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Riparian Management in Forests of the Continental Eastern United States

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Chapter 15

Harvesting Options for Riparian Areas

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"My objective is not to stop the ax but to guide it so the forest is used wisely."
Gifford Pinchot — as quoted by Max Peterson, Chief, U.S. Forest Service, 1985.

As the chapters in this book demonstrate, forested riparian areas provide many important functions and values, including wildlife habitat, recreation, water, timber production, and cultural resources. The high soil moisture and nutrient availability in these areas make them highly productive sites for plant and animal life, including trees, and this, coupled with the fact that many of these areas have gone unharvested due to difficult terrain and wet soil conditions, makes them a valuable source of wood products. Much of the current debate about riparian areas is focused on the level of timber harvesting that should occur within these areas.

Riparian management areas are defined to recognize that management practices may need to be modified to protect and enhance the diverse functions and values of the riparian ecosystem. They are not intended to be zones of management exclusion, although the best prescription may be to exclude active management in some cases. Minimizing disturbance is the primary objective when developing strategies for timber harvesting operations in riparian areas. Limiting disturbance helps reduce the potential for erosion, and minimizes impacts on shade and other terrestrial and aquatic habitat factors.

Harvest Planning for Riparian Areas

Timber harvesting includes felling, processing, extracting, sorting, loading, and hauling of timber products. Harvest operations usually require that haul roads, landing areas, and skid

trails be constructed and maintained to access the resource. All these operations have the potential to negatively impact riparian resources and should be carefully planned to protect the riparian area functions (Meek 1994). Many states now have operational guidelines, commonly called Best Management Practices (BMPs), that are designed to protect water quality and a limited number of other resources (MI DNR 1994; MN DNR 1995; WI DNR 1995). The guidelines for locating roads, skid trails, landings, buffer strips, and water crossings are particularly pertinent to harvesting operations in the riparian area.

Landowner objectives, terrain, and season of operation are also significant factors that need to be considered when planning harvesting operations. A well-developed harvest plan using appropriate BMPs will lead to harvesting operations that protect water quality and other riparian functions and values, remove forest products efficiently and profitably, promote sustainable forest growth, and maintain aquatic biodiversity. It is also important to meet with operators on-site before harvesting to make sure provisions of the harvest plan are well understood. Active supervision during operations is critical to ensure that the plan is being properly implemented.

Each site and harvest operation is unique and should have a separate harvest plan. The need to consider each site individually is illustrated by an example from the Monongahela National Forest where past harvesting practices and activities on adjacent private land resulted in stream sediment at or above critical levels (Baumgras 1996). Harvesting operations that produced just a small amount of sediment may have harmed populations of native brook trout. Although harvesting with conventional systems could comply with state water quality BMP requirements, the unique attributes of this site required alternative harvesting systems to protect riparian resources. Consequently, much of the wood on this large timber sale was yarded with helicopters.

Access

Forest roads that are poorly located, constructed, or maintained are one of the largest sources of nonpoint source pollution from forest management activities (Patric 1976). Roads on steep slopes, erodible soils, or stream crossings hold the greatest potential for degrading water quality. Effective road construction techniques minimize the disturbance to the natural flow of water over the landscape and ensure the structural integrity of the road embankment (Kochenderfer and Helvey 1987; Swift 1984c). The goal is to provide a simple road structure of adequate strength to support heavy vehicle traffic while providing drainage structures for water to pass through the road corridor at normal levels. Choices about road construction standards and maintenance activities will be influenced by site characteristics, the value of the resources served, the season of use, and the intended duration of use of the road. State BMP manuals generally contain road building recommendations

Operating equipment in or near perennial or intermittent stream channels may add sediment directly to streams (Lynch and Corbett 1990; Martin and Hornbeck 1994). Stream crossings that are poorly located or constructed may erode streambanks. As roads approach a stream crossing, proper road drainage is critical to avoid depositing sediment into streams. Stream crossings must be designed, constructed, and maintained to safely handle expected vehicle loads and to minimize stream disturbance.

A variety of environmentally and economically acceptable temporary or portable stream and wetland crossing options can be used during timber harvesting and hauling operations (Blinn, et al. 1998). Increased awareness of options that reduce damage to streams and wetlands can help minimize the cost of protecting these valuable resources. State BMP manuals include sections on stream crossing options that are permitted in that state and make recommendations for their proper installation and use. Before installing a stream crossing, contact the appropriate water resource regulatory agency in your state to determine if permits are required.

Buffer Strips

Many state BMPs recommend the use of filter and shade strips around water bodies (MI DNR 1994; MN DNR 1995; WI DNR 1995). The main purpose of a filter strip is to provide a zone of infiltration to slow down the water and to help keep sediment and other polluting agents from washing into the water body (Castelle et al. 1994). Activities conducted within the filter strip must minimize the exposure of mineral soil to help ensure that vegetation is continuously present on the site. The recommended width of the filter strip varies with slope length and percent. A shade strip helps maintain moderate water temperatures by minimizing the warming of the water body, reducing the warming of overland flow into the water body, and moderating temperatures in the filter strips (O'Laughlin and Belt 1995).

The amount of timber left within a shade strip depends on site conditions and the management goals. Many states have adopted minimum operational widths with minimum tree stocking levels and special water protection measures. These Riparian Management Zones (RMZs) are usually narrower than the variable width Riparian Area defined in Chapter 2. Managing shade-tolerant species generally results in a higher residual tree volume. Filter and shade strips can be a valuable source of coarse woody debris for the terrestrial and aquatic systems. They can also provide energy to the water body, serve as a visual screen, and provide cover and travel corridors for wildlife species. Where RMZ management goals include a desire to establish long-lived species, minimum soil disturbance levels may be exceeded to provide adequate regeneration. Many long-lived species, which are important sources of coarse woody debris and downed logs, require mineral soil exposure to naturally regenerate. Check with the appropriate organizations before deviating from the recommended

guidelines; sedimentation is still a concern even where minimum disturbance levels of filter strips are purposely exceeded.

Terrain

Riparian areas are sometimes thought of as low-lying flat areas adjacent to water bodies. However, the terrain can vary considerably within a riparian area. In mountainous areas, stream courses will be found in the bottom of valleys or gullies, the sides of which can often be very steep (Hornbeck and Reinhart 1964). In steep terrain, especially sites with a relatively dense network of small intermittent streams, harvesting, road building, and skid trail construction, even located far from larger perennial streams and more typical riparian areas, can still contribute to stream sedimentation. Therefore, protection of aquatic habitats in mountainous terrain may require careful planning and conduct of forest operations on sites not normally classified as riparian.

Even in gentler terrain typical of the Midwest, many streams and rivers have created deeply cut river valleys and channels that have very steep slopes. Steep terrain in riparian areas will increase the potential for erosion, sedimentation, and mass movement of the hillside. Bank instability can be a serious problem in some areas, especially where residual basal area is low (e.g., clearcuts) and the residual root mat breaks down before the new stand can become established. Slope and natural surface roughness are the main factors determining how far sediment and other contaminants are transported to the water body. The steeper the terrain, the further away from the water body that impacts from operations can be felt, making it necessary to consider terrain when defining the riparian area. The combination of wet and steep ground on the same site can lead to significant negative impacts on the site if harvesting operations are not carefully planned and conducted.

Seasonal Effects

Seasons of the year have a significant impact on harvesting operations in riparian areas throughout the Eastern United States. Precipitation in all parts of this region varies over the course of the year, making soil moisture levels vary considerably from season to season. This causes the bearing capacity and trafficability of the soil to vary by season. In many areas, winter or spring flooding can be extensive. Vernal ponds also have wet soils adjacent to them requiring caution with equipment operation. Aust (1994) summarized recommendations for improving the operation of harvesting systems on wet sites:

- Recognize difficult site conditions — Use available topographic, soils, and vegetation maps, on-site inspection, as well as GIS, to identify difficult site characteristics before beginning harvesting operations.

- Plan better — Use better harvest planning techniques before operating on a site. Time the harvest on very wet sites to occur during dry or frozen periods that permit equipment operation. Lay out designated skid trails on the drier, higher strength soils. If stream and/or wetland crossings are required, follow state BMP guidelines. Paint the boundaries of the RMZ so that operators can identify them.

- Use existing equipment better — Use existing equipment and technologies properly to minimize the impacts of harvesting on wet sites. Low ground pressure technologies, such as wide tires, dual tires, bogies, tire tracks, and tracked machines, can be used to reduce impacts. A common problem with these technologies is the tendency of some operators to build larger loads and extend their operation into areas they would not normally traffic with conventional equipment. Without proper planning and control of the harvesting operation, this can result in more serious impacts than would have occurred with standard equipment.

- Develop new technologies — As new technologies are developed, their potential application to sensitive sites needs to be evaluated. Aerial systems, tracked machines, and other low ground pressure concepts have been developed that may be lower impact alternatives for harvesting on wet sites. Also, cut-to-length technologies offer an option for conducting low impact harvesting within these areas. These alternative technologies will be discussed further later in this chapter.

Temperature regimes vary greatly over the Continental Eastern United States. Ground in the northernmost areas may be frozen over part of the year, while ground in the southernmost areas may never freeze. Areas in between have the potential for frozen ground, but occurrence is highly variable. Even where air temperatures remain below freezing for extended periods, deep snow can reduce frost penetration. Packing the snow may be required in these situations to produce or maintain frozen ground conditions (Blinn and Dahlman 1995). Harvesting operations in the region have to be highly mobile and flexible to take advantage of dry and frozen ground when it does occur.

Operational Site Impacts

Many riparian areas have a gradient of site conditions ranging from upland conditions away from the water body to conditions typically characterized as wetlands near the water. With

the exception of unstable soils on steep slopes, the most serious constraints placed on selecting and operating harvest systems (except possibly for unstable soils on steep slopes) are the conditions occurring closest to the water body where high soil moisture is the predominant consideration. Extensive research has studied the impacts of forest harvesting on wetland functions and values, particularly in the Southern United States where extensive wetland forests contain large volumes of high-value hardwood timber (Aust 1994; Aust et al. 1995). Much of this work can be drawn upon to discuss appropriate harvest systems for riparian areas of the Eastern United States in unfrozen ground conditions.

The interactions between machines, soil, and soil moisture are the primary determinants of site disturbance during forestry operations (Reisinger and Aust 1990). Soil moisture governs the effect of machinery traffic on the soil. Dry soils generally have sufficient strength to resist most compaction and rutting. Moist soils are weaker, making them vulnerable to compaction. Compaction increases soil bulk density and decreases the size of large soil pores, resulting in poor soil aeration and drainage. As moisture content increases water fills the soil pores, reducing soil strength and shear resistance. When trafficked, very wet soil ruts rather than compacts. Rutted soils have slow rates of soil aeration and drainage and can serve as a conduit through which sediment can move toward a water body.

Potential impacts of harvesting on wetland soils were reviewed by Aust (1994). Studies have shown that compacted and rutted skid trails slow internal water movement in both moderately well drained soils and poorly drained soils. However, poorly drained soils already have low rates of hydraulic conductivity before being compacted or rutted. Harvesting effects on water quality for these wetland soils were found to be minimal as long as forestry BMPs were properly applied.

In several studies, compaction and rutting were found to reduce site productivity. Loss in site productivity can result in a reduction in the type, amount, and structure of terrestrial biodiversity, leading to direct economic losses over the life of the stand. Severe rutting on sites may have an immediate economic effect for the operator. The difficult operating conditions result in decreased harvest system productivity, lowering profitability. Also, machines subjected to severe operating conditions require more maintenance and repair than similar machines operating in good conditions, further reducing profits.

Site disturbance by harvesting equipment can also harm cultural resources, such as cemeteries, archeological sites, traditional-use areas, and historic structures. The displacement of soil during harvest operations can break fragile artifacts, disrupt human remains, and make interpretation of the artifacts difficult when they are moved from their original setting. Erosion resulting from soil disturbance can do the same and may destabilize building foundations.

Overview of Equipment Systems

Harvesting systems for riparian areas need to be able to perform the same functions as systems operating on upland areas. Felling, delimbing, bucking, in-woods transport, sorting, and loading all need to be accomplished efficiently and economically. Operating in the riparian management zone requires special considerations of soil and water impacts when selecting and operating the harvesting system. Avoiding the direct operation of equipment within the RMZ is the most effective way to minimize impacts. If possible, operational activities such as loading, fueling, and maintenance should be located outside the RMZ. Roads and skid trails should be located outside the RMZ whenever practical.

Ground-based harvesting systems are still the most commonly used because they have a definite productive and economic advantage over alternative systems available at this time. However, ground-based systems have the greatest potential for site disturbance and associated degradation of site and water quality.

Carrier Vehicles

All mobile harvesting equipment has some sort of vehicle base that serves as the platform for mounting the operating hardware and provides the mobility of the unit. It is the interaction between the carrier vehicle and the ground that causes most of the impact to the site. The characteristics of carrier vehicles are generally independent of the operating equipment they carry, and thus can be discussed independently of the functions they perform in the harvesting operation.

Low ground pressure vehicles are generally recommended when operating in RMZs. Reducing the pressure applied to the soil limits compaction and rutting, which can decrease plant growth, adversely affect surface and subsurface water movement, and accelerate erosion. Rubber-tired carrier vehicles for harvesting machinery are still by far the most popular option because of their proven performance, productivity, lower purchase and operating costs, and flexibility. However, the negative side of conventional rubber tired machines is their propensity for rutting and site damage.

Many studies have looked at the use of rubber-tired forest harvesting machines, primarily skidders, and documented the rutting potential of these machines (Koger et al. 1984; Sirois and Hassan 1985; Murosky and Hassan 1991). Reisinger and Aust (1990) reviewed several studies that investigated the feasibility of using wide and dual tire set-ups on skidders and found that most studies concluded that these tires do have the potential to provide better flotation and improved traction. However, use of these tires may still damage the site if used too long into the wet season. Skidders equipped with dual tires have been found to be a more acceptable and less expensive alternative to wide tires (Rummer et al. 1997). Contractors also

have the flexibility of removing the outer tires when soil conditions are dry enough to operate without the dual tires.

Before the development of rubber-tired skidders, tracked machines were the most commonly used ground skidding equipment. Lower ground pressure, increased traction, and reduced site disturbance are still advantages of tracked machines. Disadvantages include lower productivity and higher operating and maintenance costs. Tracked machines used in logging are typically machines designed for construction uses and modified for forestry uses. Typical crawler tractors and excavators are the machines generally adapted to forestry uses. Many crawler tractors, together with a winch and logging arch, are seen in use as skidders, quite often on steep terrain where the inherent stability of the crawler tractor is an advantage, or on wet sites where the lower ground pressures aid trafficability.

Excavators have commonly been adapted to use as feller-bunchers. The inherent stability of tracked excavators, the long reach of the boom that minimizes the need to move the machine to each tree to be felled, and the low ground pressures exerted by these machines make them natural choices for feller-bunchers. The success achieved with modified construction excavators in forestry uses has led to the design and development of a new generation of tracked rotating platform machines specifically for forestry (Figure 15.1).

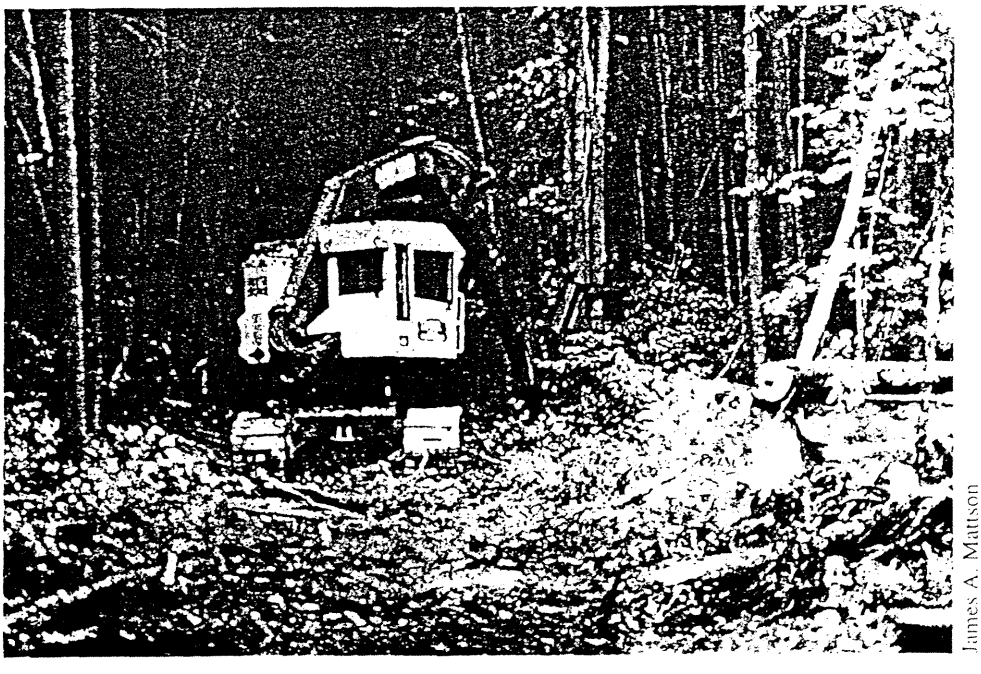

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Figure 15.1 Typical feller-buncher utilizing a tracked rotating platform carrier designed for forestry applications.

An inherent problem with this machinery is the wide tail (back end) of the rotating platform that extends outside of the tracks, making it difficult to operate in narrow corridors. Recent developments have led to "zero tail swing" machinery where the entire rotating platform is able to stay within the width of the tracks.

The low speeds and high maintenance costs of steel track crawler tractors led to the development of flexible track machines intended to increase speeds and lower costs while maintaining the advantages of tracks. Stokes (1988) found that flexible track machines were commonly used in skidding applications in wetlands in the South. Skidders with flexible steel tracks generally have a front-drive sprocket (in contrast to the rear-drive sprocket rigid track machines) that reduces track tension. This allows the track to conform with uneven ground conditions and provides better traction and lower ground pressures. High initial and maintenance costs have limited the use of these machines, but the concept is still viable. Major manufacturers have introduced tractors with rubber tracks. These machines are currently being used in agriculture, but the potential for forestry use is significant.

The development of forwarder technology to a high level of sophistication in Scandinavia over the last two decades has led to the availability of another alternative for carrier vehicles in forest harvesting machines. The forwarder chassis has become the carrier of choice for several harvest machines, notably harvesters that use the forwarder chassis for mobility and will attach a harvester head to the boom for felling and processing. The trafficability of the forwarder chassis, particularly those versions that have double-axle bogie wheel assemblies either on just the rear or on both front and rear axles, is extremely good (Figure 15.2). The

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Figure 15.2 Double-axle Bogie assemblies on a clam bunk skidder.

low ground pressure, low speed, and high load capacity of this combination make it especially well suited to harvest operations on sensitive sites, such as riparian areas.

Felling Equipment

Mechanized felling is used for a larger percentage of wood production each year; the notable exception to this trend is hand felling large timber on steep terrain. Mechanized felling methods are safer, more productive, and permit better integration with the other components of modern, generally fully mechanized, harvesting operations. Various designs of shears, chain saws, and circular saws have been incorporated into commercially available felling/bunching heads. For harvesting near recreational areas or home sites, the felling head should be selected to minimize the noise created in the felling operation, as well as the likelihood of the felling head throwing debris a significant distance from the machine. A shear or chain saw unit will generally operate more quietly with less chance of throwing debris than a circular saw unit.

The most significant consideration for mechanical felling in riparian areas is the carrier vehicle of the unit. Rubber-tired feller-bunchers are generally considered to be faster moving machines with lower initial and operating costs than other alternatives. However, rubber-tired feller-bunchers generally have fixed felling heads that require them to drive to each tree to be felled. This need to drive to each tree and the need to move rapidly to maintain production rates raise the possibility of significant disturbance across the entire site when a rubber-tired feller-buncher is used on soft ground. Residual stand damage is also more likely as the machinery moves back and forth through the stand.

Tracked swing-to-tree feller-bunchers are preferred when site disturbance is a major consideration, such as in a riparian area. Although more costly and slower moving, this type of feller-buncher can fell several trees from one location, reach into sensitive areas without entering them, and pile wood away from the water body, all of which will help minimize the area impacted. These machines can also be quite productive because travel time is minimized. Some tracked feller-bunchers have been developed to operate on slopes up to 50%. The lower ground pressure they exert and the smaller percentage of the site being trafficked are significant advantages for these machines in riparian areas. However, reduced soil disturbance may make it more difficult to establish species that require soil scarification.

Extraction Equipment

Rubber-tired skidders are still the most common means of moving wood from the stump to a landing. Cable skidders and grapple skidders are both widely used. The cable skidder, in particular, has significant advantages on difficult sites because it can be kept out of sensitive

areas and its winch can be used to pull wood to the machine. This feature can be used to limit the area trafficked, thereby reducing impacts. A cable skidder can also drop its load when it bogs down in difficult conditions, then move ahead and winch the load through the difficult area.

Cable skidders tend to be narrower than grapple skidders, making them more maneuverable and reducing impacts to residual trees. They are also better suited to staying on designated trails and working in steeper terrain. Alternatives to wire rope are being examined to help overcome problems associated with operator fatigue when pulling the cable over distances longer than about 50 feet.

Grapple skidders are generally more productive than cable skidders when operating conditions are favorable. Their advantage comes from the operator not having to get down from the machine to secure the load. Grapple skidders also tend to come in much larger sizes, which under the proper operating conditions, leads to greater production rates. In either case, the trafficability of the skidder in difficult conditions can be greatly improved by the use of dual or wide tires as discussed earlier. Grapple skidders are not recommended for use on steep slopes because of stability and safety concerns.

Skidding, by definition, involves dragging trees or logs across the ground. Where site disturbance is a major concern, forwarding may be a good alternative. Forwarding consists of carrying the wood, usually in the form of cut-to-length logs or pulpwood, out of the stand on the back of a machine. Site disturbance from the wood dragging on the ground is eliminated, a cleaner product is delivered to the landing, and landing size requirements are relatively small. On the negative side, a forwarder can create greater ground pressure, which increases the potential for soil compaction and rutting. An additional disadvantage is that conventional forwarders traffic more of the area than a cable skidder. This effect is somewhat offset by the forwarder's ability to move the same volume of wood in fewer trips because of larger average load size.

The soft ground and steep terrain in riparian areas, can make aerial extraction systems a viable possibility. Skyline cable yarding is an extraction system uniquely suited to harvesting timber on steep slopes and unstable soils (Baumgras et al. 1995). In its simplest form, this system uses a yarder with a tower and two cable drums. One cable is a skyline that is strung between the tower and the far end of the site where it is anchored to a holding point such as a large tree or stump. A carriage runs along the skyline and carries the mainline with chokers out to the logs. Logs are pulled into the yarder by the mainline. The main advantage of this system is that heavy machines do not traverse the site, and the need for skid trails is reduced. Steep terrain in riparian areas can be beneficial to the operation of a cable yarding system, providing the change in elevation needed to get good deflection, or lift, on the cable system.

Helicopters are also a technically viable harvesting system for riparian areas. The system is very expensive to operate, but causes virtually no site disturbance. High timber values or high values on other resources such as water quality or aquatic habitats are required to justify helicopter logging, and the planning and logistical support for the operation are critical. Balloons, another option, have not been widely examined. Also, walking machines are under

development and may soon be used in the woods. Because extraction and transport equipment can cause both on-site and in-channel resource damage, its use requires diligent planning.

Processing Equipment

Traditionally, processing functions such as delimbing, topping, and bucking were done with chain saws, either at the stump or at the landing. The trend toward mechanization has resulted in machinery to handle these functions. Except for cut-to-length harvesters that process harvested trees at the stump, most of the mechanical processing equipment is designed to work at the landing. Delimbers, slashers, and whole-tree chippers are intended to be landing-based machines with the felled trees brought to them from the stump area, generally by skidders. Some combination of feller-bunchers, skidders, roadside delimbers, and slashers is the most common full-tree harvesting system currently in use. A major advantage of this type of system for harvesting sensitive sites is that much of the operation is done at the landing rather than the stump area, which is the area most vulnerable to site disturbance. Disadvantages are that full-tree skidding can increase site and residual stand disturbance and results in nutrients being taken off-site. Full-tree skidding also removes most sources of coarse woody debris from the riparian area.

The other common configuration for mechanizing processing functions is in combination with felling in a harvester. A harvester combines the functions of felling, delimbing, topping, and bucking into one machine. A harvester can be built onto a rubber-tired or tracked carrier, rigidly mounted to the front of the carrier, or boom mounted on the carrier. Regardless of the configuration of the harvester, the result is harvested wood that is delimbed, cut-to-product lengths, and piled in the stump area. A significant advantage of harvesters for working in sensitive areas is their ability to deposit the delimbing residue they generate in front of the machine and thus build a slash mat to travel on. This capability can greatly reduce site disturbance and rutting. Forwarders are generally used to collect the processed wood and transport it to the landing or roadside where it can be piled or loaded directly onto haul trucks.

Harvesting Systems

Regardless of the individual pieces of equipment involved, the total harvest system needs to be able to function as a whole, producing wood products in an economically efficient manner while protecting the diverse functions and values of the ecosystem (Stokes and Schilling 1997). With the continuing trend toward increased mechanization, most harvest systems used in the near future will likely be some variation of the full-tree system or a shortwood cut-to-length (CTL) system.

The full-tree system consists of feller-bunchers, skidders, processing equipment such as delimbers, slashers, and whole-tree chippers, haul trucks, and support equipment. Selection of specific equipment will depend on several factors such as species and size of trees being harvested, size of harvest areas, products, production levels, terrain, soil type, and ground moisture. General advantages of full-tree systems include (Gingras 1994):

- Full-tree systems can efficiently handle a variety of tree sizes.
- The individual machines in full-tree systems are generally mechanically simpler, which leads to less down time.
- Owning and operating costs are generally lower for full-tree systems because less labor is required and production is high.
- Operation of the machines in a full-tree system is simpler, thus requiring less operator training and quicker attainment of maximum productivity.

The CTL system consists of pairs of harvesters and forwarders matched to their productive capacity. Selection of harvester specifications, such as cutting capacity, can be further refined to match the machine with the available stands to be harvested, optimizing use of the technology. General advantages of the cut-to-length systems include (Richardson and Makkonen 1994):

- CTL systems can efficiently work small tracts because there are only two machines to move between jobs, and minimal landing space is required on small sites.
- The CTL system is well suited to partial cutting because it processes the harvested trees to shortwood lengths at the stump, minimizing damage to the residual stand.
- The CTL equipment works well in wet areas and on sensitive sites because of its capability to work on a slash mat it produces as it moves through the stand.
- Forwarders can economically work over longer distances because of the larger loads they can carry, reducing the needed road network.
- Well-defined skid trails do not have to be created. The trails that are used can be narrow and meandering.
- Decking areas smaller than typical landings can be used along the roadside.
- The CTL system facilitates product sorting and merchandising.

Special Equipment for Riparian Areas

Working in many riparian areas requires crossing streams or wet and weak soils. The crossing should minimize the potential for sedimentation as well as the obstruction of waterflow and the movement of aquatic organisms. Temporary structures are most often used to facilitate these crossings and protect the environment. Blinn et al. (1998) provide a review of these technologies, which can be divided into temporary stream crossings and wet area crossings (see Chapter 6 for culvert sizing recommendations that allow spawning fish to pass).

Temporary Stream Crossings

Avoid crossing intermittent and perennial streams whenever possible because these locations are the most vulnerable to harvesting impacts on water quality and aquatic habitats. Where avoidance is not practical, the number of crossings should be kept to a minimum. Stream crossing options include fords, culverts, and temporary bridges. A permit may be required in some states to cross some or all perennial and/or intermittent streams. Check with the appropriate regulatory or natural resource agency before establishing any stream crossing.

Fords

A ford is a crossing where vehicles drive directly through the stream. They are inexpensive to install and can result in minimal impacts when constructed, used, and maintained properly. Fords should be used only for short-term or infrequent access. A location with a low flow, a firm base of rock or gravel, and a gentle slope with low-banks is best for a non-frozen ford. Placement of suitable base materials may be necessary if no adequate natural base exists. A trench should be excavated to hold the added base material so it does not extend into the normal channel cross section area, constrict flow, and induce bank erosion at and below the ford site. Sediment from excavation is minor compared to the everyday sediment produced from blocking the channel cross section. Use at least small cobble material or material larger than that found on point bars (an indication of what the streams will carry at bankfull flows). Logs, brush, and soil should not be used in ford crossings because these materials may be carried downstream during high flow periods, causing sedimentation and/or obstructions in the stream channel. Fords should not be constructed during fish spawning, incubation, or migration.

Culverts

A culvert is a structure (usually a large pipe) that allows the stream to flow under the road. Culverts are recommended for some locations where a ford is not, such as streams with steep banks, streams with a soft base, or areas where frequent or extended access is required. The primary disadvantages of a culvert include sedimentation during placement and removal, the potential for the culvert and fill to wash out during high stream flows, and the need to frequently maintain the culvert to avoid blockage. Care must be taken to size the culvert properly to accommodate normal high-water levels (see Chapter 6) and to ensure that it extends to the toe of the fill slope. Cover the culvert with at least 12 inches of road base (24 inches is needed to ensure ponding water upstream of the road for the 25 to 50-year events and avoiding road washout). This depth minimizes damage to the culvert during maintenance of the road surface and distributes the weight of passing vehicles, thus preventing crushing. During installation, compact fill properly to minimize seepage of water through the subgrade. Place the culvert deep enough in the stream channel (about 1/6 of the culvert diameter) to prevent perching which can obstruct fish migration.

Temporary bridges

Temporary bridges provide an excellent means of crossing a stream without disturbing the stream channel (USDA FS 1997). They have been built of timber (native logs or lumber), polyvinyl chloride (PVC) or high density polyethylene (HDPE) pipe bundles, snow or ice, steel, pre-stressed concrete, reinforced used truck trailers, and used railroad flatbed cars. We recommend only the use of bridges that have been engineered to safely carry the intended load. Bridges are commercially available in a variety of lengths and carrying capacities and should last for many years. Although some of these bridges are expensive, the fact that they are reusable brings the cost per use down considerably.

Bridges should be placed on appropriate abutments to help level the structure, to minimize disturbance to the streambank, and to make removal easier (MNDNR 1995). PVC or HDPE pipe bundle crossings function best with geotextile underneath. Geotextile is a fabric mat that allows water to drain through, provides additional support to the crossing, and provides separation from the soil, facilitating removal. A frozen streambed or a snow and ice bridge may work well in the winter in some areas.

Temporary Crossings for Areas with Weak or Wet Soil

Many access roads and skid trails must cross soils with poor bearing capacity (e.g., peat and wet clay). Waiting for the soil to freeze or dry is often not an option. The hauling and placement of fill to stabilize these areas can be expensive and may negatively impact them.

Several alternative methods for crossing these areas are available. Most of these options function best with a nonwoven geotextile under them.

Corduroy is a mat formed from logs, sawmill slabs, or brush placed across the wet area. It is a common method for crossing soft soils because the material used is normally abundant and found on-site. Expanded metal grating can sometimes provide adequate support for crossing soft soils, and it is relatively cheap, reusable, and easy to handle. Other reusable crossing options include wood mats, wood planks, wood pallets, and tire mats. Most of these options can be built from local materials or are commercially available. Although some of these options are expensive and bulky, all are reusable and provide summer access at a much lower cost than building a permanent road.

For any of these options, the surface should be flat (maximum-grade of 3%) and free of high spots (e.g., stumps and large rocks). The length and width of the various options should be sized to meet anticipated loads, soil strength, and installation equipment. On very weak soils with low bearing strength (e.g., muck and peat), the option used may need to be longer and wider than usual to spread the weight over a larger surface area. Most options are best suited for use with hauling and forwarding operations because skidding can cause movement and increased wear of the crossing material.

Conclusions

Forested riparian areas are highly productive and a valued source of wood products and many other resources. Harvesting operations in riparian areas must protect and even enhance the resource functions and values of the riparian zone. Minimizing disturbance is the primary objective when developing strategies for harvesting operations in riparian areas. Operational guidelines, commonly called best management practices (BMPs), have been developed in most states to provide practical guidelines for protecting water quality. BMPs may also provide some level of protection for many other riparian functions and values. Well-developed harvest plans that apply BMPs and timber sale provisions are needed to protect riparian resources while recovering forest products efficiently and cost effectively. It is also important to meet with operators on-site before harvesting to make sure provisions of the harvest plan are well understood. In addition, active supervision during operations is critical to ensure that the plan is being properly implemented.

Ground-based equipment will be the basis of most harvesting systems used in the foreseeable future because of its productive and economic advantages. However, ground-based systems also have the greatest potential for site disturbance and associated degradation of riparian resources. Proper selection and use of equipment features that can lower site impacts, such as wide or dual tires, flexible tracks, and double-axle bogie wheel assemblies, will be essential. Decisions about specific equipment and mitigation strategies to apply must be made on a site-specific basis, considering site conditions, landowner goals, silvicultural

requirements, economic implications, local regulations, and anticipated site and stand impacts. Opportunities to reduce impacts should be fully employed wherever possible (e.g., designated skid-trails or taking advantage of frozen or dry ground). Alternative harvesting systems, such as aerial cable systems, helicopters, balloons, and walking machines, should be further developed to take advantage of their low impact nature in an economically effective manner.

Art Elling

Operating equipment on frozen soils, whether organic or mineral, minimizes soil compaction (roadside loading of black spruce harvested from a frozen peatland in northern Minnesota).

Federal Interagency Restor. Group

Protective measures like this installation of silt fencing actively recognize the link between heavy equipment operations and fishing.

Sandy Verry

Caught and eaten! It's the fishing!