees.

A feller buncher severs trees and lays them in bunches with limbs and tops attached. Bunches are oriented with tree trunks facing downhill.

A crawler tractor or skidder with a grapple picks up bunched trees and drags them to a landing or roadside. Some grapples can swing 180 degrees, making it easier to operate in tight spaces.

The stroke-boom delimber operates at the landing or roadside, removing tree limbs and top, cutting the stem into logs and stacking them.

In addition to loading log trucks, the loader is used to pile tops, branches and log chunks for burning.

#7 Locate skid trails to avoid concentrating runoff and provide breaks in grade. Locate skid trails and landings away from natural drainage systems and divert runoff to stable areas.

#7 Limit the grade of constructed skid trails on geologically unstable, saturated, highly erosive or easily compacted soils to a maximum of 30 percent. Use mitigating measures, such as waterbars and grass seeding, to reduce erosion on skid trails.

#7 Tractor skid when compaction, displacement and erosion will be minimized. Avoid tractor or wheeled skidding on unstable, wet or easily compacted soils and on slopes that exceed 40 percent unless operation can be conducted without causing excessive erosion. Avoid skidding with the blade lowered. Suspend leading ends of logs during skidding whenever possible.

#14 Ensure adequate drainage on skid trails to prevent erosion. On gentle slopes with slight disturbance, a light ground cover of slash, mulch or seed may be sufficient. Appropriate spacing between waterbars is dependent on the soil type and slope of the skid trails. Timely implementation is important.

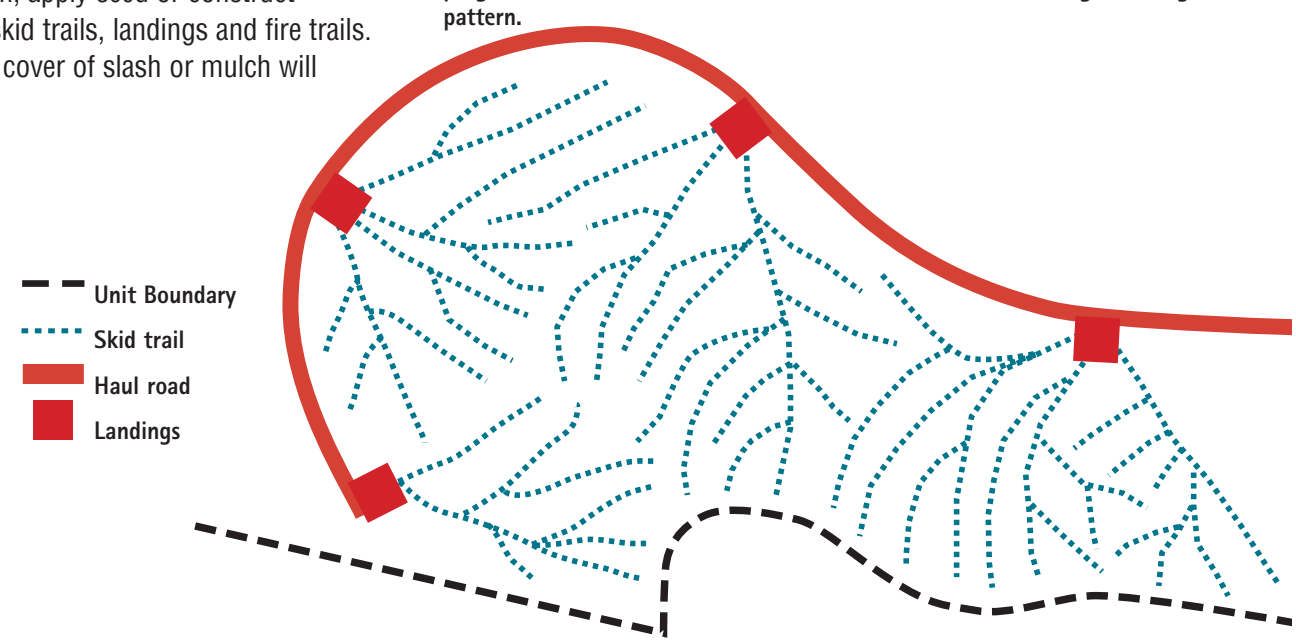
#14 When existing vegetation is inadequate to prevent accelerated erosion before the next growing season, apply seed or construct waterbars on skid trails, landings and fire trails. A light ground cover of slash or mulch will retard erosion.

As much as 40 percent of an area may be covered with skid trails if they are not planned and marked in advance. Soil disturbance can reduce the soil's ability to grow trees. Avoid "go-anywhere" skid trails.

Planning can help avoid steep skid trails on slopes greater than 30 percent with highly erosive soils. Always install waterbars on skid trails as needed and use slash filters (see page 30).

Typical Harvest Layout

The main skid trails should be planned and marked in advance. As the harvest progresses, other skid trails lead into the main skid trails, making a herringbone pattern.



Hand Harvesting

Advantages
- Adaptable to smaller harvest locations.
- Generally less costly equipment.

Topography Considerations
- Can be used on slopes up to 50 percent.
- Haul roads are usually at the bottom of the logging unit.

Soil Considerations
- Designated skid trails confine machines to predesigned locations and reduce soil disturbance.
- Multiple trips on the same skid trail can result in a trench.
- Soil disturbance can be minimized by widely spaced skid trails. This requires hand pulling winch line to reach logs that are further from the skidder.

Forest Stand Considerations
- Gives maximum flexibility to a variety of stand management goals.

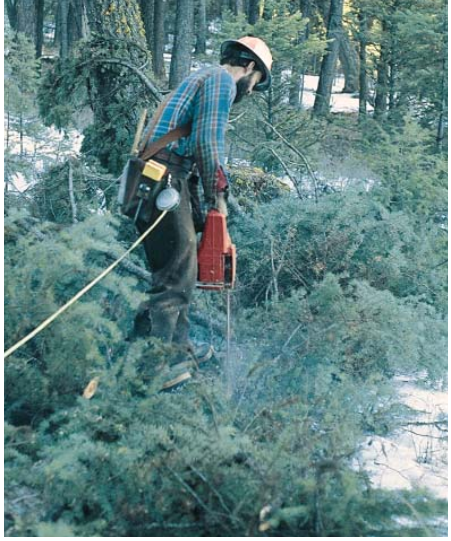
Equipment Used
- Chainsaw
- Log skidder
- Log loader

Slash Disposal
- Allows for lop and scatter of slash in the forest.
- Alternatives to lop and scatter are pile and burn or whole tree harvesting.

Reforestation Considerations
- Results in ground scarification, creating locations for natural regeneration or hand planting.

Economic Considerations
- Often more labor intensive.
- Generally, more roads are necessary.

#7 Design and locate skid trails and skidding operations to minimize soil disturbance. Using designated skid trails is one means of limiting site disturbance and soil compaction.



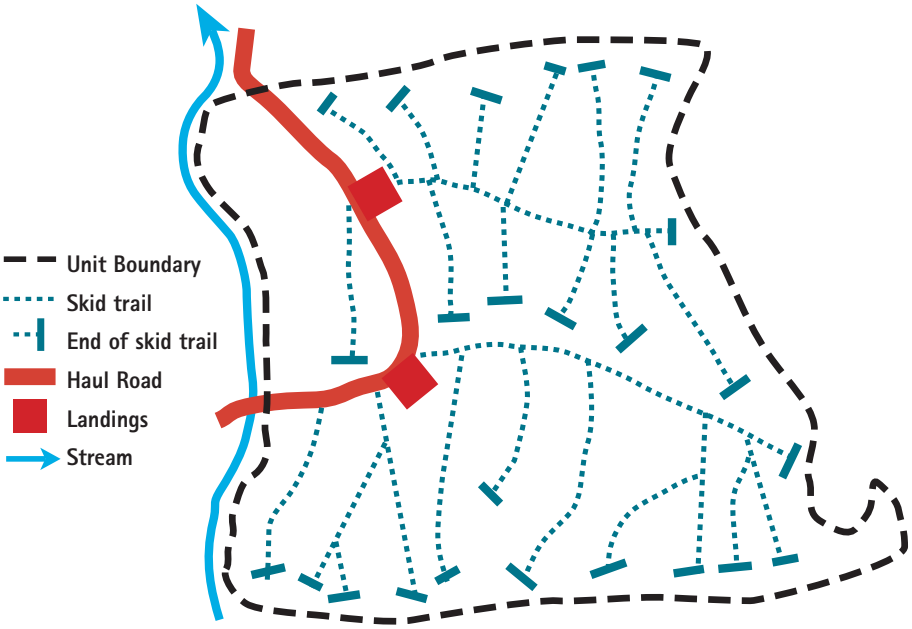
Tree felling, limbing and bucking are done with chainsaws.

#8 Consider the potential for erosion and possible alternative yarding systems prior to planning tractor skidding on steep or unstable slopes.

Logs are dragged by a skidder from the forest to a log landing. Rubber tired skidders or crawler tractors remain on the skid trail and winch line and chokers pull the logs to the machine. Limbing and bucking are done with chainsaws.

Once at the landing, a self-loading log truck loads the logs for delivery to the mill.

Typical Harvest Layout



Skid trails should be planned and marked in advance. They often follow a parallel branching pattern as shown. By winching logs from greater distance, skid trails can be farther apart, reducing the number of designated skid trails and minimizing the soil impact by equipment.

Cable Yarding Harvesting

This system pulls logs to a log landing using a steel cable.

Advantages

- Allows harvesting to occur on steep ground.
- Eliminates the need for skid trails.
- Haul roads are usually at the top of the logging unit.

Topography Considerations

- 55 percent slopes and greater.
- Concave slopes allow more cable deflection and greater system efficiency

Soil Considerations

- Significantly reduces soil compaction and disturbance.
- All equipment is confined to roads.

Forest Stand Considerations

- Used in partial cuts and clearcuts.
- Difficult for commercial thinning.
- Difficult to reach sideways from the cable corridor.

Equipment Used

- Cable yarder
- Log loader
- Chainsaw

Slash Disposal

- More complicated than other systems.
- If clearcut, may require broadcast burning (see page 55).

Reforestation Considerations

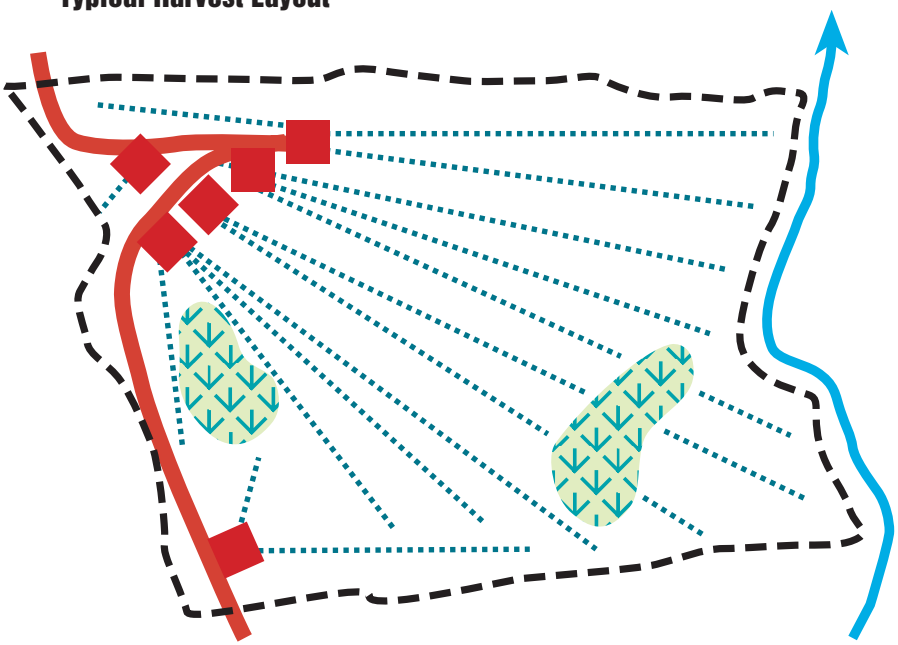
- Cable harvesting is effective in partial cuts and clearcuts.

Economic Considerations

- Typically twice the cost of ground-based harvest systems.
- More labor intensive.

Trees are hand felled, limbed and bucked with chainsaws. A cable is stretched from the yarder to another point on the ground (stump, tractor, etc). The cable carries the logs over the terrain with either one end suspended or fully suspended, from where the tree is felled to the roadside or log landing. From there, logs are loaded on trucks. Yarders can reach out 1,000 to 2,500 feet.

Typical Harvest Layout



- Unit Boundary
- Cable corridor
- Haul Road
- Landings
- Wetland
- Stream

This example of cable yarding shows both fan-shaped and parallel corridors extending out from the roadside landings. Logs can be carried over streams and canyons. Generally, logs are usually pulled uphill, but can also be moved downhill.

Helicopter Harvesting

A harvest system once used exclusively for large, high value timber, helicopter harvesting has now become more common for smaller logs.

Advantages

- Ability to harvest visually sensitive, inaccessible areas or areas that cannot be harvested with other systems. Areas with high recreational use, special wildlife habitat, riparian/wetlands and geologic hazard locations are common.
- Slash (tree branches and tops) remains in the forest.
- The number of miles of roads may be reduced.

Topography Considerations

- It can be used on any type of terrain.

Soil Considerations

- Preferred where soils are susceptible to compaction.
- Minimizes soil disturbance because logs are fully suspended.

Forest Stand Considerations

- Efficient, but costly, method of commercial thinning.
- Moves short logs out of the forest rather than long logs due to weight limitations.
- Works well to reduce wildfire hazard

Slash Disposal

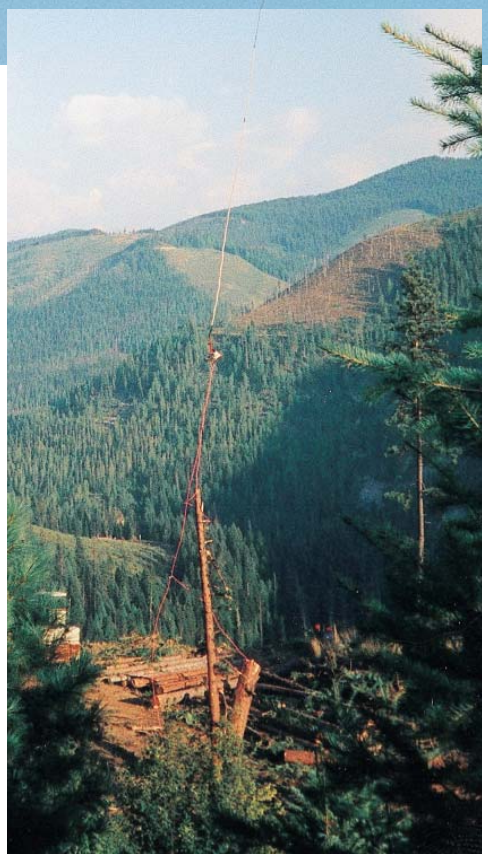
- Typically, lop and scatter is used to reduce fire hazard. If inadequate, additional methods may be necessary and will be very costly due to no road access.

Reforestation Considerations

- Ground scarification may not be adequate for successful regeneration.

Economic Considerations

- Fewer roads are needed.
- Sophisticated machinery used and larger crew size typically results in costs that are 3 to 4 times more than ground-based systems.
- High costs can make entire sales uneconomic when log markets take a downturn.



Equipment Used

- Logging helicopter
- Log loader
- Bulk fuel handling equipment
- Maintenance support equipment

This KMAX Heavy Lift helicopter has a payload capacity of 6,000 pounds. Flight distances are kept to .5 to 1.5 miles. Longer distances are more costly. Optimum payload of each load makes the operation economic.

Log landings are receiving logs every three minutes or less. Adequate space for drops is essential.

At the log landing, incoming logs are quickly trimmed and measured.

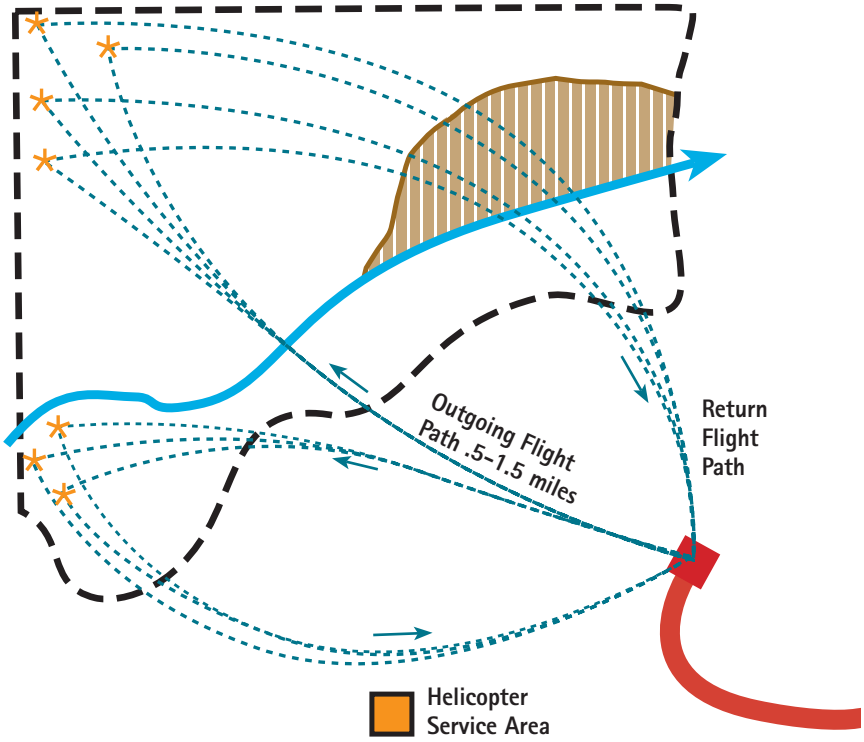
#11 Minimize the size and number of landings to accommodate safe, economical operation. Avoid locating landings that require skidding across drainage bottoms.

#11 For each landing provide and maintain a drainage system to control the dispersal of water and to prevent sediment from entering streams.

A swing boom log loader sorts logs according to species, size and quality and loads them on trucks.

Helicopter service areas are located away from log landings. Operators are required to provide fuel truck containment in case of accidental spills. Portable water tanks and pumps are ready for fire emergencies.

Typical Harvest Layout



- Unit Boundary
- Flight path
- Haul Road
- Landings
- Cliffs/sensitive soils
- Stream
- Log pick-up point

Slash Treatment/Site Preparation

#6 Rapid reforestation of harvested areas is encouraged to re-establish protective vegetation.

Why treat slash and prepare the site?

- To reduce the wildfire hazard from logging debris.
- To prepare the harvest area for a new forest.
- To leave enough organic matter for the next forest.

Problems of slash treatment and site preparation

- Soil can be exposed to erosion, especially on steeper slopes.
- Soil can be compacted and/or rutted (see page 45).
- There can be loss of organic matter needed for the next forest.

Too much slash cleanup. When the forest is swept clean, soil erosion, compaction and soil displacement (moved and rutted soil) interfere with a successful next forest.

To reduce wildfire risk, slash is piled and burned, or otherwise treated to reduce the fire hazard. However, the foliage and branches left after a harvest are a source of organic matter and fertilizer needed for the next forest. Slash also protects soil from erosion. A balance is required between the need to reduce fire hazard and the need for organic matter and soil protection.

Starting a new forest requires patches of exposed mineral soil on the forest floor. Seed from nearby trees germinates best in bare mineral soil. Mechanical slash treatment and site preparation must create some bare soil while minimizing erosion. At the same time, heavy equipment can compact soil, especially wet soil (see page 45).

Slash Treatment/Site Preparation On Gentle Terrain

How to achieve the balance between the need for mineral soil and organic matter while minimizing erosion and reducing fire hazard.

Method 1: Machine Pile and Burn Slash

After logs are removed, excavators or tractors equipped with a brush blade are used to pile slash for burning. Machine piling reduces the fire hazard and creates a seedbed for the new forest. Some landowners like the look of a "cleaned-up" forest. But this method is expensive, not recommended on compactible soils, and may not provide the next forest with the organic matter needed for best growth.

******** Minimize or eliminate elongated exposure of soils up and down the slope during mechanical scarification.

******** Carry out brush piling and scarification when soils are frozen or dry enough to minimize compaction and displacement.

What to Avoid When Machine Piling

Work around small trees, low brush and large logs.

Stay clear of wet areas where compaction, soil rutting and erosion can result.

******** When piling slash, care should be taken to preserve the surface soil horizon by using appropriate techniques and equipment. Avoid use of dozers with earthmoving blades - use a brush rake.

******** Scarify the soil only to the extent necessary to meet the resource management objectives. Some slash and small brush should be left to slow surface runoff, return soil nutrients and provide shade for seedlings.

Method 2: Whole Tree Harvesting

Whole tree harvesting brings the entire tree, branches and top, to the landing. There, the branches and tops are removed, piled and burned. All slash is brought to a central location, and efficiently disposed of, leaving a clean forest floor. But important soil organic matter is removed, and the disturbed forest floor may be susceptible to erosion.

Method 3: Whole Tree Harvest but Return Slash

The same machines that bring whole trees to the landing can carry a portion of the slash back and scatter it on the forest floor. This method makes slash fertilizer available to the next forest and keeps soils protected from erosion, especially on skid trails. The fire danger is minimal because the slash is crushed and close to the ground. Some landowners object to the appearance.

Method 4: Lop and Scatter

Tree branches and top are left at the stump. To meet hazard reduction standards, this material must be cut or lopped, so it lays close to the ground for rapid decay. This method protects and nourishes forest soils, but some landowners object to the appearance, while others claim it inhibits livestock and wildlife movement. However, while this is an inexpensive slash treatment for light harvests, it can leave a fire hazard in heavy harvest areas. Lop and scatter, combined with machine trampling, may be a remedy for heavy slash areas.

Slash Treatment/Site Preparation On Steep Terrain

******** Carry out scarification on steep slopes in a manner that minimizes erosion. Broadcast burning and/or herbicide application is the preferred means for site preparation, especially on slopes greater than 40 percent.

#40 Limit water-quality impacts of prescribed fire by constructing waterbars in firelines, not placing slash in drainage features and avoiding intense fires unless needed to meet silvicultural goals. Avoid slash piles in the SMZ when using existing roads for landings.

Method 1: Broadcast Burning

On steep slopes, broadcast burning can be an effective site preparation technique, eliminating the problem of soil disturbance and controlling heavy fuels. By carefully monitoring moisture conditions, a fire can be set that consumes only part of the slash, leaving large material in place. Afterwards, the site is either planted or allowed to regenerate naturally. Whole tree harvesting (see page 48) and air quality requirements are making broadcast burning more rare.

Winter freeze-up is an opportunity for low-impact logging. With proper precautions, work in sensitive areas can be done without affecting water quality.

Winter Logging Precautions

Winter logging on frozen ground is one way to avoid soil, watershed and riparian and wetland area damage. However, there are potential problems with winter logging.

1. Failure to mark riparian and wetland areas prior to snow cover results in damage when operating unknowingly in these areas.

2. Failure to install adequate erosion control prior to spring runoff.

**** Conduct winter logging operations when the ground is frozen or snow cover is adequate (generally more than one foot) to prevent rutting or displacement of soil. Be prepared to suspend operations if conditions change rapidly and when the erosion hazard becomes high.

**** Consult with operators experienced in winter logging techniques.

**** Consider snow-road construction and winter harvesting in isolated wetlands and other areas with high water tables or soil erosion and compaction hazards.

**** In wet unfrozen soil areas, use tractors or skidders to compact the snow for skid road locations only when adequate snow depth exists. Avoid steeper areas where frozen skid trails may be subject to erosion the next spring.

Winter Logging Tips

Compact skid trail snow before skidding logs. This avoids damage to soils that may be wet or not completely frozen.

SMZs can be totally obscured by heavy snow. Avoid confusion by marking boundaries ahead of the first snow.

Winter thaws can happen. Don't take chances with soil compaction, rutting and possible erosion. Expect to shut down temporarily.

Waterbar all skid trails prior to spring runoff. If prohibited by frozen ground, install waterbars during dry summer months. Slash on skid trails can act as temporary erosion control until waterbars are installed.

To provide a winter road grade capable of heavy hauling, always remove snow cover. Deep-frozen road surfaces have tremendous strength. Don't let snow cover insulate and weaken the road. Plow during cold weather.

Road surfaces deteriorate rapidly under heavy hauling and thawing temperatures. This road surface is starting to break up. Hauling should be suspended or limited to colder portions of the day.

Winter Road and Drainage Considerations

**** For road systems across areas of poor bearing capacity, consider hauling only during frozen periods. During cold weather, plow any snow cover off of the roadway to facilitate deep freezing of the road grade prior to hauling.

**** Before logging, mark existing culvert locations. During and after logging, make sure that all culverts and ditches are open and functional.

**** Use compacted snow for roadbeds in unroaded, wet or sensitive sites. Construct snow roads for single-entry harvests or for temporary roads.

**** Return the following summer and build erosion barriers on any trails that are steep enough to erode.

**** Be prepared to suspend operations if conditions change rapidly and when the erosion hazard becomes high.

See Road Maintenance, page 32 for tips on snow berm breaks for drainage.

Trying to rely on memory can be expensive when it comes to culvert maintenance. Mark them before the snow falls to avoid logging machinery damage and avoid sidecasting into streams during snowplowing.

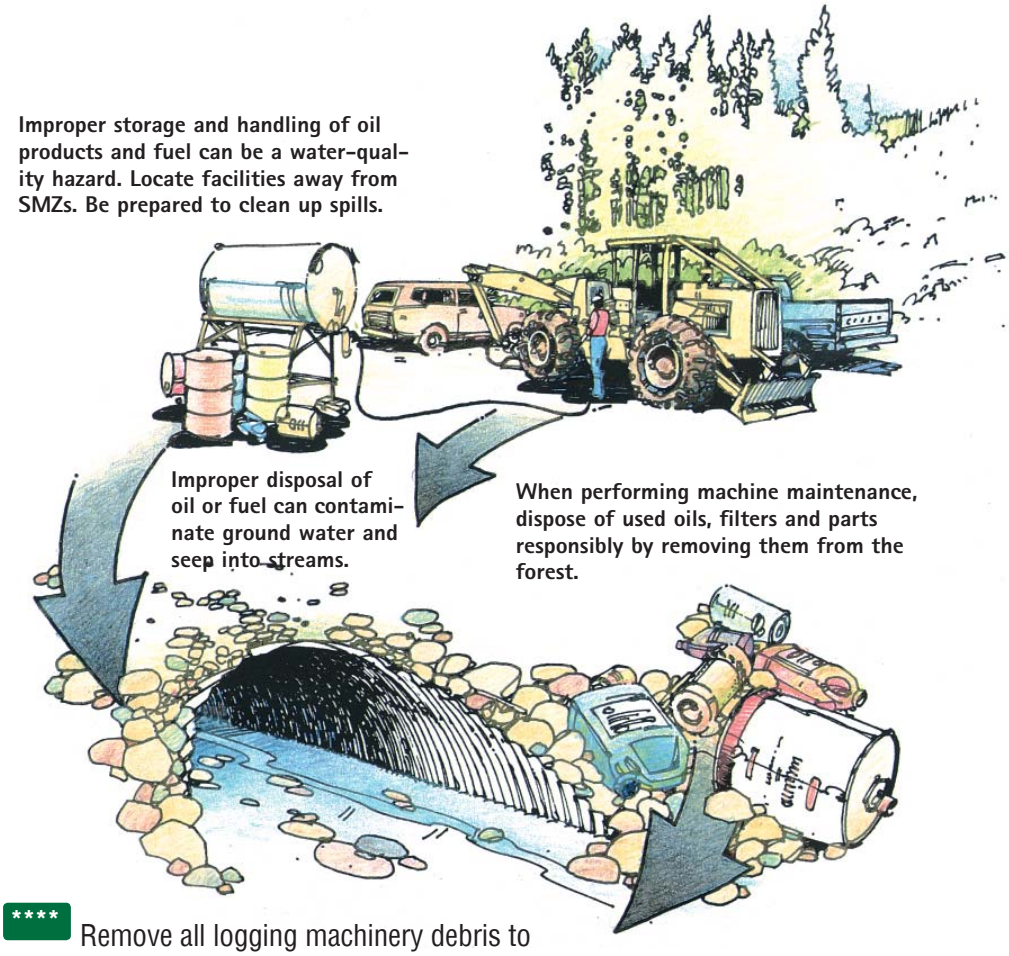
Hazardous Substances

"Hazardous or toxic material" means substances which by their nature are dangerous to handle or dispose of, or a potential environmental contaminant, and includes petroleum products, pesticides, herbicides, chemicals and biological wastes.

**** Know and comply with regulations governing the storage, handling, application (including licensing of applicators) and disposal of hazardous substances. Follow all label instructions.

#4 Develop a contingency plan for hazardous substance spills, including cleanup procedures and notification of the state Department of Environmental Quality. A spill prevention and countermeasure plan is required by federal law for storage of more than 1320 gallons and state law requires the reporting of spills over 25 gallons.

Spill kits are used to contain hazardous materials.

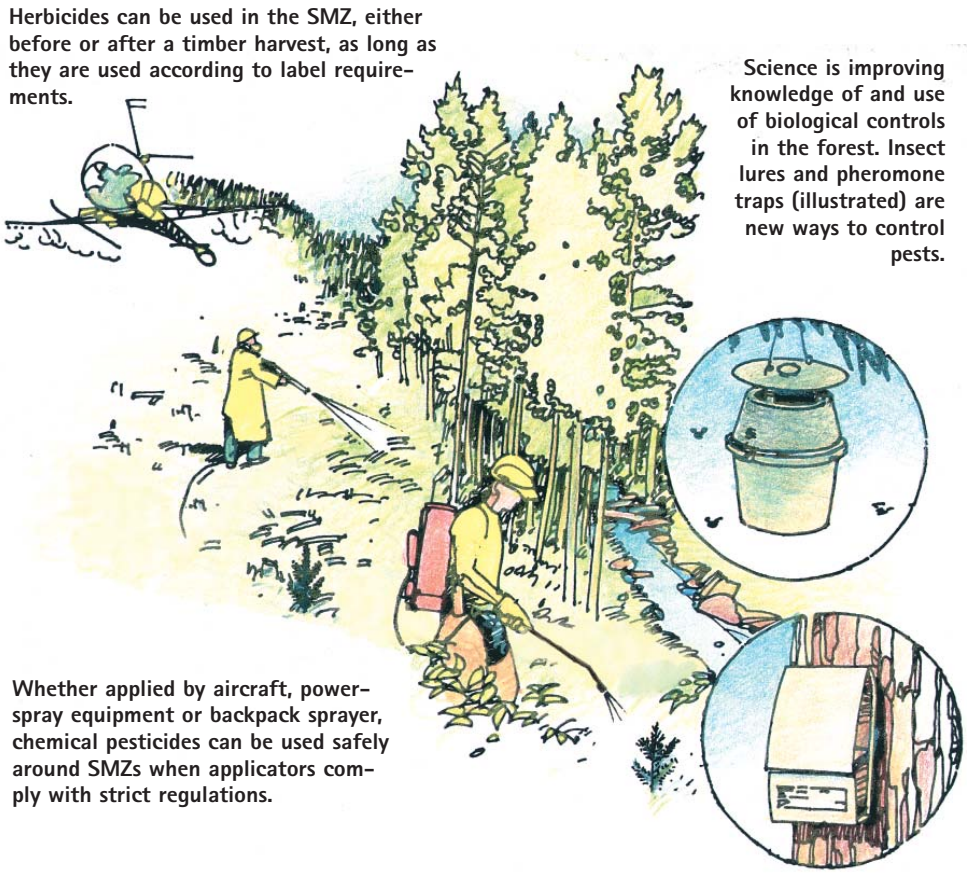


**** Remove all logging machinery debris to proper disposal site (tires, chains, chokers, cable and miscellaneous discarded parts).

Pesticides/Herbicides

#35 Use an integrated approach to weed and pest control, including manual, biological, mechanical, preventive and chemical means.

**** To enhance effectiveness and prevent transport into streams, apply chemicals during appropriate weather conditions (generally calm and dry) and during the optimum time for control of the target pest or weed.



Prescribed Burning and Wildfire Suppression

During prescribed burning and wildfire suppression operations, ground vegetation is removed by fire and the soil surface is disturbed by the construction of fire control lines.

 # 40 Protect soil and water from prescribed burning effects, by maintaining soil productivity, minimizing erosion and preventing ash, sediments, nutrients and debris from entering surface water.

Avoid intense fires which may promote water repellency.

Retain or plan for sufficient ground cover to prevent erosion of burned sites.

 # 42 After an intense wildfire or prescribed burn, emergency rehabilitation may be necessary to minimize the the loss of soil, prevent the deterioration of water quality and to mitigate threats to life and property.

Firelines and Roads

 # 41 Stabilize all areas that have significantly increased erosion potential or drainage patterns altered by suppression activities by:

Installing waterbars and other drainage diversions in fire roads, firelines and other cleared areas.

Seeding, planting and fertilizing to provide vegetative cover.

Spreading slash or mulch to protect bare soil.

Repairing damaged road drainage.

Clearing stream channels of debris deposited by suppression activities.

Scarification may be necessary to encourage percolation on excessively burned soils.

Dozers and excavators can be used to rehabilitate firelines and restore road drainage features, to safeguard water quality and prevent erosion.

For most fireline rahbilitation, some hand work will be necessary to ensure water quality protection.

Avoid excessive soil disturbance and scarification when building fire control lines

Revegetation of Areas Disturbed by Harvesting Activities.

On some harvest areas, it is desirable to artificially revegetate disturbed areas, to prevent soil erosion and subsequent water quality impacts. It is also advantageous to quickly revegetate disturbed areas to prevent the germination of any noxious weeds that may be present. The best solution of all is to allow native vegetation to recover on the site, but often, supplemental seeding is necessary.

#13 Establish vegetative cover on disturbed sites to prevent erosion and sedimentation.

Seed disturbed areas with an appropriate seed mix for the forest type in question. Use mixtures of quick growing annual grasses and perennial native species.

Apply seed to disturbed areas as soon as harvesting activites are over and before disturbed soil 'hardens up'.

Place slash on skid trails and landings to aid with vegetation recovery and to help avoid soil erosion.

Consider using straw mulch and other supplements to ensure adequate and prompt vegetation recovery around streams.

Use fertilizer sparingly to avoid polluting streams.

Contact your local Conservation District or NRCS office for complete details about appropriate seed mixes and seeding rates for your area. The complete text of BMP # 13 includes more information on seeding rates, suitable native shrubs and other aspects of revegetation.

Recommended Grass Seed Varieties (*= native) X = Suitable for Forest Zone							
	1	2	3	4	5	6	Zone #
Bannock or Critana thickspike wheatgrass*	X	X					
Ephriam or Fairway crested wheatgrass	X						
Manska or Luna pubescent wheatgrass	X						
Hycrest crested wheatgrass	X						
Reliant or Oahe intermediate wheatgrass	X						
Greenar intermediate wheatgrass			X				
Pryor slender wheatgrass*	X						
Vavilov Siberian wheatgrass	X						
Sodar streambank wheatgrass*	X	X					
Tegmar dwarf intermediate wheatgrass	X						
Rosana western wheatgrass*		X					
Whitmar beardless wheatgrass		X	X				
Goldar or Secar bluebunch wheatgrass*	X						
Durar hard fescue		X	X	X			
Cover sheep fescue*	X	X	X	X			
Kenmont tall fescue		X	X	X		X	
Pennlawn chewings red fescue			X				
Redondo Arizona fescue*		X	X	X			
Nevada bluegrass*		X	X				
Sherman big bluegrass*	X	X	X				
Reubens Canada bluegrass			X	X			
Alpine bluegrass*					X		
Manchar smooth brome		X	X				
Regar meadow brome		X					
Bromar mountain brome*			X	X			
Garrison creeping foxtail		X	X	X		X	
Meadow foxtail		X	X	X	X		
Latar orchardgrass		X	X	X			
Climax timothy		X		X	X	X	
Alpine timothy*				X	X		
White Dutch clover			X	X			
Alsike clover						X	
Tretana birdsfoot trefoil			X			X	
Tufted hairgrass*					X	X	
Annual wheat, Rye, or Oats should make up at least 10% of any seed mix							

Site Adaptation Zones

Zone 1 - Dry Douglas fir, limber pine, lodgepole and ponderosa pine habitat types.

Zone 2 - Moist ponderosa pine and Douglas fir habitat types.

Zone 3 - Moist Douglas fir on well drained soils.

Zone 4 - Subalpine fir/Engleman spruce habitat types.

Zone 5 - High, cold environments and timberline habitat types.

Zone 6 - Wet sites and poorly-drained soils - typically spruce and subalpine fir.