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Temporary Stream and Wetland Crossing Options for Forest Management

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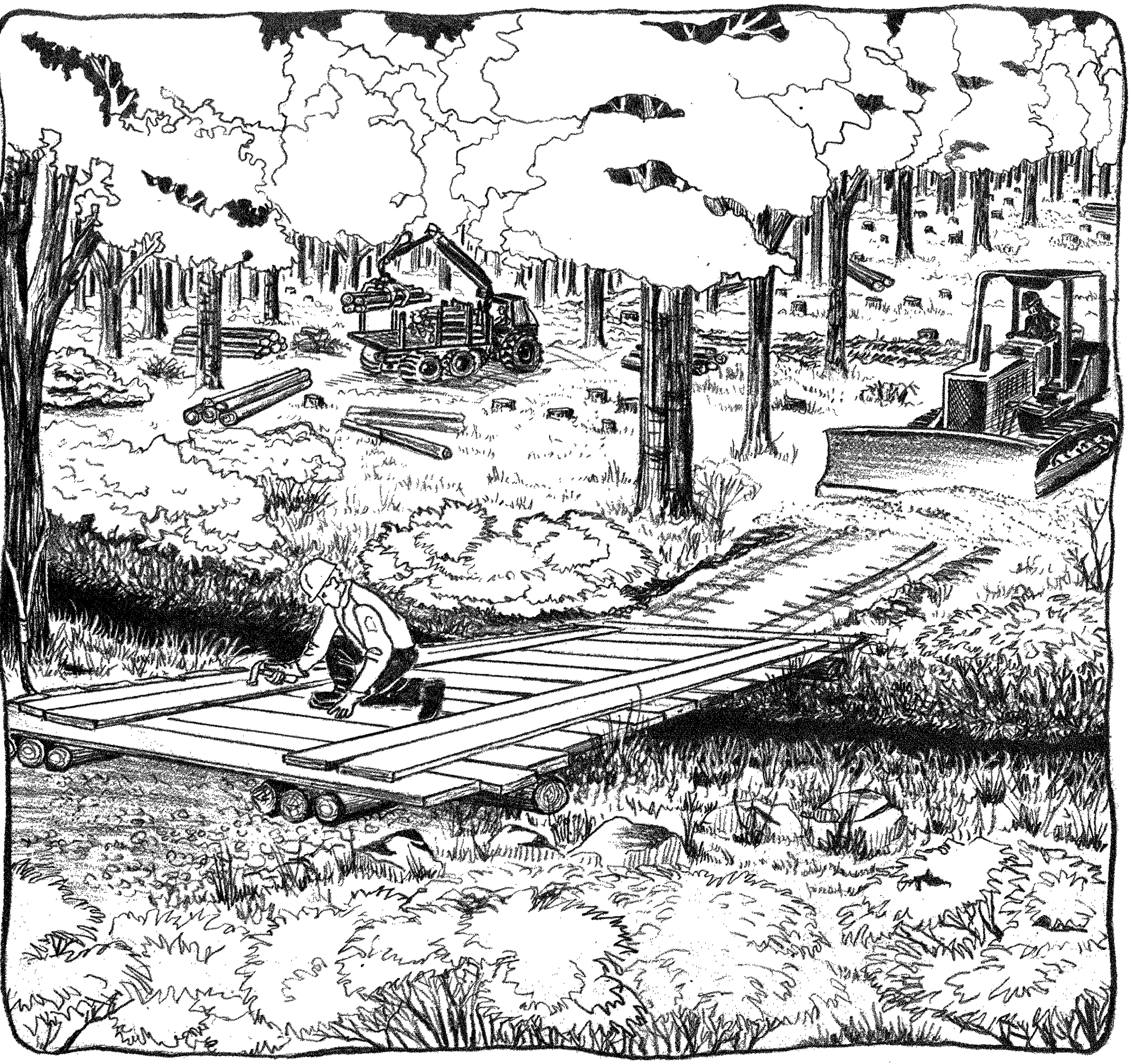

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INTRODUCTION

Expansion of economies and populations worldwide has increased the demand for forest products and other uses of forests. Removing wood products from the forest requires access systems, such as truck roads and skid trails. Roads and trails must often cross streams (fig. 1) and wetlands[1] (fig. 2). The construction and use of these access roads and trails has the potential to negatively impact streams and wetlands directly by soil compaction, rutting, or the placement of fill (fig. 3). Streams and wetlands can also be impacted indirectly by funneling the movement of sediment, debris, and nutrients into the water body or by causing changes in hydrologic flows across the area.

The best way to protect streams and wetlands is to avoid crossing them. If this is not feasible, it is important to minimize and mitigate impacts while using the crossing. For any particular application, selecting a crossing option that is cost-effective for the contractor and/or landowner, that adequately addresses the environmental concerns of society, and that satisfies the wide range of regulatory constraints is becoming increasingly difficult.

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In many areas, fords, culverts, and ice bridges are the types of stream crossings most commonly used, although use of portable bridges is rapidly increasing. Corduroy, permanent fill, and frozen soil are the most common choices for crossing wetlands. While there are numerous other options, lack of information has been an obstacle to expanding the range of options that landowners, land managers, contractors, and regulatory agencies are willing to consider.

The purpose of this paper is to help reduce this obstacle by providing detailed information about a broad range of reusable temporary[2] stream and wetland crossing options. To accomplish this, we have:

- Summarized information about many of the temporary stream and wetland crossing options,
- Reviewed some of the reported environmental impacts associated with using these options,
- Highlighted some of the key points from statutes that regulate stream and wetland crossings in Michigan, Minnesota, New York, Pennsylvania, Wisconsin, Ontario, and Quebec, and
- Identified some research and education needs.

[1] *For the purpose of this report, wetlands are areas that contain soil with poor load-bearing capacity and high moisture content or standing water that are often affected by seasonal fluctuations in water level. Examples include peat, muck, wet mineral soils, or unstable sections of access roads and trails.*

[2] *For the purpose of this report, a temporary crossing is one that is used for a maximum of 3 years before it is removed or rendered unusable.*

Figure 1.—*Stream that may need to be crossed by an access road or trail.*

Figure 2.—*Wetland area that may need to be crossed by an access road or trail.*

Figure 3.—*Rutting that can occur when crossing soft, wet soils.*

Information was compiled through contacts with individual loggers, staff in several forest products companies and land management and regulatory agencies, and through a review of published literature.

The options discussed in this report include both commercial and homemade devices that are either transported to the site or built on-site. Increased use of these options can help minimize the cost of protecting water resources. While the initial price of a reusable temporary option may exceed the cost of a currently used alternative (e.g., a culvert for a stream crossing or fill for a wetland crossing), the fact that it is reusable and that it may be easier to install may make it the lowest cost option in the long-term. Also, some of the temporary options reduce environmental impacts and can be installed and removed more rapidly than the options most frequently used today.

It is likely there are additional excellent crossing options not identified in this paper. It was not possible to identify all available options, and new ideas for crossings and new applications of existing technologies are constantly being developed. We recommend that you contact vendors, contractors, and other sources for more detailed information on local experience regarding costs, installation and removal, the availability of specific options in your area, and additional options not covered in this report.

We also recommend that you compare each vendor's recommendations and specifications to your long-term needs and applications. Seek the advice of a licensed engineer when purchasing a stream crossing product that lacks engineering specifications, when using a product in an application for which it was not designed, or when constructing a crossing yourself. Inspect all products before each installation. Some criteria to consider when evaluating which option(s) to select for your particular application are noted in table 1. Before deciding to install a crossing, be sure to weigh the potential value(s) of the resource within the accessed area against the costs and potential negative environmental impacts.

Additional details and quick reference tables are provided in the Appendices. Appendix 1 contains a list of commercial vendors. Tables summarizing specifications, approximate cost, installation and removal time, and equipment needs are provided in Appendices 2 (stream crossings) and 3 (wetland crossings). All costs and prices presented in this report are in $US unless specified. Arnold (1994) and Mason (1990) also provide excellent overviews of many products, including design specifications, drawings, and photographs. Copstead *et al.* (1997) have also prepared an extensive annotated bibliography of published literature on water/road interaction technologies and associated environmental effects. Appendices 4 (stream crossings) and 5 (wetland crossings) contain additional information for each option according to the categories listed in table 2. Although we recognize that there is some redundancy built into this report, we chose to do this to make it more useful for a number of different applications and users.

Table 1.—*Criteria to consider when selecting a stream or wetland crossing option. Unless otherwise noted, all criteria are appropriate for both stream and wetland crossing options.*

Effectiveness for reducing potential impacts	Local availability
Relative safety of the option	Installation and removal time and costs
Compliance with safety regulations	Number of reuses possible
Compliance with other applicable non-safety regulations, including permitting requirements	Anticipated future need for a particular option
Potential conflicts with insurance coverage	Maintenance requirements
Season(s) of use	Driving surface traction under anticipated operating conditions
Length of time the crossing will be needed	Potential costs avoided, such as the purchase and placement of fill or the need to divert stream flow during a culvert installation or removal
Ability to handle anticipated traffic loads and speeds	Anticipated fluctuation in water level during use
Purchase price or construction cost	Site conditions (e.g., soil type, hydrology, amount of rock present, stream width and depth, volume of water in the stream, types of aquatic life in the stream, permitting requirements, etc.)
Maximum distance of crossing	Potential value(s) of the resource within the area to be accessed
Bridge abutment requirements (stream crossing options only)	Landowner’s management objectives
Availability of engineering specifications, especially for bridging options (stream crossing options only)	Rehabilitation requirements following removal
Ease of transport, installation, and removal with available labor and equipment	

Table 2.—*Informational categories summarized in Appendices 4 and 5 for each stream and wetland crossing option.*

Description of option	Approximate price of materials (March 1998)
Area of application	Construction directions and/or diagram and time required
Advantages	Equipment needed for construction, installation, and/or removal
Disadvantages	Installation approach and time required
Source(s)	Patent protection of product design
Recommended supplemental material	

STREAM AND WETLAND CROSSING CONSIDERATIONS

There are several considerations that apply to nearly all stream and wetland crossings. Do not cross unless absolutely necessary. If it is necessary to cross a stream or wetland, the number of crossings should be limited to as few as possible and the location(s) should be carefully selected. Existing crossings should be used whenever possible, unless their rehabilitation and use would be more damaging than establishing a new one.

The crossing should be as short as possible. Stream crossings should be perpendicular to the direction of water flow to the degree practical. Wetland crossings should be parallel to the direction of water flow to the degree practical. Approaches to crossings should be direct and have a low grade. Water diversion structures, such as a broad-based dip or water bars, should be constructed to direct water flowing down the road or skid trail into a vegetated area before it reaches the crossing. This will help minimize the movement of sediment into the water body.

Stream crossings should be located on a straight segment of the stream channel that has low banks (except for bridge crossings where higher banks are preferred to support the abutments). This will minimize the need to disturb the bank or to alter the natural shape of the channel. It will also reduce the impact of turbulent water action against the crossing structure itself or against any portions of the bank that need to be disturbed to permit installation of the structure. Where there is a risk of flooding, structures should be anchored at one end to allow them to swing out of the main channel without washing downstream or obstructing water flow (fig. 4).

Proper installation, maintenance, and site rehabilitation are essential for any crossing option to be fully effective. All necessary permits should be obtained in advance and terms communicated clearly to the employees or contractors working on the crossing. The crossing structure should be carefully inspected before each installation and appropriate repairs made. If the crossing structure becomes damaged, a licensed engineer should be consulted to certify that it is still safe for the anticipated loads. Structures that are installed either in or over open water should be cleaned (away from the water body) before each installation to remove accumulated debris, such as mud and branches. Stream crossing options that are placed in the water (e.g., culverts, pipe bundles) need to be frequently checked for blockage to avoid damming the stream.

Abutments and Geotextiles

Many of the structures are most effective when a proper foundation is provided. Bridges need a log, railroad tie, or similar abutment to rest on to help level the structure, to minimize disturbance to the stream bank, and to make removal easier (fig. 5).

Some stream crossing options and most wetland crossing options function best with a geotextile under them. Geotextile, also called

Figure 4.—*Anchoring of a bridge to a nearby tree.*

Figure 5.—*Abutment logs below a log stringer bridge (approach yet to be constructed).*

filter fabric, is a fabric mat used to prevent a new layer of material from mixing with the material below (usually native soil when used with crossing structures). Geotextiles allow water to drain through them, provide additional support for a crossing, and make removal of the crossing easier. A non-woven fabric is recommended for use with temporary installations because it is less slippery than woven fabrics, reducing movement of the structure during use (fig. 6). Also, non-woven geotextiles exclude fine particles while allowing water to flow through from above and below. A needle-punched non-woven polypropylene or high-density polyethylene (HDPE) geotextile of low (3 oz/yd^2 [100 g/m^2]) to medium (6 oz/yd^2 [200 g/m^2]) weight has been used in most trials of temporary crossings.

Another type of geotextile is a woven geotextile (fig. 7). It is mainly used in applications that require high tensile strength and low elongation of the fabric, such as permanent road building. The woven fabrics tend to allow more fine particles to flow through. Some properties of a few representative non-woven and woven geotextiles are compared in table 3.

A non-woven fabric will not continue to tear as a woven fabric may if it becomes punctured. Despite this, it is important to limit the number of high spots (e.g., rocks, stumps) to reduce the potential of punctures during use of the crossing. At the same time, care should be taken to avoid damaging the root or slash mat

Figure 6.—*Non-woven geotextile.*

Figure 7.—*Woven geotextile.*

Table 3.—*Properties of some geotextiles used in stabilization and separation applications*[a] *(metric units are reported in brackets).*

Property	Non-woven geotextiles 4546	Non-woven geotextiles 4551	Non-woven geotextiles 4553	Typical woven geotextile 2002
Physical				
Weight (oz/yd^2) [g/m^2]	4.6 [156]	7.0 [237]	9.2 [312]	5.0 [170]
Grab tensile strength (lbs) [kN]	100 [0.44]	150 [0.67]	203 [0.90]	200 [0.89]
Grab tensile elongation (%)	50	50	50	15
Packaging and price				
Roll width(s) (ft) [m]	15 [4.6]	15 [4.6]	15 [4.6]	12.5 [3.8] or 18 [5.5]
Roll length(s) (ft) [m]	300 [91]	300 [91]	240 [73]	504 [154] or 351 [107]
Gross weight/roll (lbs) [kg]	145 [66]	220 [98]	229 [104]	220 [100]
Area/roll (yd^2) [m^2]	500 [418]	500 [418]	400 [334]	700 [585]
Price[b] (\$/yd^2) [\$/m^2]	0.56 [0.47]	0.84 [0.70]	0.95 [0.82]	0.60 [0.50]

[a]The geotextiles shown here are produced by Amoco Fabrics and Fibers Company[3].
[b]The reported 1998 price (FOB) assumes the purchase of one roll of geotextile. Prices may vary between vendors and according to the amount of fabric purchased.

to the degree possible. This mat will provide additional support during use, lessen the movement of sediment, and can speed revegetation of the site after the structure is removed.

The geotextile should be removed at the same time as the crossing option. Sometimes, the geotextile may be too heavy with soil and water to be easily recovered in a reusable condition. For this reason, it may be beneficial to use shorter lengths with the ends overlapped (e.g., 25-ft [7.6-m] lengths with 2 ft [0.6 m] of overlap) or sewn (e.g., leave about 3 in. [7.5 cm] of overlap in the sewn seam). On very soft soil where the geotextile sinks when it is stepped on, it is best to sew the overlapped area together. If it is not possible to remove the geotextile, a biodegradable fabric should be used. Fiber options for biobased geotextiles include coir, jute, kenaf, flax, sisal, hemp, cotton, and wood fiber (English 1994).

Paper machine felt may be a low-cost alternative to geotextile (Bridge 1989). Used carpet and other materials may also be viable alternatives to geotextile. However, some materials may contain toxic substances that could leach into the water. Therefore, the appropriate regulatory agencies should be contacted before any substitute materials are used.

Erosion Control Measures

The installation, use, and removal of stream and wetland crossing structures frequently results in movement and exposure of soil. Use of temporary erosion control measures is strongly recommended to prevent movement of sediment into water bodies while these soils are being adequately stabilized by vegetation or armoring. Adamson and Harris (1992) recommend development of a sediment control plan to reduce sediment concerns at water crossings. The four broad categories they recommend that need to be considered in formulating a plan for a particular water crossing are noted below. Not all measures will apply for all crossings.

- Administrative measures (e.g., purchase of adequate pipe length, training and instruction of workers, timing of the construction to avoid fish spawning periods, inspection frequency, contingency plan to follow in case of change).

- Protection (e.g., protecting the existing ground cover, limiting the area of disturbance to reduce the area requiring stabilization).

[3] *The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the University of Minnesota, the Minnesota Department of Natural Resources, or the USDA Forest Service to the exclusion of others that may be suitable.*

- Strategic planning of the sequence of operations to manage the factors affecting sediment entering the water body (e.g., storm water flowing toward the water body, flowage within the water body during construction).

- Structural controls that will be used individually or in combination for reducing sediment (e.g., silt fencing, hay or straw bales, mulch, erosion blankets, diversion ditches, water bars).

Options that may be used for reducing sediment include silt fencing, hay or straw bales, mulch, and erosion blankets. Silt fencing and hay bales are installed as barriers across the slope of exposed soils to intercept and slow the movement of water down the slope. They trap the sediment the water is carrying and release the water slowly. To be most effective, they should be placed at spacings similar to that recommended for water bars on long slopes (refer to the Best Management Practices [BMP] guidelines in your State or Province). The barrier closest to the water or wetland is most critical. Proper installation and maintenance is essential for these barriers to work effectively.

To properly install hay or straw bale barriers (fig. 8):

- Set the bales in a shallow trench to prevent water from flowing under the barrier. If digging is impractical due to frost, pack snow against the uphill side of the bales.

- Overlap the bales to avoid leaving gaps between them.

- Drive stakes or lath through the bales so that the stakes are buried 6 to 10 in. (15 to 25 cm) into the soil to firmly anchor them in place.

To properly install silt fencing (fig. 9):

- Drive wooden stakes or lath spaced 4 to 6 ft (1.2 to 1.8 m) apart into the ground to hold the geotextile or other permeable fabric silt fencing in place.

- Cut the fabric in long strips that are 2 to 3 ft (0.6 to 0.9 m) wide.

Figure 8.—*Installation of hay or straw bale barriers.*

Figure 9.—*Installation of silt fencing.*

- Attach a continuous length of the fabric to the uphill side of the stakes so that pressure from water and sediment will not pull the fabric loose. The lower 6 in. (15 cm) of the fabric should form an “L” facing uphill. This should be buried, preferably in a shallow trench, or covered with soil to prevent water from running under the barrier. Pack the soil firmly over this part of the fabric.

Silt fence and hay bale barriers should be inspected periodically and maintained as necessary to make sure they remain functional. They may fill with sediment or become damaged, rendering them ineffective. Once the site is effectively stabilized by revegetation, the barriers should be removed.

In some situations, additional erosion protection may be needed. The force of raindrops on exposed surfaces can loosen and wash away substantial amounts of soil. In most cases, a layer of mulch or an erosion blanket over the exposed soil will provide good protection. Mulch or erosion blankets shield the soil and help disperse and slow the surface flow of water. Mulching with loose straw or hay (fig. 10) on level or moderate slopes can work well. On steeper slopes, it may be necessary to lightly disk the mulch into the soil to keep it in place. Where the risk of erosion is high or where concentrated flows of water are anticipated, such as the bottom of a ditch, an erosion blanket may be needed. These blankets (fig. 11) are mats made of shredded wood or other fibers. They are commercially marketed by several manufacturers and should be available through suppliers that sell culverts and geotextiles.

Steep excavated cuts, particularly on the bank of a stream, may require permanent protection, such as heavy rock riprap (fig. 12). Information on this and several other possible treatments for slope failure prone areas can be found in Moll (1996) and Mohoney (1994). Moll (1996) also discusses techniques used to close and obliterate access routes after use. The level of restoration required for a particular access corridor will depend on many site, management, and political factors.

In any case, speeding the revegetation of disturbed soil surfaces is always a good idea. Vegetation provides a root mass that holds soil in place and soaks up water, reducing runoff. Fertilizing and seeding disturbed soil facilitates and speeds revegetation, minimizing erosion potential (fig. 13). Care should be taken to use native seed sources to avoid introducing non-native species to the ecosystem unless they have been proven to be innocuous. Fertilizer and seed mixture recommendations for exposed soil are generally available from most local land management organizations.

Figure 11.—*Erosion blanket samples.*

Figure 12.—*Riprap slope.*

Figure 10.—*Mulched surface.*

Figure 13.—*Seeding an area with a hand seeder.*

TEMPORARY STREAM CROSSING OPTIONS

Crossing streams is often perceived to be one of the most controversial, time consuming, and expensive parts of any forest management operation. Properly designed, installed, and maintained temporary stream crossing structures can greatly reduce costs and help meet the concerns of regulatory agencies. The types of temporary stream crossing options discussed below include fords, culverts, polyvinyl chloride (PVC) and high-density polyethylene (HDPE) pipe bundles, and portable or on-site constructed bridges.

It is important to follow the proper permitting process when installing and using a stream crossing. A local hydrologist should be contacted to determine whether a permit is required. The permit may specify what type of crossing as well as when it can be installed and/or used.

As noted previously, engineering input from a licensed engineer into the design of many stream crossing options is recommended. However, engineering design information for some of the alternatives is limited, and the additional costs for an engineered design may be considered exorbitant for a temporary crossing. Caution is necessary when using any crossing that has not been engineered and/or that has not been inspected during and between uses.

The condition of any crossing should be monitored as long as it exists. Regular maintenance may be needed to keep the crossing functional. Maintenance is especially important for culvert and pipe bundle crossings to make sure that they are clear and free of debris. Weak soils on the approach to a crossing can be stabilized by placing one or more of the temporary wetland crossing options (e.g., corduroy, wood mats, wood panels, expanded metal grating, tire mats, etc.) on top of a non-woven geotextile.

Appendix 1 contains a list of commercial vendors for several stream crossing options. Appendix 2 presents a summary of product specifications and approximate costs for some of the options discussed. Additional information can be found on the Internet. The *Logging and Sawmilling Journal* has a World Wide Web page (http://www.forestnet.com/log&saw/stream/introstr.htm) that includes information on a variety of stream crossing options, planning tips, and suggestions for protecting aquatic resources and rehabilitating the site.

Fords

A ford or low-water crossing uses the stream bed as part of the road or access trail (fig. 14). They are best suited for short-term, limited traffic. Use should be limited to periods of low flow when the water is less than 2 ft (0.6 m) deep. Because the spawning beds of many fish species occur within the same areas that make a good ford crossing, fords should not be constructed or used during periods of fish spawning. Also, construction should not occur during fish migration periods. Fords should maintain the natural shape and elevation of the stream channel to avoid creating obstructions to the movement of fish and other aquatic organisms.

Figure 14.—*Ford crossing.*

Because equipment will be directly in the stream channel when using a ford, it is especially important to keep vehicles clean and well-maintained. Mud and debris dragged in on skid loads or on tracks and tires, as well as oil and fuel leaks, contribute to polluting the water. Protecting the approaches to a ford with clean gravel, corduroy, wood mats, wood panels, expanded metal grating, or other temporary surfacing material is recommended for this reason. (See the section on wetland crossing options for a description of corduroy, wood mats, wood panels, expanded metal grating, tire mats, etc.)

Existing crossings should be used whenever practical unless rehabilitating and using the crossing would be more damaging than establishing a new one. New fords should be located where the banks are low, less than 4 ft (1.2 m) high, and gently sloping; where the grade of the approach to the stream does not exceed 5:1 (horizontal to vertical); and where the stream bed is firm rock or gravel. Such locations require little or no modification to accommodate traffic. More often some grading, excavating, and placement of road base material is needed.

To facilitate construction of a ford where the stream bed is not dry, it may be desirable to temporarily divert the main flow of the stream around the work site using ditches, berms, dikes, piping, high capacity pumps, or an existing alternate channel crossing. This makes placement and compaction of fill much easier and minimizes sediment movement in the stream. It may also be desirable to place large rocks or logs or to construct a sediment trap below a ford to catch sediment introduced by use of the ford. However, excavation of material within the stream bed should only be done with the advice of a qualified hydrologist or licensed engineer and approval of the appropriate regulatory authorities.

A mucky or weak stream bed is not acceptable as a base for a ford unless it is frozen. When the soil within the stream bed is weak, it will be necessary to cover or to replace it with materials that will support traffic. There are several alternative materials for creating a firm base for a ford. Those applicable to normal forestry operations include:

- Permanently constructed fords using clean gravel or rock with or without geotextile or a plastic cell webbing known as a cellular confinement system.[4] A ford constructed with the cellular confinement system is sometimes known as a plastic ford.
- Temporarily constructed fords using mats made of wood, tires, expanded metal grating, logs or poles, or a floating rubber mat.

Use of a geotextile below any material (e.g., clean gravel, rock, wood, or tire mats) in either a permanently or temporarily constructed ford can provide additional support to the crossing while separating the material from weak native soil. However, use of the geotextile should be approved by the appropriate regulatory authorities because of concerns about impacts if any downstream movement of the geotextile occurs.

Permanently constructed fords

Constructing a firm crossing using gravel or rock is common when the existing bed of an intermittent or perennial stream is too weak to support traffic. When using clean gravel or rock fill to construct a ford, the existing weak material in the stream bed should be excavated first. This allows the natural shape of the stream channel to be maintained and reduces the problem of the gravel mixing with the mud, making the fill ineffective. A minimum of 6 in. of gravel or rock fill should be used unless it is not possible to excavate deep enough to accommodate this much fill. The gravel or rock fill should not raise the crossing higher than the original stream bed level.

We recommend that a geotextile be laid down before placing gravel or rock fill (fig. 15), as long as it is approved by the appropriate regulatory authorities. This keeps the fill separated from the weak native materials and provides added support to the crossing. Although fords that are constructed with gravel or rock fill are intended as temporary crossings, the gravel or rock fill is not removed when the crossing becomes inactive.

[4] *A cellular confinement system is an expandable honeycomb plastic panel into which different types of fill material can be added. The panels confine the fill into small compartments, holding them in place.*

Figure 15.—*A geotextile used in a ford.*

Pence (1987) and Tufts *et al*. (1994) describe plastic fords that were constructed to help keep the gravel or rock fill in place. Without the cellular confinement system, the fill can be pushed aside by heavy vehicles or frequent traffic over a crossing. Also, the cellular confinement system reduces the chance that fast currents will wash the gravel downstream.

A vented ford or emergency spillway can be formed by providing culverts to handle the day-to-day flow and by partially lowering the road grades for passing floods (Adamson and Racey 1989). This type of ford is suitable where the normal flow may exceed a fordable depth either seasonally or following storm events. A wall must be provided along the downstream edge of the spillway to keep the gravel fill from eroding under the action of the flowing water. Various wall types include gabions and precast concrete sections. Riprap erosion protection is required downstream of the wall. Coarse granular fill is required to make the vented ford erosion resistant.

Temporarily constructed fords

A firm base for a ford can be temporarily established by using materials such as mats made of wood or tires, or by using expanded metal grating, logs, or floating rubber mats. (See the section on wetland crossing options for a description of wood mats, tire mats, and expanded metal grating.) Wood or tire mats or expanded metal grating, in combination with a non-woven geotextile, can be placed directly across a stream to create a firm base for the ford (fig. 16). Installation is quick and easy. Removal is also simple, but may require re-turning at a later date if the site is frozen when the operation is finished. In some instances,

Figure 16.—*A tire mat used to provide support in a temporary ford.*

the stream bed or bank may be too weak for the geotextile and mats or expanded metal grating to provide sufficient support for traffic. Supplemental corduroy, gravel, or rock fill may be needed in the weakest portions of the crossing to create a firm base for the ford.

In some jurisdictions, a pole or log ford may be established for crossing small streams. For this type of ford, the stream channel is filled with logs laid parallel to the direction of stream flow. This works well for crossings that will be used only a few times and where the logs can be easily removed as soon as the work is completed. It is best suited for dry ditches and intermittent stream channels because of the risk of blocking stream flow, particularly during spring breakup or following a heavy rain. Placement of two or more steel cables laid bank-to-bank below the pole ford will facilitate removal of the logs. To minimize the risk of blocking stream flow, polyvinyl chloride (PVC) pipe bundles can be used in place of logs. (See the section on PVC pipe bundles below for a description of this option.)

A "dam bridge" or "rubber mat bridge" can also be used to provide a temporary ford (Arnold 1994, Looney 1981). It is constructed from strips of rubber conveyor belting joined side-by-side. Looney (1981) describes a dam bridge constructed of 0.5-in.- (1.3-cm)-thick strips of rubber conveyor belt that was cemented and bolted together. Support cables hold the sides upright so the mat floats on the water when no vehicles are in the crossing. When a vehicle enters the dam bridge the mat is pushed down to the stream bottom, momentarily damming the stream. Once the vehicle is across the stream, the mat floats up again, allowing the stream to flow normally. Looney (1981) recommends placing rock on the approaches to the dam bridge to assist vehicles in climbing out, particularly for skidders with chains.

Culverts

A culvert is a structure that conveys water under a road or access trail (fig. 17). It is one of the most common methods of crossing intermittent and perennial streams. Manufactured culverts come in many shapes (round, oblong, or arched), lengths, and diameters, and may be made of corrugated steel, concrete, or polyethylene. An arch culvert is an open-bottom arch with appropriate footings into which the arch is fitted. New culverts are available from a variety of suppliers. Used culverts suitable for temporary installations may be available from state, provincial, or local road authorities or from construction, pipeline, or drilling companies.

Although corrugated steel culverts are used most frequently, the use of polyethylene pipes is increasing for temporary installations and low standard roads. Polyethylene pipes have several limitations that should be considered (Stjernberg 1987); however, proper installation can overcome most problems. Other materials are often used as substitutes for manufactured culverts on temporary forest roads and skid trails. Some examples are hollow steel piling, well casings, gas pipeline, wooden box culverts, and hollow logs. Small culverts can be installed and removed with a bulldozer or backhoe. An excavator may be needed to install and remove larger culverts. Low-cost culvert transportation systems have been developed (Ewing 1992).

Figure 17.—*Culvert.*

Proper sizing and installation of culverts are critical to constructing a successful crossing. Both culvert diameter and length need to be considered when determining culvert size requirements. The recommended minimum diameter for any culvert is generally 12 in. (30 cm). Smaller sizes are difficult or impossible to clean out if they become clogged. Temporary installations that are removed seasonally may only need to accommodate estimated peak flow for the season of use. Year-round installations need to consider peak flows of longer term events (e.g., 10-, 25-, 50-, or 100-year floods). In all cases, it is important to confirm sizing requirements with a hydrologist or licensed engineer and the appropriate permitting authority.

A single large-diameter culvert is better than two or more smaller culverts. A common mistake is to assume that two 12-in. (30-cm) culverts equal the capacity of a single 24-in. (60-cm) culvert. However, it takes at least three 12-in. (30-cm) culverts to equal the capacity of one 24-in. (60-cm) culvert. The greater surface area of the three smaller culverts will also cause more turbulence, reducing the flow rate through each culvert. The pipe must also be long enough to extend to at least the toe of the fill slope. Placement of the culvert should follow the same grade as the existing stream channel and should be placed deep enough to avoid washing out from below. If the upstream end of the culvert becomes too elevated, the water may move through the culvert too fast and impede the migration of aquatic organisms. Culverts should not be installed during fish spawning and migration.

The pipe should be placed in line with the direction of stream flow. Attempting to use the culvert to redirect the stream may violate the terms of a permit and can result in the culvert being washed out. The side slope of the fill should be no steeper than 2 to 1 (horizontal to vertical) to ensure it is stable. The culvert should be covered with fill to a depth of 12 in. (30 cm), or one-half the diameter of the pipe, whichever is greater. This protects the pipe from being crushed and avoids damage to the pipe during grading of the road surface. When earth fill is used, it should be compacted in layers (fig. 18). This is especially important for the bottom half of the culvert, which may be washed out if the earth fill is not properly compacted. Compaction of the road surface over the culvert will help ensure that the driving surface sheds water rather than turning to mud.

Figure 18.—*Packing earth around a culvert during installation.*

Some jurisdictions may permit logs or brush to be used as fill around a temporary culvert to avoid placement of soil that would need to be disturbed when the pipe is removed. A hydrologist or the appropriate permitting authority should be consulted before using logs or brush. There may be concerns about the logs or brush washing away during use of the crossing, or that the fill material will not be removed from the stream when the culvert is removed. In either case, downstream movement of the logs and/or brush may dam the stream.

To facilitate installation and/or removal of a culvert where the stream bed is not dry, it may be desirable to temporarily divert the main flow of the stream around the work site using ditches, berms, dikes, piping, high capacity pumps, or an existing alternate channel crossing. This makes placement, compaction, and/or removal of fill much easier and minimizes sediment movement in the stream. It may also be desirable to place large rocks or logs or to construct a sediment trap below a culvert to catch sediment introduced by use of the crossing. However, this should only be done with the advice of a qualified hydrologist or licensed engineer and approval of the appropriate regulatory authorities.

Periodic maintenance of culverts is important to ensure proper function. Both ends of the culvert should be checked and cleared of debris to allow an unimpeded flow of water. This is especially important in areas subject to beaver activity. Problems with unnatural erosion around the culvert should be corrected to minimize the chance of washout of the culvert and sedimentation of the stream.

PVC and HDPE Pipe Bundles

A pipe bundle crossing is constructed using 4-in.- (10-cm)-diameter Schedule 40 PVC or SDR11 HDPE pipes that are cabled together forming loose mats that can be formed into bundles. The bundle provides mechanical support for the vehicle while allowing water to pass through the pipes unimpeded (fig. 19). Streams with a U-shaped channel to contain the pipes are most appropriate for this option.

Because standard PVC pipe is light-sensitive and will lose strength when exposed to sunlight, using PVC pipe that has been exposed to the sun should be avoided. Strength of the crossing can be maintained by covering or

Figure 19.—*PVC or HDPE pipe bundle.*

painting PVC pipe or by using an ultraviolet-resistant type of pipe, such as HDPE. HDPE pipe also tolerates temperature extremes of -40° F (-40° C) better than PVC without becoming brittle or losing shock resistance and will return to its original shape after being deformed (Légère 1997). No published studies have evaluated the use of PVC or HDPE pipe bundles for stream crossings during winter in an environment where temperatures are consistently below freezing.

HDPE pipes may be more expensive than standard PVC and may need to be purchased through a vendor that specializes in plastic pipe. The thickness of many alternative plastic pipes is often specified using the term "standard dimension ratio" (SDR), which is calculated by dividing the average outside diameter of the pipe by its minimum wall thickness. For any given outside diameter, SDR will increase as wall thickness decreases.

It is important to make the crossing wide enough for the widest vehicle that will use it. Plastic pipe is generally sold in multiples of 10-ft (3-m) lengths; therefore, it may be necessary to purchase 20-ft (6.1-m) sections that can be cut to the desired length. Mason and Greenfield (1995) proposed using shorter pipe sections, end-to-end, between full-length pipes making a 14-ft- (4.2-m)-wide crossing.

Constructing pipe bundles consists of drilling 1/4-in.- (6.4-mm)-diameter holes at 1 ft (0.3 m) and 4 ft (1.2 m) from each end of each pipe. Four 3/16-in.- (4.8-mm)-diameter galvanized steel cables are threaded through the holes to connect the individual pieces. It is important to drill round holes to avoid creating potential stress points that could later facilitate pipe shattering. It may be necessary to control cable end fray before stringing the cable through the sections. Loops should be made at the end of each cable, extending beyond the last pipe, and then secured using 3/16-in.- (4.8-mm)-diameter cable clamps to prevent individual pipes from rolling or moving in other directions.

Our experience has shown that it takes about 1 hr for two people using two hand drills and one saw to cut, drill, and cable 4-in.- (10-cm)-diameter and 20-ft- (6.1-m)-long PVC into a 10-ft x 12-ft (3-m x 3.7-m) section. The initial construction cost of this size section, including materials and labor, is about $500. Two 10-ft x 12-ft (3-m x 3.7-m) sections are necessary to build a crossing for a 6-ft (1.8-m) wide x 2-ft (0.6-m) deep channel. Each cabled section should be loose so the pipes can conform to the stream channel. A tight connection is used for a single layer crossing.

The crossing is created by first laying down a geotextile fabric (fig. 20) to ensure separation from the stream bottom and to facilitate removal (Mason and Greenfield 1995). A layer of connected pipes is then placed on top of the geotextile along the stream bottom, parallel to the stream flow. If necessary, loose or connected pipes are then layered to the desired height (fig. 21). A layer of connected pipes should be placed as the top mat. Loops at the end of connecting cables should be covered so that they don't hook onto the underside of a passing vehicle. The top and bottom layers of pipe should be long enough to go beyond the stream edge to protect the stream banks.

Figure 20.—*Installation of a geotextile under a pipe bundle.*

Figure 21.—*Pipe bundle crossing layered to the desired height.*

Typically, a stiff surface such as expanded metal grating, tire mats, or wood panels are laid over the top mat to limit pipe movement (wave action) and to provide traction. The crossing surface needs to be sufficiently connected to the pipe to avoid flipping up under a crossing vehicle (Mason and Greenfield 1995). Wood mats or expanded metal grating can be placed on top of a non-woven geotextile to stabilize the approaches to the crossing if they are weak.

The time required to install the crossing depends on the crossing length, stream depth, water volume, equipment available, and the amount of room needed for the equipment to maneuver. It took about 1.5 hr to place a PVC pipe bundle crossing with a wood pallet running surface within a stream channel that was 35 ft (11 m) wide (the bundles covered 25 ft [7.5 m] of that span). It took about 20 minutes to remove a PVC pipe bundle crossing consisting of a non-woven geotextile placed below two 10-ft x 12-ft (3-m x 3.7-m) bundle sections, a wood plank running surface, and one 10-ft x 12-ft (3-m x 3.7-m) wood mat that was used on each side of the stream to protect the banks.

Transportation equipment needed to bring the pipe or bundles to the crossing site depends on the length and amount of pipe (Mason and Greenfield 1995). In some cases, the drilled individual pipes may be transported by pickup truck and constructed on-site. Preconstructed mats may be too heavy for a pickup truck, requiring a dump truck or lowboy. Front-end loaders or skidders are typically used to place the mats.

Bridges

By spanning the stream, bridges keep fill and equipment out of the water body to the greatest degree of any stream crossing option (fig. 22). For this reason, they have the least impact on streams. Designs are available for a wide range of span lengths and load capacities (e.g., pickup trucks, skidders and forwarders, or loaded semi-tractor trailers). Temporary bridges can be made from ice, timber, used railroad cars (flatcars and boxcars), used flatbed truck trailers, steel, or pre-stressed concrete.

Little site preparation is normally required when installing a temporary bridge. To provide stable, level support for the structure, it is recommended that bridges be installed on abutments on both sides of a stream. This will also facilitate removal if the ground is frozen. Logs or large wooden beams are often used for abutments. Crossing permit requirements, local statutes, or specific site conditions may require more extensive abutments. Also, crossing permit requirements or local statutes may specify the minimum clearance between the bridge and the stream to accommodate peak flows and/or recreational use.

Figure 22.—*Temporary bridge spanning a stream.*

Ramps from the approaches up to the bridge traffic surface often need to be created on-site. Soil, snow, and corduroy are usually adequate, but permit requirements and/or site conditions, such as weak soil, may require use of other materials. Also, if the soils within the approaches to the bridge are weak, or if they will be significantly disturbed during installation and use of the bridge, we recommend using corduroy, wood mats, wood panels, expanded metal grating, or other temporary surfacing material to strengthen the approaches. (See the section on wetland crossing options for a description of corduroy, wood mats, wood panels, and expanded metal grating.) This will reduce rutting or other damage that may inhibit use of the crossing. It will also minimize the potential for sediment reaching the stream.

Bridges are generally designed to be a fixed length. Unfortunately, a fixed-length bridge is not applicable to all streams. Engineered bridges have been evaluated and a load (weight) rating established for a maximum span distance. If that maximum span distance is lengthened and/or the maximum load is exceeded, the bridge may fail. It may be feasible to span longer distances; however, the maximum load will need to be decreased and should be determined only by a licensed engineer.

Some bridge designs are open in the middle, or have holes or gaps in the traffic surface. These designs may be less expensive or easier to install, but also allow dirt and debris to fall into the stream. As a result, some jurisdictions may not permit use of these designs. Also, movement of individual bridge panels may occur during use if they are not adequately connected. For structures with a gap in the traffic surface, it is recommended that a decking material (e.g., plywood, lumber) be added to close this space. Installation of curbs or guardrails is an important safety consideration for bridges designed for truck traffic. They help the driver position the vehicle safely on the structure. The curbs or guardrails may need to be removed for skidder traffic if the skid loads will damage them.

Most temporary bridges can be installed and removed with a knuckleboom loader, front-end loader, bulldozer, or skidder. Long spans for wide streams may require special equipment, such as a crane or excavator. Keliher *et al.* (1995) recommend that individual bridge sections weigh less than 5,000 lb (2,300 kg) and be under 30 ft (10 m) long if a grapple skidder is to lift the structure. Sections could weigh as much as 11,000 lb (5,000 kg) if the skidder drags, winches, or pushes them. The size and weight of the bridge or its individual components is also an important consideration for loading, unloading, and transport from one location to another. In some circumstances, the machine installing the bridge may need to cross through or work in the stream channel to get the structure in place. This should be avoided whenever possible and may require prior approval from the local permitting authority.

Prefabricated, portable bridges made of steel, treated or untreated lumber, and pre-stressed concrete can be purchased from commercial manufacturers. When they are retrofitted, used railroad cars and flatbed truck trailers can also serve as a prefabricated crossing. Although they are generally more expensive than a structure built of locally available materials, prefabricated options offer two important advantages. First, commercially manufactured bridges generally incorporate engineering input into their design. This will help reduce concerns about safety and liability. Second, they can be used many times over several years, considerably reducing the cost per crossing. Prefabricated designs include single, rigid structures, and hinged or modular panels. The hinged or modular panels facilitate transport, installation, removal, and handling. Prefabricated bridges can usually be installed or removed in less than 2 hr.

Bridges fabricated from locally available materials also come in a wide variety of shapes and sizes. Some are built on-site for a single use; others are portable and can be used several times. Examples of on-site constructed bridges include ice and log stringer bridges. Portable bridges may be constructed from solid sawn timbers and planking, flatbed truck trailers, steel beams, pre-stressed concrete panels, or other materials. Because the initial cost of a bridge fabricated from locally available materials is often much lower than that of commercially manufactured bridges, they are a viable alternative for many stream crossings. The installation and removal time may be longer for a bridge fabricated from locally available materials than for a prefabricated bridge.

We recommend that a licensed engineer review the design of any bridge that is fabricated from locally available materials to ensure that the structure will be safe and is adequate for the intended use. However, this review may be difficult to obtain and the cost may be considered too exorbitant in some cases. Construction specifications have not been established for some materials (i.e., hardwood lumber), and others may be converted to a use for which they were not originally designed (e.g., flatbed truck trailers). Many materials or structures have had substantial wear and tear before their use as a bridge structure (i.e., railroad flat cars, flatbed truck trailers, concrete panels), which may have significantly reduced their strength or limited their remaining service life.

Ice bridges

Ice bridges are a common type of winter crossing over streams, lakes, and rivers in areas where there are extended periods of temperatures below freezing (fig. 23). In some areas, the ice may be thick enough that no construction is needed. Where construction is necessary, ice bridges are made by packing snow and/or pumping water onto the existing ice. Some jurisdictions permit slash or brush to be placed in the stream channel when there is no ice to build on, but this is generally undesirable because it is often difficult to remove the brush. Because an ice bridge will take longer to melt than the stream, a new channel may be cut around the blockage on streams with large or high velocity spring flows. Therefore, ice bridges may not be appropriate on those streams.

Figure 23.—*Ice bridge.*

Creating an ice bridge requires cold weather. Night temperatures below 0° F (-18° C) are best, with several days required to build up ice thick enough to safely support traffic. Once an ice bridge is in use, the thickness and condition of the ice should be checked frequently to be sure it remains adequate. This may need to be done as often as once or twice a day, or more, on fast moving streams or large rivers and lakes and as temperatures warm up.

On lakes, ice bridges are sometimes created by plowing snow off the path chosen for the road. Removing the snow enables the ice to grow thicker faster, thereby increasing the load bearing capacity. Because the plowed snowbanks represent concentrated loads on the ice, they should be spread over as large an area as possible. When a vehicle crosses floating ice, a deflection bowl moves with it, generating waves in the water (Haynes and Carey 1996). If the speed of these waves is the same as the vehicle speed, the deflection of the ice sheet is increased and will likely lead to failure of the ice. The problem is more serious for thin ice and shallow water depths. When in doubt, operators should drive less than 15 miles (24 km) per hr.

The following formula was developed to estimate the minimum ice thickness required to support a given load above a flowing river or stream or on a lake (Haynes and Carey 1996).

$$h=4(P)^{1/2}$$

Where: h = ice thickness in inches
P = the load or gross weight of the vehicle plus its contents, in tons.

This equation can also be expressed in tabular format, where the vehicle class equals the total weight of the vehicle plus its load (table 4).

Timber bridges

Donnelly (1997) provides a good overview of timber bridges. Engineering design guidelines are available for many different types of timber bridges. Two popular designs for temporary structures are log stringer bridges and solid sawn stringer bridges with or without a plank deck. Log stringer bridges (fig. 24) are built by cabling logs together from trees felled in the area of construction. It is especially important to bundle stringers together with cable (fig. 25) when building a log stringer bridge to improve performance. A narrow stream can sometimes be crossed by bundling stringers together with chains or cable and placing them only in the wheel path. Several log stringer bridge options are discussed in Peterson (1987). Solid sawn stringer bridges (fig. 26) are built with new lumber, railroad ties, or demolition materials. Kittredge and Woodall (1997) describe a solid sawn stringer bridge made with 6-in. x 6-in. (15-cm x 15-cm) and 6-in. x 8-in. (15-cm x 20-cm) cants. This design provides an uneven driving surface for better traction.

Table 4.—*Minimum ice thickness required to support a given load above a flowing river or stream or on a lake (Haynes and Carey 1996)*[a]

Vehicle class[b] (tons) [tonnes]	Minimum ice thickness (in.) [cm]	Minimum distance between vehicles[c] (ft) [m]
0.1 [0.1]	2 [5.1]	17 [5.2]
1 [1.1]	4 [10]	34 [10]
2 [2.2]	6 [15]	48 [15]
3 [3.3]	7 [18]	58 [18]
4 [4.4]	8 [20]	67 [20]
5 [5.5]	9 [23]	75 [23]
10 [11]	13 [33]	106 [32]
20 [22]	18 [46]	149 [45]
30 [33]	22 [56]	183 [56]
40 [44]	26 [66]	211 [64]

[a] Information in this table assumes clear, sound ice. If white, bubble-filled ice makes up part of the ice thickness, count it only half as much as clear ice. If the air temperature has been above freezing for at least 6 of the previous 24 hr, multiply the vehicle class by 1.3 to obtain a larger minimum thickness. If the air temperature stays above freezing for 24 hr or more, the ice begins to lose strength and the table no longer represents safe conditions. Maximum recommended speed is 15 mi (24 km) per hr.
[b] Vehicle class equals the gross weight of the vehicle plus the weight of its contents in tons.
[c] At ice thicknesses greater than the minimum, the spacing between vehicles can be reduced on sound ice.

Figure 24.—*Log stringer bridge.*

Figure 25.—*Cabled logs in a log stringer bridge.*

Figure 26.—*Solid sawn stringer bridge.*

Plank decks provide a smooth running surface, decrease lateral movement of the structure during use, and reduce the amount of dirt and debris that may fall into the stream. If a plank deck is to be installed on either of these bridge types, annularly threaded (ring-shank) or helically threaded (spiral) spikes should be used to attach the surface deck. The spikes should be at least 9 in. (23 cm) long to reduce withdrawal during use of the crossing. If care is used during installation, removal, and transport, stringer bridges can be reused several times.

The main concern with log stringer and solid sawn stringer designs is that there is limited information on the engineering properties of logs, railroad ties, and demolition materials. Thus, designs using these materials typically include little, if any, engineering input. Care should be exercised when using these materials if they have not been evaluated to determine their structural strength and engineers are not involved in the design or in accurately estimating their load ratings. Rot, decay, knots, and grain can greatly affect their strength properties. Some of these factors become more important the longer a bridge is in use, especially if the species does not have a high decay resistance.

Muchmore (1976) presents basic design criteria to determine whether single lane log stringer bridges are designed and constructed to safely support specific loadings and to meet minimum safety criteria. Bradley and Krag (1990) present span designs for seven tree species (white spruce [*Picea glauca*], eastern white pine [*Pinus strobus*], jack pine [*Pinus banksiana*], red pine [*Pinus resinosa*], eastern hemlock [*Tsuga canadensis*], quaking aspen [*Populus tremuloides*], and balsam poplar [*Populus balsamifera*]) and two types of bridges (with and without needle beams[5]). Guidelines are also available for evaluating the capacity of sawn timber and log stringers in existing bridges (Ontario Ministry of Natural Resources 1989). The USDA Forest Service is currently developing guidelines for different types of portable timber bridges.

Other timber bridges have been constructed using treated panels of stress-laminated, glued-laminated (glulam), dowel-laminated, or nail-laminated materials. Stress-laminated panels consist of lumber placed edgewise and held together with high-strength steel rods (fig. 27) that are stressed in tension, up to 100 lb/in.^{2} [PSI] (7,000 g/cm^2). There is a need to retension the steel rods periodically. Russell (1997) presents a review of stress-laminated technology. Glulam panels consist of dimension lumber glued together on the wide face. Dowel- and nail-laminated panels are similar to stress-laminated panels, except that dowels or nails are used to connect each successive piece of lumber. In all cases, the panels are placed side-by-side across a stream.

One advantage of these designs, as well as a solid sawn stringer design using new lumber, is that the lumber is a known species and grade. Thus, structural properties are known and an engineer can properly design a safe structure. Also, because they are panelized, transportation to the site may be easier than for some other bridging options. Field performance for some of these engineered bridges

Figure 27.—*Stress-laminated timber bridge panel.*

[5] *A needle beam distributes a live load to all stringers and is positioned across the stringers at midspan.*

installed for permanent use indicates that their performance is generally satisfactory (Ritter *et al.* 1995).

Behr *et al.* (1990) compared the initial costs of timber, steel/concrete, and prestressed concrete bridges. Five New England general contractors performed cost estimates on bridge designs spanning 20, 40, and 60 ft. Also, three timber bridge suppliers provided cost estimates for nine bridge designs, three at each span length. Results from general contractors indicated that timber was cost competitive with steel/concrete and was less expensive than prestressed concrete. Results from timber bridge suppliers showed a distinct initial cost advantage for timber over both steel/concrete and prestressed concrete.

The USDA Forest Service Wood in Transportation Program has established the Wood in Transport National Information Center. The Center maintains a website at http://wit.fsl.wvnet.edu that describes the program and provides an on-line order form to obtain free publications, design plans, cost information, etc. The Center can also be contacted directly at 304-285-1591 (voice) or 304-285-1505 (FAX). The Forest Products Lab also has a website at http://www.fpl.fs.fed.us/wit/ containing some of their publications on wood-in-transportation technology. The Forest Service has also published an excellent reference on timber bridge design, construction, inspection, and maintenance (Ritter 1992).

Used railroad cars and flatbed truck trailers

Railroad cars (flatcars and boxcars) and flatbed truck trailers can be retrofitted for use as stream crossings (fig. 28). The retrofitting provides additional reinforcing to the main support beams so they will support vehicle traffic. Bradley and Pronker (1994) present a standard design for using railcars as temporary bridges. Carraway (1997) indicated that railroad boxcars are much lighter than flatcars, allowing a 50-ft- (15-m)-long x 10-ft- (3-m)-wide bridge to be transported on a lowboy trailer. A railroad boxcar bridge can be unloaded with a knuckleboom loader and placed across the stream with a skidder. A crane may be needed to lift and install a railroad flatcar bridge. Individual railroad cars and flatbed truck trailers tend to be narrow which may be a limitation for hauling applications.

Figure 28.—*Bridge made from a used railroad car.*

Used railroad cars may be purchased from third-party vendors who purchase old railroad cars from railroad companies. Contact your local railroad company or railroad car repair facility to find out how to obtain one. Used flatbed truck trailers are lighter and are more readily available locally through trailer repair and salvage operations. While it is possible to purchase retrofitted used railroad cars for use as bridges, most used flatbed truck trailer vendors do not provide the additional reinforcement needed.

Steel bridges

Steel bridges include hinged portable bridges and modular bridges (fig. 29). Where permitted, two or more bridge spans or bridge panels (multi-spans) may be connected across a pier to span wide crossings. Hinged bridges fold up for transport. Modular steel bridges are designed as a series of individual panels that interlock, forming a bridge of variable length.

Figure 29.—*Steel bridge.*

We are aware of a locally fabricated, non-engineered, steel bridge that is about 50 ft (15 m) long and was constructed using I-beams. Also, catwalks with wood decking have been used.

Pre-stressed concrete bridges

Precast, pre-stressed concrete panels can be locally fabricated. Generally, two or more panels are placed side-by-side to form the bridge (fig. 30). Although the initial cost of this bridge may be low, they are usually heavy and require larger equipment to install and remove. It is important to make sure that the panels are engineered to handle the anticipated loads. Highway departments or local road authorities may be a source for used panels.

Figure 30.—*Pre-stressed concrete bridge.*

TEMPORARY WETLAND CROSSING OPTIONS

This overview of temporary wetland crossing options focuses on alternatives that can be applied to the surface of a wetland soil, including a wet spot on a haul road, to stabilize it for short crossing distances (fig. 31). While we define "short" as being less than 200 ft (61 m), the distance may depend on the initial cost to purchase or construct the selected option, the value of whatever is to be accessed, and the costs associated with other travel routes. Although a very long distance could be crossed when the option is matched to site needs, the cost may be prohibitive. The ability to reuse options makes them more viable, especially those with a higher initial cost.

Temporary wetland crossing options include wood mats, wood panels, wood pallets, bridge decking, expanded metal grating, PVC and HDPE pipe mats or plastic road, tire mats,

Figure 31.—*Wet area in a haul road.*

corduroy, pole rails, wood aggregate, and low ground pressure equipment. Low ground pressure equipment includes machines with wide tires, duals, tire tracks, bogies, tracks, light weight, and/or central tire inflation (CTI). We have chosen not to discuss road construction activities or wetland dredging and filling operations that are associated with constructing a new road or crossing over long distances. We have also not included cable yarding systems, helicopters, or balloons. Although use of frozen ground may be the most viable crossing option in many areas, that option is also not discussed.

Many of the options should not be placed on areas that have firm high spots (e.g., stumps, large rocks) to reduce bending stress and breakage during use. Hislop and Moll (1996) recommend blading the surface as flat as possible before installation. For sites with grass mounds or other uneven vegetation, blading should not disturb the root mat associated with the vegetation. The performance of any wetland crossing option is enhanced if there is a root or slash mat to provide additional support to the equipment.

Maintaining the root mat can also speed revegetation of the site following removal of the crossing. The performance of the crossing is also enhanced by use of a geotextile (fig. 32), which helps segregate the crossing from the underlying soil and provides additional flotation. Most of the options are best suited to be used in conjunction with hauling and forwarding, but not during skidding. If used during skidding operations, the options will wear faster and may move out of position when trees are dragged over them. Also, if a geotextile is used, it may become torn and displaced by skidding.