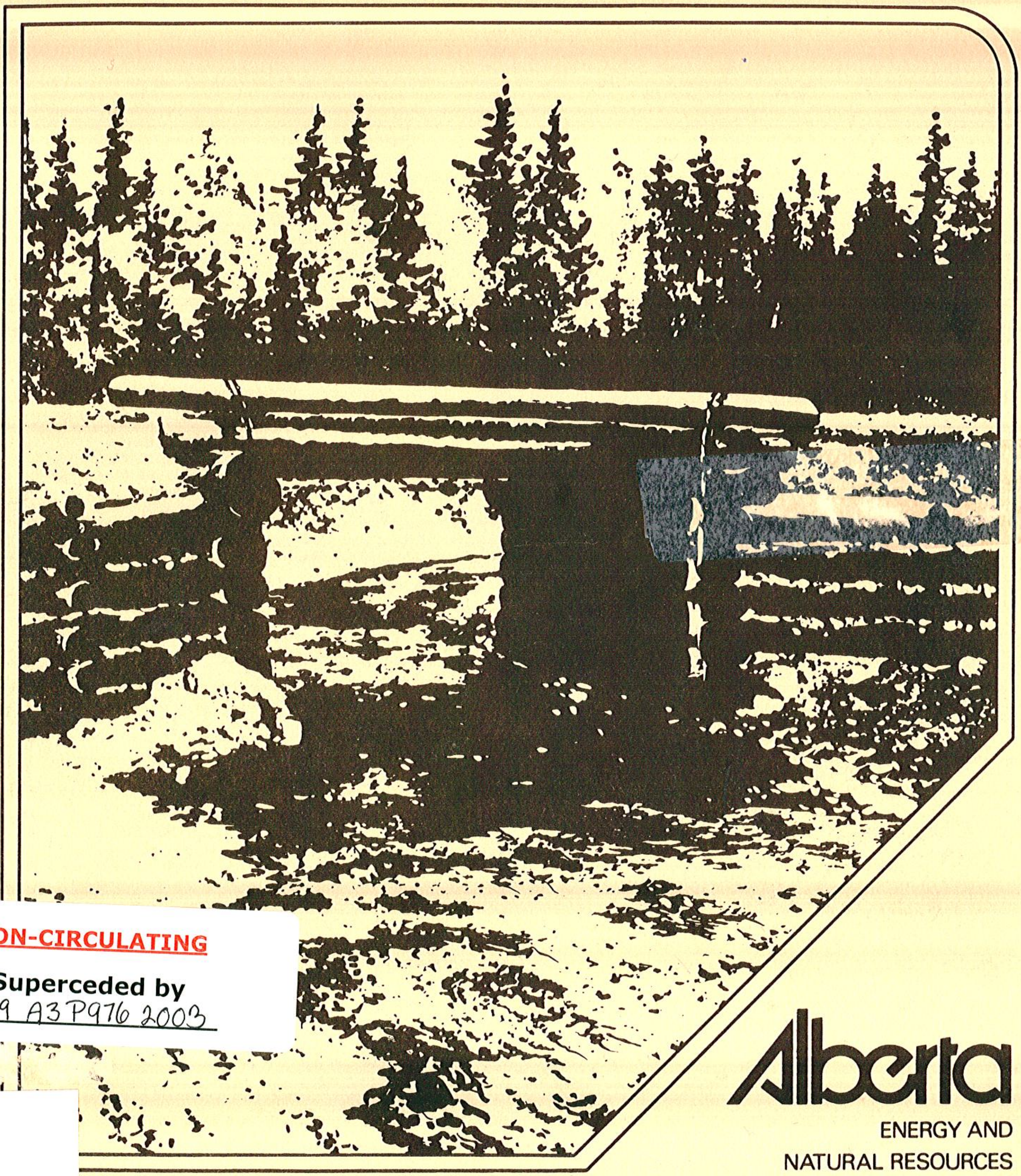
# Stream Crossing Guidelines

## Operational Guidelines For Industry





Alberta
ENERGY AND
NATURAL RESOURCES

# STREAM CROSSING GUIDELINES

# OPERATIONAL GUIDELINES

# FOR INDUSTRY

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1985
Edmonton

Alberta
ENERGY AND
NATURAL RESOURCES

ENR Technical Report Number: T/80
International Standard Book Number: 0-86499-222-X

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## ABSTRACT

The stream crossing guidelines provide recommended environmental protection practices for the planning, construction, maintenance and abandonment of stream crossings on Crown land.

This report is an industry guide for building stream crossings for the exploration of and/or development of resources such as coal, timber, oil and gas. The types of stream crossings considered include snow and ice bridges, timber bridges, steel/concrete bridges, culverts, fords and log fills.

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# PREFACE

The stream crossing guidelines are provided to assist users on the many aspects of stream crossings. Considerations of the planning and environmental parameters are a major part of this report.

Planning is the key to minimizing environmental impact; however, to succeed, environmental awareness must be observed and practised. Many people are involved. Misunderstandings, inconsistencies and conflicts often arise and may result in delays of programs and projects.

The user of these guidelines should acquire an understanding of the many concerns at stream crossings and benefit by practising sound environmental protection measures. It is also hoped that the problems associated with stream crossings will be reduced in number and severity.

ACKNOWLEDGMENTS

Appreciation is extended to members of the Stream Crossing Task Force: Gerald Stuart (Alberta Forest Service, Bow/Crow Forest); John Sorochan (Land Management and Development Branch, Public Lands Division); and Keith Taylor and John Bastone (Timber Management Branch, Alberta Forest Service). Mr. Taylor now resides in Winnipeg.

Appreciation is also extended to the steering Committee for their comments, advice and guidance: D.R. Lyons (Land Use Branch, Alberta Forest Service); Bruce Stubbs (Habitat Branch, Fish and Wildlife Division) and Brian Hudson (Land Management and Development Branch, Public Lands Division).

Special thanks and appreciation is extended to the many directors, regional directors, superintendents and field personnel of the Alberta Forest Service, Fish and Wildlife Division and Public Lands Division who reviewed and critiqued earlier drafts. Without their assistance and experience, this report would not have been possible.

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# 1. INTRODUCTION

## 1.1 Purpose and Objective

The stream crossing guidelines have been developed to provide industry with practical information on environmental protection practices at and around stream crossings. The guidelines can be applied during the planning, construction, maintenance and abandonment phases of stream crossings which may be required by industry for the exploration of and/or development of resources such as coal, timber, oil and gas on Crown land.

Stream crossings are defined as any structure, device or modification to the stream or banks used to provide access across a stream. Streams are considered to be any natural channel, regardless of size, where water flows for at least part of the year.

The guidelines present important factors for consideration; however, site specific situations may require unique alternatives or solutions. Each crossing is different and each should be assessed individually. The guidelines are intended to complement a design and to be incorporated into a design to meet the following environmental objectives:

1. to maintain and preserve water quality and stream environment of watercourses
2. to prevent depositing slash, dirt and debris into watercourses or onto ice surfaces

These objectives can be achieved through the application of these guidelines and by the application of the following:

1. proper supervision
2. proper site selection
3. proper site preparation
4. proper crossing structure
5. proper design for peak flows and fish passage
6. proper maintenance and erosion control
7. good construction techniques and workmanship
8. minimizing the number of crossings
9. minimizing disturbance to streamside vegetation
10. planning for other uses

## 1.2 Legislation

Legislation for stream crossings is governed by several provincial acts and associated regulations; most notably are the Water Resources Act and Public Lands Act.

Under these two acts, the minister has the power to insert operational conditions which control how streams are to be crossed and what structures are to be used in order to protect streams.

The Federal Fisheries Act provides for the management and protection of all provincial fisheries through the Fish and Wildlife Division of Alberta Energy and Natural Resources.

## 1.3 Regulatory Agencies

Energy and Natural Resources (ENR) and Alberta Environment (AE) are the two major agencies responible for controlling activities affecting streams. For example, Public Lands Division of ENR can issue dispositions (with ministerial conditions) which control these activities. Similarily, the Water Resources Administration Division of AE can issue permits and/or licences (with ministerial conditions) which control these activities.

These two regulatory agencies co-ordinate all watercourse crossing authorizations, particularly permanent crossings. For example, applications dealt with by the Water Resource Administration Division are usually referred to the Fish and Wildlife Division of ENR in order to address fisheries concerns.

## 1.4 Multiple Use

Stream crossings originally designed for a single purpose (e.g. well access) may not be adequate for a secondary use (e.g. timber haul). This may result in crossing failure or in duplication. During planning, consideration of the present and/or potential use of the surrounding land and resources can assist planners and designers in selecting a suitable crossing structure. For example, future land clearing activities can cause increases in peak water flows and should be incorporated into the crossing design. Good routing, site selection and alignment will minimize the need for duplication or realignment if upgrading or replacement of a crossing structure becomes necessary. Cost sharing of a crossing structure is usually preferable to duplication of crossing structures.

## 2. STREAM BIOLOGY

### 2.1 The Fisheries Resource of Alberta

Protection and management of the fisheries in Alberta is the responsibility of the Fish and Wildlife Division of Alberta Energy and Natural Resources. In Alberta there are 13 species of game fish and approximately 30 species of non-game fish. Many of these species inhabit streams on a year-round basis, while others live in lakes but move into rivers and streams to spawn.

The importance of Alberta's fishery resource is reflected in the increase of fishing licences and commercial fisheries. Sale of fishing licences increased by 187% in the 1970s. In 1982-83, there were 350 000 recreational licences sold. The 1980 Sports Fishing Questionnaire of Canada showed that anglers fished an average of 17.1 days for a total of approximately six and half million angler days and a catch of over 10 000 000 fish, or about 4 535 900 kg in 1979-80. In addition, about 2 500 commerical fish licence holders harvested about 2 000 000 kg. Alberta's sport fishermen also reported spending about $250 million in 1979-80 on their recreation. The 1983-84 commercial catch had a market value of $2.7 million.

### 2.2 The Sport Fish of Alberta

The 13 species of sport fish in Alberta are classified into cold water and warm water species. Cold water species are found in cool, clear, highly-oxygenated, fast-flowing water, typical of the mountain and foothill areas (Photo 1). The warm water fish are characteristically associated with warmer, slower-flowing, more productive waters, with lower dissolved oxygen and relatively-higher concentrations of suspended sediment (turbidity). In any river system ther is a transition zone between cold and warm water reaches, where both cold and warm water species exist.

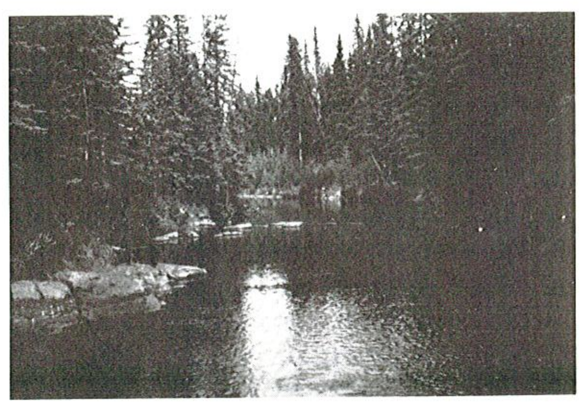


Photo 1. FOOTHILLS TROUT STREAM.

## 2.3 Habitat Requirements and Environmental Concerns

The cold water species (e.g. salmonids) are a group of fish which can inhabit a wide variety of habitat. While salmonids live in what is considered a harsh environment, this family of fish are very finely-tuned to their habitat and are considered environmentally very sensitive. They require very special conditions throughout their life cycle and very specific conditions during the spawning and egg incubation phases. Any change results in stress and leads to a decline in populations.

In general, salmonids require cool, clear, well-oxygenated water, a clean gravel substrate and abundant cover and shade. If water temperatures rise above 20°C for an extended period and the concentration of dissolved oxygen falls to a low level, mortality can occur.

The warm water sport fish (e.g. Northern pike, goldeye, yellow perch and walleye) can tolerate waters with slightly lower concentrations of dissolved oxygen, higher temperatures (up to 27°C) and higher turbidity (suspended sediment). For example, goldeye are adapted to inhabit the lower reaches of rivers where natural levels of suspended solids are much higher than those in the headwaters. While these species are tolerant to naturally-occurring levels of suspended solids (those associated with spring runoff) they cannot withstand extended periods of increased levels of suspended sediments at all times of the year.

The most common and significant problems of stream crossings affecting a stream fishery are the release of sediment to the stream, the obstruction of fish movement and the removal of available habitat.

### 2.3.1 Suspended and Settled Sediment

Suspended sediment is usually released into a stream during the installation of stream crossings. Disturbed areas which have not been revegetated and stabilized and/or without other erosion control measures, also release sediment into the stream. All life stages of fish (egg, fry, juvenile, adult), plants and invertebrates are affected by sediment. When sediment settles on the streambed, fish habitat may be covered.

Adult and juvenile fish are affected by suspended sediment in several ways:

1. The protective mucous covering the scales and eyes is removed, making the fish vulnerable to infection and disease. Suspended sediment irritates the gills, causing the fish to secrete mucous. Persistent high concentrations can cause excessive mucous secretions, resulting in the gills no longer being able to absorb oxygen and the fish dies of asphyxiation.

2. Suspended sediment lowers the feeding efficiency of fish that feed by sight. It is important that the water be clear and relatively free of suspended sediment.

3. Suspended sediment absorbs radiant energy which increases the stream temperature. This results in stress on the fish.

4. Suspended sediment is abrasive and acts much like sandpaper. It scours and dislodges plants and aquatic insects associated with the streambed. The habitat and food source is lost resulting in reduced fish production.

5. The stream water must be clear enough to permit sunlight to reach the stream bottom and the algae community, where most of the primary production of a stream occurs. Elimination of such production will affect invertebrate production severely.

   This effect passes through the entire food chain resulting in smaller and fewer fish.

6. As water movement slows, the suspended sediment begins to settle out covering the substrate. The eggs and recently-hatched young no longer receive oxygen by intragravular flow and die. The silt fills in the gravel beds, making them unsuitable for future spawning sites. Successful incubation of the eggs is dependent on a constant supply of water flowing through the gravel where the eggs have been laid. Recently-hatched fish (alevins) remain in the streambed until they absorb their yolk sacs. The flowing water supplies the eggs and alevins with dissolved oxygen and removes waste products such as carbon dioxide and ammonia.

7. Gravel substrates are also the habitat for aquatic invertebrates. They are the major food supply for fish. The adult flying insects make up only a small part of a fish's diet. The immature forms of aquatic insects, found along the stream bottom in the rocks and stones, are the major food source for fish. When these areas for invertebrate production become covered with sediment, the habitat is lost and subsequently fish production is reduced.

Natural catastrophes occur so infrequently that stream life is not normally continuously threatened. Unfortunately, the timing and duration of stream crossing activities, which result in the release of sediment, replicate natural catastrophes much more frequently, with the result that fish populations may be affected severely.

### 2.3.2 Channelization

Stream channelization reduces the stream length and destroys habitat. Also, channel slope, water velocity and erosion increases. These problems will remain until erosion and sediment deposition cause the stream to readjust to these changes. Erosion, however, is not confined to the diverted portion of the new channel but takes place for variable distances upstream and downstream of the diversion, thereby increasing the loss of habitat. Limited ability to control these impacts makes diversions incompatible with protection of the fishery resource.

### 2.3.3 Migration

Fish of all ages require freedom of movement to fulfil needs (e.g. reproduction, growth) which cannot be satisfied where they are. Obstructions such as dams or hanging culverts can have long-term effects, while temporary activities (construction of stream crossings) result in short-term stoppages of movement.

Spawning migrations are undertaken typically by mature fish, although they are accompanied periodically by immature fish. Some migrations are extensive; fish may move more than 100 km. The migration period may take several weeks. Within this time frame there is a relatively-short period when most fish migrate. Spawning migration occurs in the spring and fall depending on the species. The slightest obstacle can prevent the passage of fish.

Fish also move from one area to another to feed. These movements may be upstream or downstream and occur over an extended period of time. Before winter freeze-up, fish move downstream to deeper pools for overwintering. This movement is triggered by a reduction in stream discharge.

Fry and juvenile fish also show movement in seeking rearing habitat. As they grow older, they require access up and down the stream and into side channels and tributaries to find food and escape predators.

Factors such as age, sex, maturity of sex organs, water temperatures, time since last swimming activity, light conditions and species all affect swimming performance. Consequently, considerable emphasis must be placed on retaining as many qualities of the original stream channel as possible at each crossing.

### 2.3.4 Streambank Vegetation

Streambank vegetation serves several purposes in keeping a stream's ecology in balance, one being to shade the stream from the sun, thereby keeping the water temperature down. If this vegetation is removed, the stream is opened up to sunlight. Removal of large quantities of streamside vegetation causes the stream temperature to rise and the fish species to seek more favorable areas. They will ultimately be displaced by other warm water and perhaps, less desirable, species.

# 3. LOCATING STREAM CROSSINGS

Careful and adequate planning is essential to locate an environmentally-sound crossing site.

The level of planning will depend primarily on the class of stream to be crossed (Appendix A) and the use and type of crossing structure anticipated.

During the route selection process of a linear facility, the biophysical, socio-economic and engineering components must be evaluated to select a route. Stream crossing sites within the route should be evaluated on a site specific basis before a final choice is made.

During site selection, some factors to consider that may influence cost, design and location of a crossing structure are:

1. Life of crossing structure
2. Vehicle type and/or vehicle loads
3. Approaches
4. Timing constraints
5. Construction scheduling
6. Nearby existing structures
7. Other users
8. Fishery, wildlife and waterfowl values
9. Stream characteristics
10. Soil and ground conditions
11. Erosion potential
12. Environmental protection and mitigation
13. Maintenance
14. Safety

Contact with the Forest Officer or Public Lands Officer (Green and White Areas respectively; see Figure 1), the Fish and Wildlife Regional or Area Habitat Biologist and Alberta Environment is encouraged for information and assistance during planning. This provides an excellent opportunity for information exchange on the route and crossing sites.

## 3.1 Temporary Stream Crossings

A crossing which is used on a seasonal basis or on a short-term project basis for a period of less than two years is considered a temporary crossing. Crossings which may be included are fords, log bridges, snow and ice bridges, timber bridges, portable bridges and culverts. These types of crossings can usually be authorized by operating conditions specified in the land disposition issused (e.g. Licence of Occupation) or an Exploration Approval.

Crossings used during the winter season must be removed before spring break-up unless otherwise approved by a Forest Officer or a Public Lands Officer. Crossings approved for less than two operating years should ensure stream and bank stability and adequate clearance for high water levels. Crossings which are removed and reused the following season should be designed and

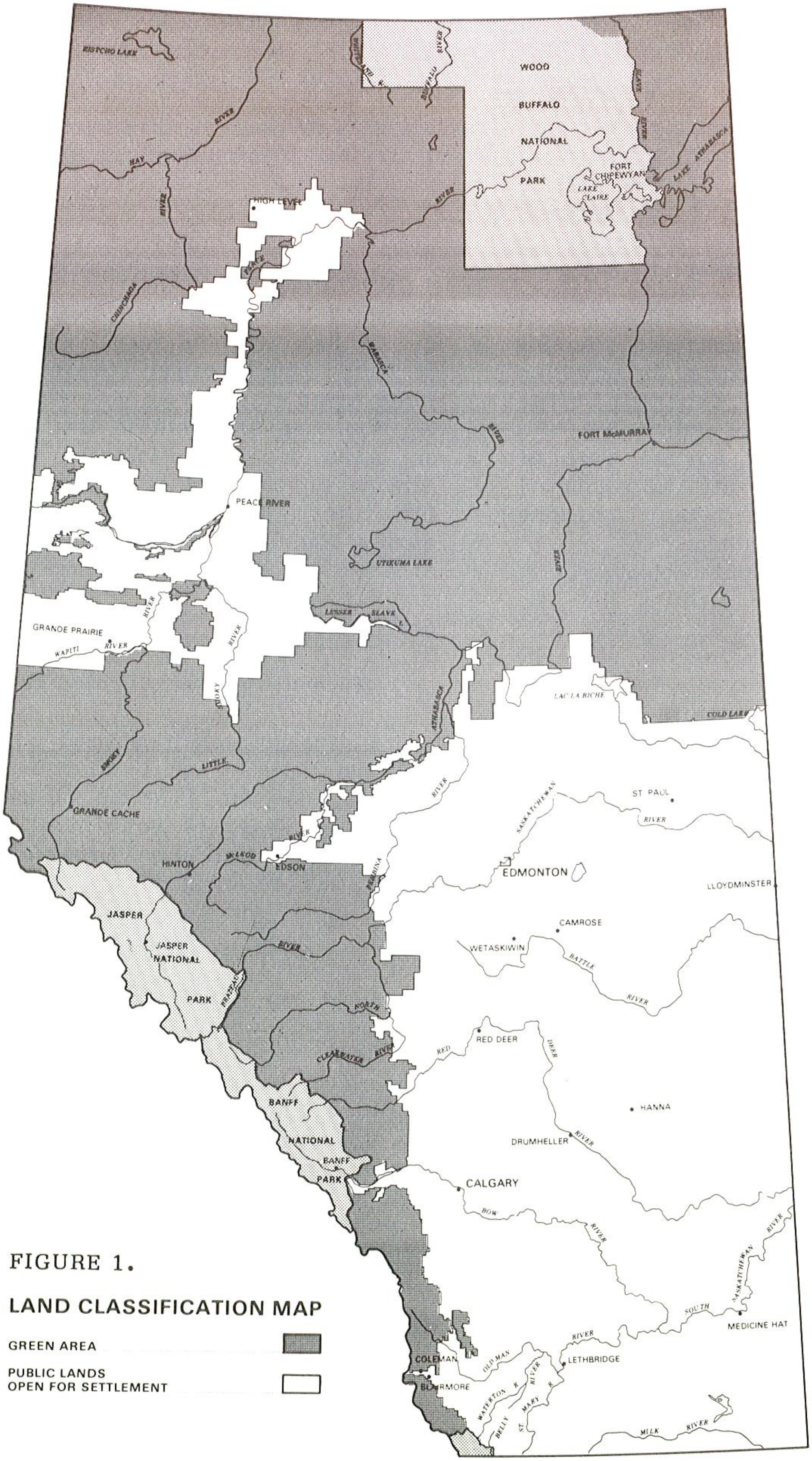



FIGURE 1.

**LAND CLASSIFICATION MAP**

constructed to ensure minimal disturbance to the stream and bank during placement and removal.

Planning for temporary crossings should include the following considerations:

1. An examination of aerial photographs and maps to select one or more possible crossing sites. Some to consider are topographical maps, surficial and bedrock geology maps, soils maps and forest cover maps.
2. An examination of the fishery, wildlife and waterfowl values. All should be given full consideration in the selection of an alignment and stream crossing. Examples are fish migration and spawning, wildlife wintering areas, mineral licks, waterfowl migration and staging areas.
3. An examination of water-level and discharge data. This data is available from Alberta Environment, Environment Canada and the Alberta Forest Service (AFS) (see Appendix B). Crossings should be designed for a minimum 25 year peak flow (the estimated discharge event having a recurrence interval of once every 25 years - see Appendix C).
4. An aerial and ground survey to provide site specific information. Features such as the stream characterisitcs (channel, scour, water flow levels) soil types, soil stability and approach grades should be examined.
5. Preparation of plans on an appropriate large-scale map (1:15 000-1:50 000) showing the crossing locations. Lineal profiles and cross-sectional profiles should also be considered to supplement documentation during application submission.

## 3.2 Permanent Crossings

A crossing designed to be used for a period of two years or more is considered a permanent crossing. Crossings which may be included are timber bridges, steel/concrete bridges and culverts. These types of crossings need to be authorized by licences/permits issued by the Water Resources Administration Division, (AE), pursuant to the Water Resources Act. Application specifications must be obtained from this division.

Planning for permanent crossings should include the following considerations:

1. An examination of aerial photographs and maps to select one or more possible crossing sites. Some to consider are topographical maps, surficial and bedrock geology maps, soils maps and forest cover maps.
2. An examination of the fishery, wildlife and waterfowl values. All should be given full consideration in the selection of an alignment and stream crossing. Examples are fish migration and spawning, wildlife wintering areas, mineral

licks, waterfowl migration and staging areas.

3. An examination of water-level and discharge data. This data is available from Alberta Environment, Environment Canada and the AFS. Crossings should be designed for a minimum 50 year peak flow.
4. An aerial and ground survey to provide site specific information. The following checklist provides some investigations:
   a. Determine where the right-of-way can cross the stream.
   b. Plot straight approaches on each side, at right angles to the watercourse (Photo 2) of a length applicable to the industry equipment (e.g. a logging truck with logs may be 23 m in length).
   c. Approaches and crossing should have the same gradient to avoid slippage and/or impact loading by vehicles.
   d. Examine the site for evidence of high water levels such as ice scars on trees, debris on the streambanks and shrubs and any log jams (photos 3 and 4).
   e. Examine any existing bridges or other structures for evidence of scour, high water levels and for any damage to the crossing.
   f. Examine the soil conditions of the stream channel and streambank for stability and scour.
   g. Examine water flow rates, stream depth, stream width and stream gradient.
   h. Determine erosion control measures such as revegetation, diversion ditches, gabions or sedimentation ponds needed to minimize sedimentation into the stream from the work-site.
   i. Determine the best time of year to schedule construction. The Fish and Wildlife Division can advise on times of year to minimize disturbance to fish populations during fish migration, spawning, egg incubation and fry emergence.
   j. Determine amount, quality and availability of suitable fill and riprap material that may be required.

Photo 2. BRIDGE APPROACHES. Curved approaches onto a bridge will increase horizontal loading and may result in unexpected deterioration. Approaches should be constructed to allow vehicles to finish their turn before crossing a bridge.

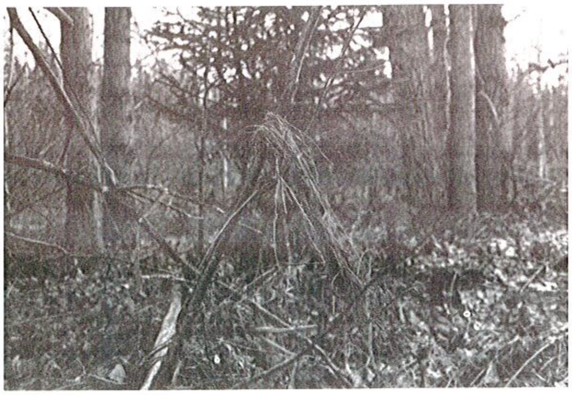


Photo 3. DEBRIS ON SHRUBS. This indicates the water level of a recent flood.

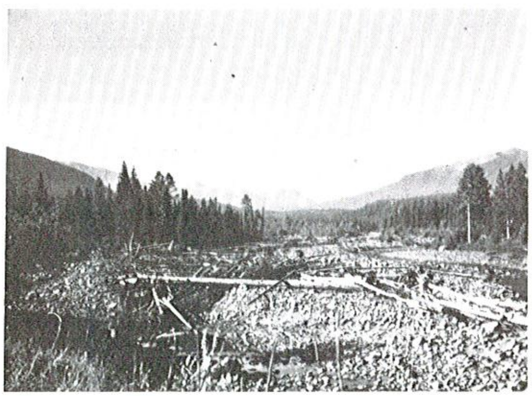


Photo 4. DEBRIS ON STREAMBANK AND STREAM CHANNEL. Position of trees and shrubs and change in river channel are indicative of water levels above normal flows.

5. After an evaluation of the aerial and ground survey, a second survey may be necessary to examine in detail the important aspects of each possible crossing site before choosing a final site. This may include a centreline survey, establishing bench marks, marking ground breaks and high water marks and examining soil conditions. Photographs of important features, profiles and cross-sections of approaches and stream should also be measured.

6. If a bridge is the anticipated crossing structure, some additional investigations to include during the ground survey are:

   a. Estimate the span length.
   b. Determine if abutments can be placed outside the wetted perimeter of the normal stream flow to avoid stream constriction.
   c. Estimate clearance required under the bridge to allow free passage of tree stumps and ice flows at high water levels.
   d. Examine the relationship between the bank height and bridge height. Fill may be required to achieve adequate clearance under the bridge.
   e. Determine if piles can be driven under the scour level for abutments and piers.
   f. Determine if a temporary structure to support the main structure and/or if access to permit stream crossings during construction will be necessary.
   g. Determine if access is required to haul materials and equipment and/or if an area for material storage is required.

h. Determine if working pads are required.

7. If a culvert is the anticipated crossing structure, some additional investigations to include during the ground survey are:

   a. Determine the amount and source of backfill material that may be required.
   b. Determine the necessity of erosion control measures such as revegetation, riprap, aprons and armoring.
   c. Estimate the length of culvert.
   d. Determine the slope gradient to place the culvert.

8. A detailed site survey may be necessary to finalize the design plans for approaches and crossing structure. Included in this survey may be geotechnical studies for scour estimation and foundation aspects such as load-bearing capactiy, settlement and construction methods. Water levels and discharge may be examined and compared with previous data. Photographs and a site map will assist in the final plan preparation.
9. Detailed plans should be submitted on appropriate large scale maps (1:15 000 - 1: 50 000). Some to consider are orthophoto mosaic maps, topographical maps and forest cover maps. A planimetric map (1:400), lineal profiles and cross-sectional profiles should also be considered to supplement documentation during application submission.

## 4. GUIDELINES TO REDUCE ENVIRONMENTAL IMPACT ON STREAM CROSSINGS

The design of any crossing structure should be conducted with the appropriate expertise. Following recommendations in section 3 should allow for the selection of a suitable crossing method and for an appropriate design.

Environmental protection should be practised during all phases of construction. Informing supervisory personnel is often not enough; the construction worker needs to be informed of the concerns and details and should be encouraged to participate actively in environmental protection. Good environmental and engineering supervision is essential to achieve good environmental protection.

### 4.1 General Guidelines

The general guidelines are based upon existing knowledge and are subject to change as new information becomes available. The guidelines do not replace detailed site investigations and recommendations of government agencies. The guidelines serve to identify areas of concern and directions which should be taken.

The following guidelines apply to all stream crossings and are considered basic requirements for installation of an environmentally-sound crossing:

1. All trees and brush should be hand-felled away from the stream and removed to a site above the high water mark. Any trees that do fall into the stream should be removed at the first opportunity in a manner that will minimize disturbance of the stream bed. Do not skid logs across the stream or use the stream for skidding logs.
2. Hand cutting or selective clearing of trees and brush may be necessary on both sides of the stream. The length and degree of slope and the water-bearing capacity of soils may affect the distance of right-of-way to be cleared. Situations may arise where clearing must extend beyond the brow of a slope.
3. Removal of stream side habitat should be limited to the immediate worksite and done only at the time of installation.
4. Ground vegetation should be removed only from areas requiring earthwork and done only at the time of installation. The shorter the period for exposure, the lower the chance of erosion problems. Undisturbed areas aid in erosion

control and reduce the total area and time exposed to erosion.

5. Material excavated from the streambanks should be pulled back away from the stream when preparing the worksite or forming approaches. An excavator (e.g. grade-all, backhoe) is preferred as it can pull material away from the stream and selectively place the spoil away from the stream above the high water mark.
6. Discharge of surface water and ground water from the worksite directly into a watercourse is not acceptable. Drainage and erosion control measures should be installed and maintained during the entire project. Some acceptable measures are:

   a. Diversion ditches may be used to direct waterflow away from disturbed areas into surrounding vegetation off the right-of-way. This may require lining the ditch through disturbed areas with rock or plastic.
   b. Gabions, rock or earth berms may also be used to divert water off the right-of-way onto stable vegetated areas.
   c. Check dams or ditch blocks may be used to restrict water flow and to allow sediment to settle. These should be checked and cleaned frequently to remove excessive deposits of sediment. Check dams consisting of large rocks or sand bags are preferred. Straw bales are acceptable only as a temporary control provided they are dug in for a minimum of 15 cm (6") and are staked. The effectiveness of straw bales depends on frequency of inspections, maintenance and spacing interval.
   d. Settling ponds may be used to collect surface runoff to allow settling of sediment before discharging clean water into the stream. Ponds should be lined with plastic.

7. Instream activity by construction equipment for the construction and placement of a crossing structure should be restricted to low pressure, pneumatic-tired, multi-wheel drive vehicles. The time spent in the channel and the number of vehicle crossings should be kept to a minimum. Unnecessary instream activity with construction equipment should be avoided.
8. Fuels and oils should be stored a minimum of 100 m away from any watercourse. Fueling and servicing of vehicles and construction equipment should also be done 100 m away from the watercourse.
9. Water crossing structures should be protected and all disturbed surfaces reveg-

etated as soon as possible following construction. This may involve recontouring streambanks, slopes and approaches, erosion control, fertilizing and seeding.

10. At least one third of the flowing channel must remain open during any instream work.
11. Except for crossings and approaches, an undisturbed buffer strip of 90 m should be retained between the right-of-way and any stream, river or lake.
12. Existing stream crossings should be used, wherever possible. The number of crossings on any watercourse should be the minimum possible and not be within 2 km (stream length) of each other.
13. Timing restrictions may be placed on construction activity at a crossing site where construction may affect areas for fish migration, spawning or overwintering and/or affect wildlife species of the area. The Fish and Wildlife Division should be contacted to determine any timing restrictions.
14. Construction of a stream crossing should take place during periods of low water flows.
15. The use of explosives for construction of any stream crossing or for any instream excavation (i.e. pipeline) requires an explosive permit from the Fish and Wildlife Division. The use of explosives should be strictly controlled and restricted to authorized personnel. Some techniques to reduce adverse impacts from blasting are to schedule blasting when fish are not in the area, remove fish from blast area and restrict their access with stop nets, use blast deflectors such as sandbags or by using detonation techniques to reduce the area of blast concussion.
16. When stream crossings are removed and will no longer be used, reconstruction of the streambank may be required (see section 4.4).

## 4.2 Specific Guidelines for Designing and Constructing Stream Crossings

This section provides guidelines for specific crossing structures. They are to be used with section 4.1 on General Guidelines.

A good framework for sound decision making is provided by these guidelines. The site specifics of unique situations, however, remain to be assessed on an individual basis.

### 4.2.1 Fords

Fords occur as natural shallow water crossings (less than 1 m deep) that allow for vehicle passage. Fords are used for geophysical exploration, the repair, maintenance or construction of a crossing, when vehicle loads are greater than the load bearing capacity of a crossing and during the installation of facilities such as a pipeline or transmission line. Fords are acceptable crossings provided the following guidelines are observed:

1. The streambed has a firm rock or coarse gravel bottom and has stable approaches which will stand up to the amount and weight of traffic that is to cross. If approaches require stabilization, sloping the streambank and placing clean, coarse granular material on the approach may be necessary.
2. Access to the ford is not on the outside of any bend in the watercourse.
3. The number of crossings are kept to a minimum.
4. Improvement to the crossing is limited to removal of large boulders or debris from the stream within the right-of-way which would interfere with vehicle passage.
5. Fisheries or water users downstream are not critical factors.

### 4.2.2 Bridges

The following guidelines are provided for the most common types of bridges used for temporary and permanent crossings.

Log Fill Bridges. Log fill bridges are logs bundled together with a cable and placed into a stream as a temporary crossing. They are often used during the summer by timber operators. Other alternative crossing methods should be evaluated. A log fill bridge may be acceptable provided the following guidelines are observed:

1. A log fill bridge may be used for crossing intermittent and ephemeral streams when fish passage is not required or when the stream channel is dry.
2. The logs should be bundled together to allow for easy placement and removal.
3. De-limbed and lopped logs should not exceed either side of the running surface by more than 1.5 m. Logs should also be stumped.
4. The logs are removed before spring breakup, on abandonment of the trail or completion of the project, whichever comes first.
5. Any soil placed on top of the log bundle to facilitate vehicle use should be separated from the logs with a synthetic mat or 0.4 m of coniferous boughs. The synthetic mat or coniferous boughs should be the width of the log fill. The soil cap, however, should not exceed the width of the running surface to avoid inception into the stream. The soil and mat removal should be done before log removal.
6. The flow of water is not unduly obstructed and any back-flooding is restricted to the stream channel.

Snow and Ice Bridges. Snow and ice bridges are temporary bridges in place for less than six months and are removed before spring breakup. These bridges are built by taking advantage of natural ice cover of lakes and streams (Photo 5). They provide access for winter operations such as logging and oil and gas exploration. The following guidelines for snow and ice bridges are recommended:

Photo 5. SNOW AND ICE BRIDGE.

1. Only snow and water are to be used for construction. The use of debris in their construction must be avoided at all times.
2. If snow is not readily [illegible] able, it may have to be trucked in from other sources or a portable bridge should be considered.
3. Approaches of compacted snow and ice should be constructed of sufficient thickness to protect the stream or riverbanks.
4. Ice bridges should not interfere with or impede winter flows in any stream.
5. Ice thickness and strength should be measured frequently to ensure the load-bearing capacity of the ice is capable of handling vehicle loads.
6. Ice thickness may be increased by pumping water onto the ice or by using fog nozzles. Snowbanks may be placed on each side of the crossing to contain the water.
7. Culverts may be placed to handle overflow; however, they must be removed before spring breakup.
8. Gently-sloping banks or banks which can be easily modified should be used to allow easy access and to reduce approach speeds. Streambanks should not be unnecessarily cut to improve access.
9. Choose crossing sites that will not endanger the ice bridge. For example, areas of a stream with strong currents may erode the underside of the ice whereas deep slow-flowing sections of a stream may provide good crossing sites.
10. Equipment such as bulldozers or trucks which fall through the ice must be removed as soon as possible. Measures must be taken to contain the escape and release of any pollutants (e.g. fuels, chemicals) into the water or onto the ice surface. Cleanup is required and monitoring of water quality may also be required.

Timber Bridges. Timber bridges are one of the most common methods for bridging a stream for the exploration and development of resources (Photo 6). They are inexpensive and materials are readily available. Many types of timber bridges are constructed (Photos 7 and 8) and placed for temporary and permanent crossings. The following guidelines are provided:

1. Abutments should be placed in areas that do not constrict the stream channel.

2. Points of impact on abutments and piers should be protected to withstand periods of high water levels when erosion, scour and floating debris potential is high and to withstand forces and pressure of ice flows during breakup. Winged abutments and planking, steel sheeting and deflectors on piers are common protection devices (Photos 9 and 10).

3. Any lumber or materials treated with creosote, pentachlorophenol or other wood preservatives should be completely dry. If materials are not dry, toxic substances will be released into the water.

4. Screened, washed rock for riprapping of abutments, piers and streambanks should be large enough to withstand forces of stream velocity.

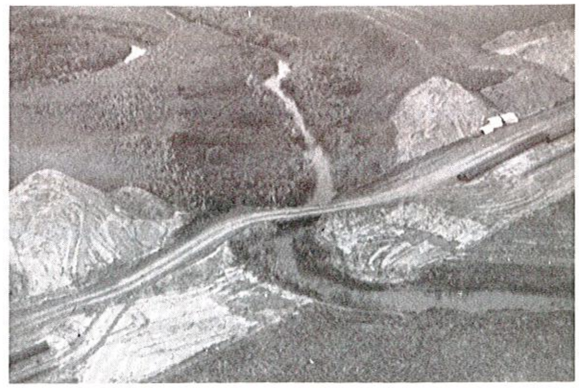


Photo 6. TEMPORARY TIMBER BRIDGE. This bridge was placed for access across a stream during pipeline construction.

Photo 7. SIMPLE LOG STRINGER BRIDGE. Note absence of erosion control measures and that fording of the stream has also occurred.

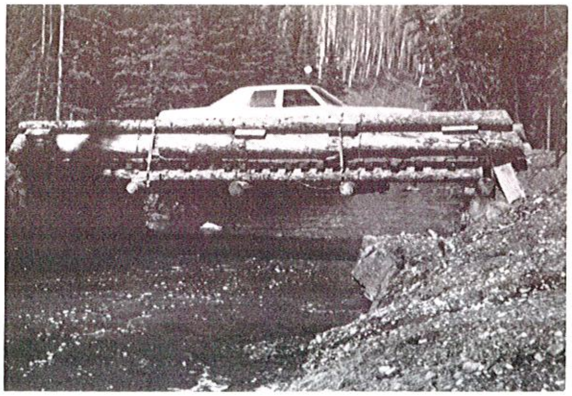


Photo 8. SIMPLE LOG STRINGER BRIDGE WITH GUARDRAILS.

Photo 9. PERMANENT TIMBER BRIDGE. Steel I-Beams are used for stringer and a steel plate has been placed on the pier to deflect debris and protect the pier. Regular maintenance would ensure the removal of debris built up around the pier.

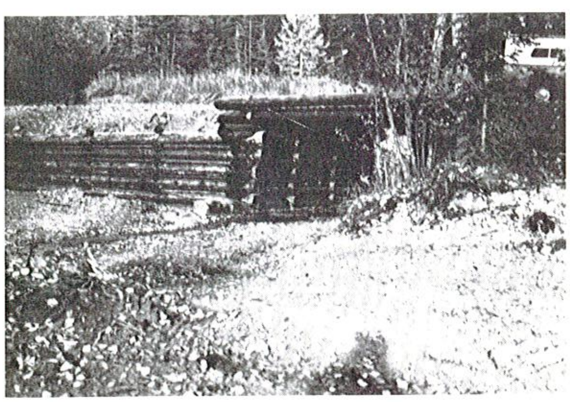


Photo 10. PERMANENT TIMBER BRIDGE. Note the winged abutments for protection and erosion control.

Portable Bridges. Portable bridges are a popular means of bridging watercourses (Photo 11). These bridges, made of sections of steel and sometimes wood, can be used to cross small streams or even large rivers. In the latter situation, multiple spans and in-stream piers can be used. Figure 2 illustrates transportation and installation techniques for portable bridges. Portable bridges are easy to place and remove. The guidelines for timber bridges apply for portable bridges. Abutments used for timber bridges are effective for use with portable bridges.

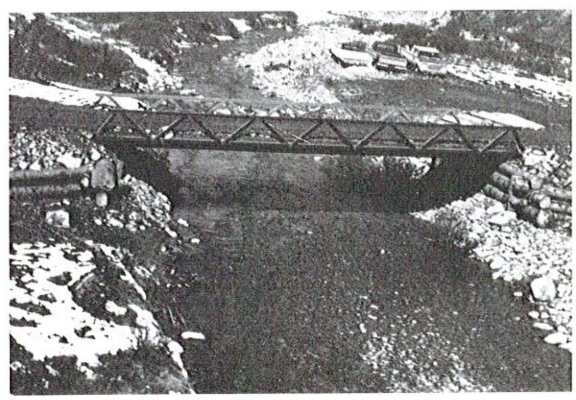


Photo 11. PORTABLE BRIDGE. Simple log cribs were constructed to hold the portable bridge.

Permanent Steel and Concrete Bridges. These are bridges with a high level of planning and technology incorporated into their design (Photo 12). When these bridges fail, it is generally related to bridge location.

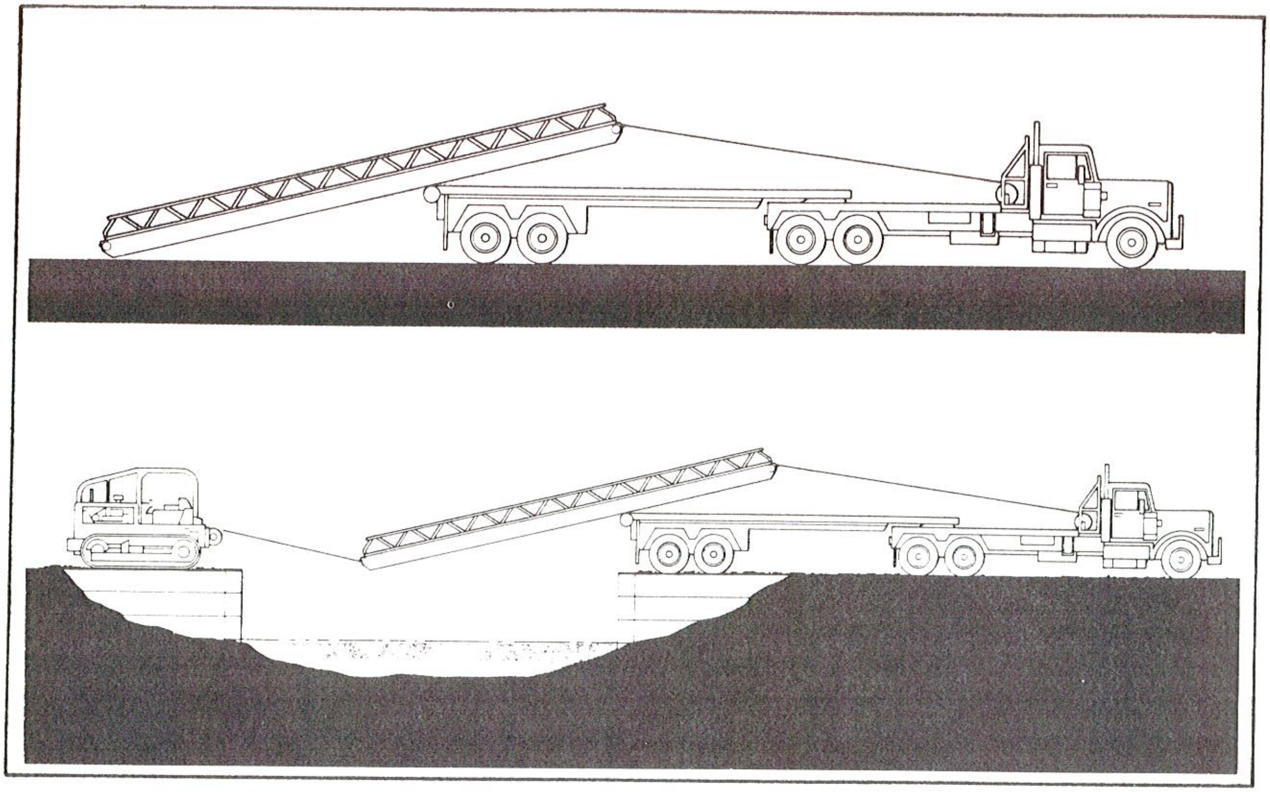


FIGURE 2. TRANSPORTATION AND INSTALLATION TECHNIQUES FOR PORTABLE BRIDGES. A simple span is winched aboard a flat-bed trailer for transportation to crossing site. With the aid of bulldozer, the portable bridge is placed into position on a previously-prepared site.

SOURCE: Jimbob Portable Bridges, n.d.

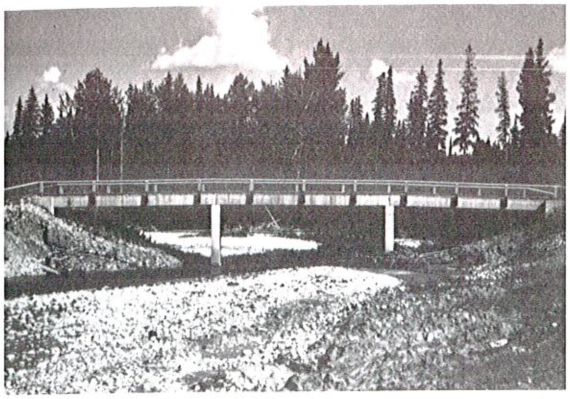


Photo 12. PERMANENT CONCRETE BRIDGE.

For permanent timber bridges, a design to accommodate a minimum 50-year peak flow has been recommended; however, for permanent steel and concrete bridges this design may be inadequate. Location planning (Section 3) may indicate that a 100-year peak flow may be a more desirable minimum design. The following guidelines are provided:

1. The design should incorporate an additional clearance level to provide free passage of ice, logs and other debris.
2. One approach should be higher than the other to allow a safety channel in the event of the bridge being blocked by debris.
3. The design should incorporate measures to protect piers and abutments by forces exerted by ice during breakup.
4. Bridge piers should not be constructed within the main channel. When this is necessary, special measures such as cofferdams, dikes or berms may be required to minimize siltation and to provide a dry work site.
5. With the use of berms (a working pad built into the stream), clean, washed gravel should be used for their construction. Berms must be removed upon completion of pier construction.
6. Precast structures for footings, piers, abutments and/or superstructures should be used. Fresh concrete should be avoided because the risk of pollution from lime and concrete increases.
7. Approaches and streambanks should be stabilized and protected to minimize erosion and to protect the bridge substructure. Screened and washed rock for riprapping should be large enough to withstand stream velocities. Indiscriminate use of riprap can lead to scour outside the protected area. Careful evaluation will be necessary.

### 4.2.3 Culverts

Culverts are used extensively as temporary and permanent crossings on streams. Culverts must be properly designed, installed and maintained to protect the stream and its environment (Photos 13 and 14).

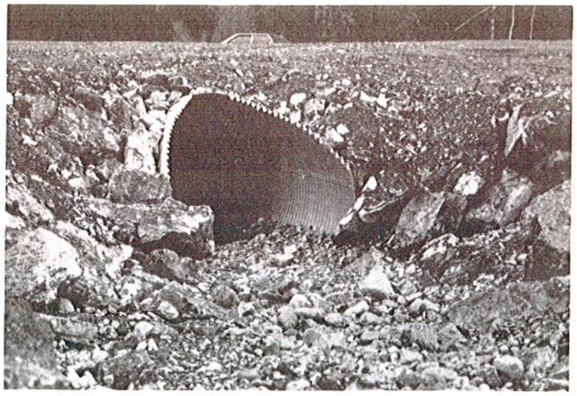


Photo 13. PROPERLY-INSTALLED CULVERT. This culvert has been placed below grade and large rock used for riprap.

Photo 14. PROPERLY-INSTALLED CULVERT. A tapered culvert with large rock for riprap. Unfortunately, inadequate stabilization on slopes and fill resulted in heavy erosion into the stream channel.

Many types of culverts are available. Table 1 presents fisheries and hydraulic considerations for four types of culverts. From an environmental point of view, the open bottom pipe arch is a preferred culvert as it retains most of the natural stream characteristics. The round metal culvert is the most commonly used culvert but is the least desirable.

Contact with regional offices of the Fish and Wildlife Division is expected as standard practice in all matters dealing with the passage of fish through a stream crossing structure. Culverts, because of many of their restrictive qualities, require specific criteria in their design to allow for fish passage and for maintaining water quality. The Fish and Wildlife Division provides expertise to assist the planner in these matters.

In many situations, the stream may not be fish bearing; however, the culvert still must be installed in an environmentally-sound manner because the downstream reaches will eventually become fish bearing.

The main criteria for culvert design is that the culvert must pass the required flow of water attained during peak flows adequately. The culvert must also:

1. be structurally sound;
2. produce neither sedimentation nor scour;
3. allow debris passage;
4. permit fish passage where required, and;
5. be cost effective.

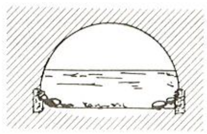
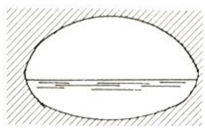
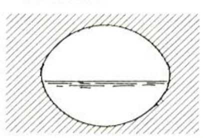
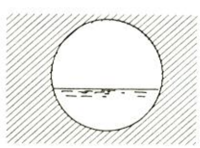
The following considerations are provided to assist in the design and installation of culverts:

1. Hydraulics

   - A temporary culvert should be designed for a minimum 25-year peak flow.
   - A permanent culvert should be designed for a minimum 50-year peak flow.

## TABLE 1

## FISHERIES AND HYDRAULIC CONSIDERATIONS FOR SEVERAL TYPES OF CULVERTS

| TYPE OF CULVERT | FISHERIES CONSIDERATIONS | HYDRAULIC CONSIDERATIONS |
|---|---|---|
| 1. OPEN BOTTOM PIPE ARCH  | - If properly designed and installed, it does not limit fish passage.<br>- Retains natural stream substrate.<br>- Water velocities not significantly changed. | - Wide bottom area enables passage of high flows minimizing increases in flow depth.<br>- Large waterway opening for low clearance installations. |
| 2. PIPE ARCH CULVERT  | - Acceptable for use with approved design in fish-bearing streams.<br>- Can be designed to retain some stream substrate.<br>- Wide, flat profile makes it possible to improve fish passage by back watering the structure. | - Wide bottom area of culvert enables passage of high flows while minimizing increases in flow depth.<br>- Large waterway opening for low clearance installations. |
| 3. HORIZONTAL ELLIPTICAL CULVERT  | - Avoid use in fish-bearing streams or incorporate design modifications.<br>- Represents a compromise between pipe arch and round culvert cross sections.<br>- Stream substrate not easily retained in culvert. | - Squat profile useful in low fill situations.<br>- Shape results in deeper water depth than pipe arch, but does not offer as broad a bottom area. |
| 4. ROUND METAL CULVERT  | - Whenever possible, avoid use where fish passage is important.<br>- If installed, incorporate approved design modification to permit fish passage.<br>- High turbulence and other hydraulic properties greatly discourage fish passage.<br>- Baffles are difficult to install. | - Generally constricts stream width and creates high flow velocities with increased chance of scour.<br>- Concentrates water during low flows. |

SOURCE: Adapted from Saremba and Mattison, 1984.

- The culvert diameter for a non-fish-bearing stream should be a minimum of 0.5 m. Smaller sizes may become plugged with debris.
- The culvert diameter for a fish-bearing stream should be a minimum of 1 m. Smaller sizes may obstruct fish passage.

2. Velocities

- A continuous flow of water sufficient in volume to attract and pass fish must exist during periods of major fish movements. An average water velocity of 0.5 metres per second for warm water fish (e.g. pike, perch) and an average water velocity of 0.9 metres per second for cold water fish (e.g. trout) should be maintained during these periods.
- The selection of culvert velocities to accommodate fish passage should be done on an individual stream basis.
- If velocities within the culvert cannot be met during fish migration periods, then energy dissipators such as baffles should be considered.
- Baffles should be considered when the gradient of a culvert is greater than 2%. Beyond a 5% slope, the effectivness of baffles decreases as the slope increases.

3. Migration Delay

- A three-day delay is considered the maximum time during which blockage of major fish movements can be tolerated during any construction, installation or maintenance of a culvert.
- This time should not be exceeded during fish migration.

4. Water Levels

- Water levels within the culvert should be sufficient in depth to allow passage of the largest fish.
- Depth may vary due to species and size but a minimum level of 20 cm should be maintained during periods of fish movement.

5. Installation and Gradient

- Culverts should be installed within the natural streambed (Photos 15 and 16). The culvert inverts should be laid below the normal streambed for a minimum of 15 cm.
- Culverts should be anchored and clean granular fill should be well compacted at least halfway up the side to prevent water leaking around the culvert.
- The culvert gradient should be the same as the

natural stream gradient. The maximum slope in which a culvert should be installed is 5%.
- Fill material should be free of large rocks.
- Fill above culverts should camber slightly to allow for soil settlement.
- Depth of fill placed above the culvert should be a minimum of half the culvert diameter. A more desirable depth for better protection of the culvert is a depth at least equal to the diameter of the culvert.

Photo 15. HANGING CULVERT. Cutback of the streambanks and road bed has occurred and obstructs fish passage upstream.

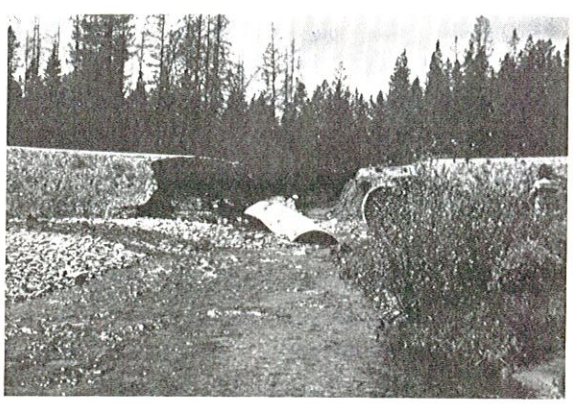


Photo 16. IMPROPERLY-DESIGNED AND INSTALLED CULVERT.

6. Erosion Prevention

- All culverts should be riprapped with rock, sand bags or concrete aprons.
- Armoring of the streambed and streambank with riprap should extend for a minimum of two and preferably six culvert diameters past the culvert outlet at the downstream end.
- The upstream end of the culvert should be armored with riprap on all disturbed surfaces to protect them from erosion during periods of high water.
- All disturbed surfaces should be revegetated.
- Plantings of trees and shrubs are recommended to stabilize the streambank and to re-establish stream side habitat.

7. Multiple Culverts

Multiple culverts may be desirable under site specific situations to provide for fish passage. This may occur when water flows are extremely variable. A single culvert may create excessive velocities during high water flows or not provide adequate depth for fish passage during low water flows. Multiple culverts may alleviate this problem; however, in these situations a bridge may be the better alternative.

The most common occurrences for multiple culverts arise from under-designed culverts and/or frequent culvert icing (Photo 17). Multiple culverts in these situations are generally not acceptable. Some methods to resolve icing conditions in culverts include:

- Relocation and/or realignment of the right-of-way.
- Reinstallation of the culvert and ensuring it is correctly sloped.
- Installation of a larger culvert provided the first culvert has been removed.
- Construction of underdrains to prevent seepage from coming to the surface.
- Provide freezing belts upstream of the culvert by keeping areas clear of snow to allow frost to penetrate and eventually block the flow.
- Provide regular steaming programs to keep the culverts open.
- Replacement of metal culverts with wooden culverts. Wooden culverts are not commonly used but in severe icing conditions, they may alleviate the problem provided they are properly designed and installed.

8. Culvert vs. Bridge

Many situations exist where culverts are placed instead of a bridge; often at the expense of the stream and crossing structure. These situations may arise when:

- Cost of bridge exceeds the culvert.
- Steep approaches may increase loading stress on a bridge and shorten its life.
- Alignment is significantly skewed from the perpendicular of the stream and no viable alternative exists.

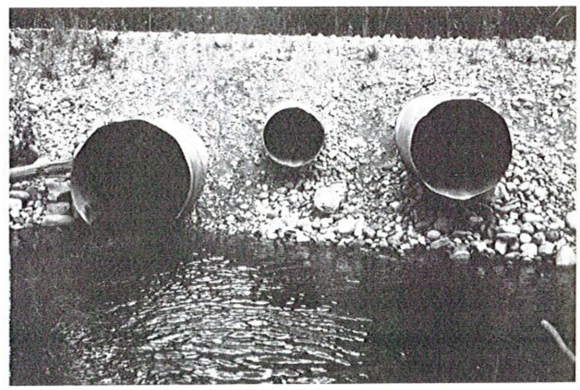


Photo 17. MULTIPLE CULVERTS. These are inadequately designed and placed. A larger culvert, properly placed, or a bridge would serve better.

Bridges are the preferred crossing structure from an environmental point of view. Replacement of a culvert with a bridge usually occurs in an upgrading program due to increased development activity or the frequent replacing and/or adding of culverts. Subsequent work interruptions often become costly (Photo 18). Bridges should be selected when:

- Risk of erosion and sedimentation is high.
- Important fishery migration route is present.
- Design flow of the stream exceeds 8.5 cubic metres

per second.
- Diameter of the culvert exceeds 1.8 m.

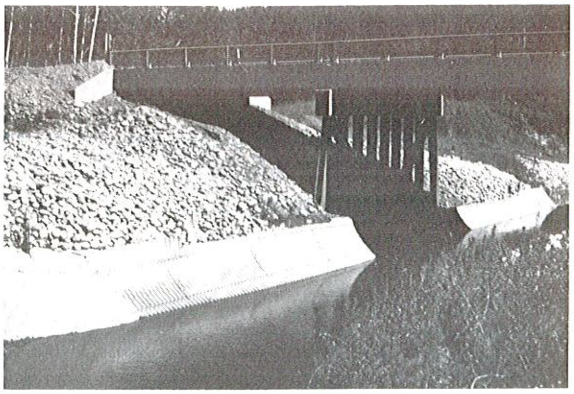


Photo 18. CULVERT VS. BRIDGE. This bridge replaced a culvert which frequently failed to handle peak water flows and heavy loads. Portions of the culvert were retained to prevent scour on the pier.

The use of the above criteria would generally be acceptable when the selection of a bridge or a culvert is undefined.

## 4.3 Maintenance

Once a bridge or culvert has been installed, a regular maintenance and inspection program should be conducted. Washouts are often maintenance related and the lost time, repair or replacement because of a washout can become costly. Regular inspections of all crossing structures should realize a significant long-term cost savings.

Maintenance ensures the operation and safety of a crossing and controls erosion. When washouts occur, the cause should be determined and the crossing repaired or upgraded accordingly. If a washout was due to an under designed culvert, upgrade to a larger one, or, if the washout was due to improper installation or poor fill material, the new crossing should be installed correctly or better fill material should be used. Replacing a culvert with a bridge should also be considered.

### 4.3.1 Bridges

The level of inspection and maintenance on bridges will vary with the users and the period required. Primary considerations must be on the safety of the bridge for users.

Inspections should be required at least once a year. Frequency of inspections may be determined by peak water flows, heavy rainfalls or amount of use of the crossing structure. Inspections should include:

1. An examination of the bridge structure for any deterioration caused by factors such as high water, ice and debris.
2. An assessment of scour around piers and abutments. Excessive scour requires immediate remedial action by filling scour holes and protecting with riprap materials capable of withstanding high water velocities.
3. An assessment of any erosion associated with the bridge structure, streambanks and approaches. Stabilization and riprapping of disturbed areas may be required.

4. Debris buildups around piers, abutments and streambanks must be removed from the stream channel.

### 4.3.2 Culverts

Culvert inspections should be conducted before and during spring breakup and after heavy rainfalls. Sensitive areas may require frequent culvert inspections during high runoff periods. Inspections and maintenance should ensure that culverts are functioning properly and that they are free of debris and sediment (Photo 19). In making inspections:

1. Clear and remove any debris blocking or obstructing the culvert inlet.
2. Repair or replace riprap as necessary at culvert inlet and outlet.
3. Inspect for scour and repair using clean gravel or larger rock.
4. Inspect the culvert barrel for damage. Damage to the barrel may be caused by excessive loads and/or inadequate fill above the culvert. Poor fill material during installation may also damage the barrel.
5. Repair and maintain any damage to the streambed and streambank caused by an improperly-designed and/or improperly-installed culvert. Corrective measures to install an adequate-sized culvert properly should be taken.
6. Areas of beaver activity may require frequent inspections to clear obstructions from culverts (Photo 20). Devices to deter culvert blockages and allow water flow can be installed (Photo 21). Recurring problems should be referred to the Regional Fish and Wildlife office.

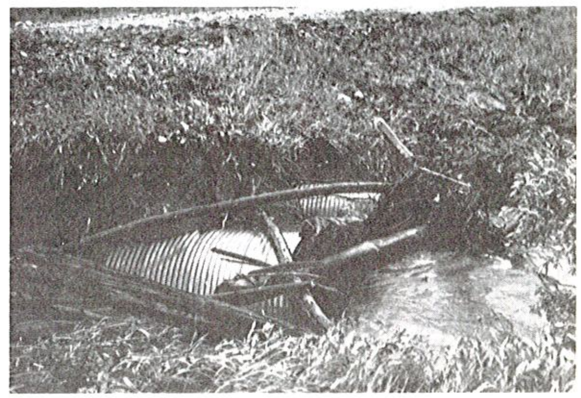


Photo 19. OBSTRUCTED CULVERTS. Inadequate maintenance allowed blockage by debris and sediment. Back flooding occurred and washed out portions of the road at the inlet and oulet ends. Four culverts are located at this site of which only two are visible.

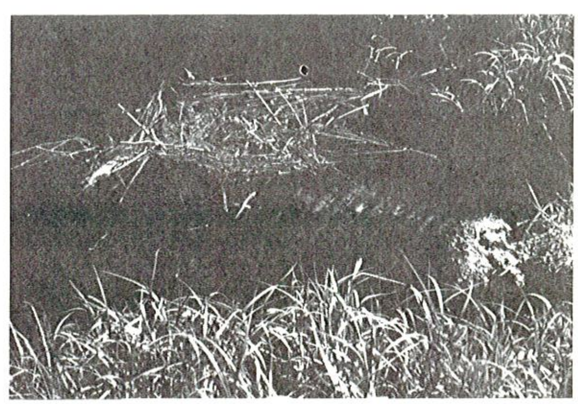


Photo 20. CULVERT OBSTRUCTED BY BEAVER ACTIVITY.

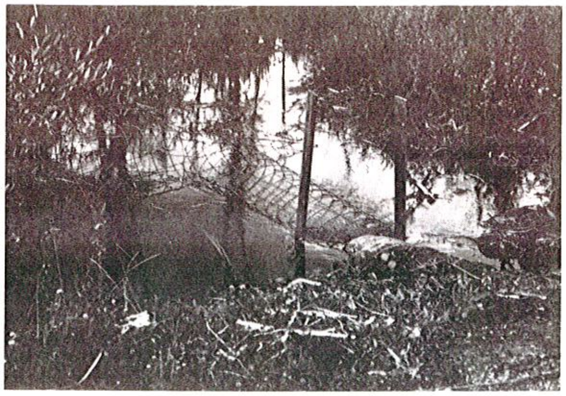


Photo 21. CHICKEN WIRE "T" CULVERT. This device was placed to allow water to flow in an area of beaver activity. The Fish and Wildlife Division should be contacted on other available devices.

## 4.4 Abandonment

Each crossing site should be assessed and reviewed with the Regional Habitat Biologist because a great potential exists to rehabilitate riparian vegetation and fish habitat successfully after abandonment. Effective abandonment should be considered during planning of the crossing structure.

Abandonment of stream crossings may include:

1. Complete removal of all culverts.
2. Complete or partial removal of all bridges. Abutments may be left in place if they provide good erosion protection.
3. Cross drains and diversion ditches should be installed on all approaches as necessary.
4. Restoration and stabilization of streambanks require overhanging banks by using logs or gabions (Figure 3).
5. Revegetation of disturbed areas after restoration and recontouring is considered standard practice. Plantings of trees and shrubs in addition to normal seeding may be required (Photo 22).
6. Measures should be taken to prevent vehicular access after abandonment.
7. Follow up inspections to appraise the crossing site for effectiveness of rehabilitation measures should be conducted. Additional measures for erosion control and streambank protection may be required.

Photo 22. STREAM RESTORATION. Note that logs have been used to reconstruct overhanging banks. Also, the area has been seeded and trees have been planted to stabilize the streambank and to re-establish riparian habitat.

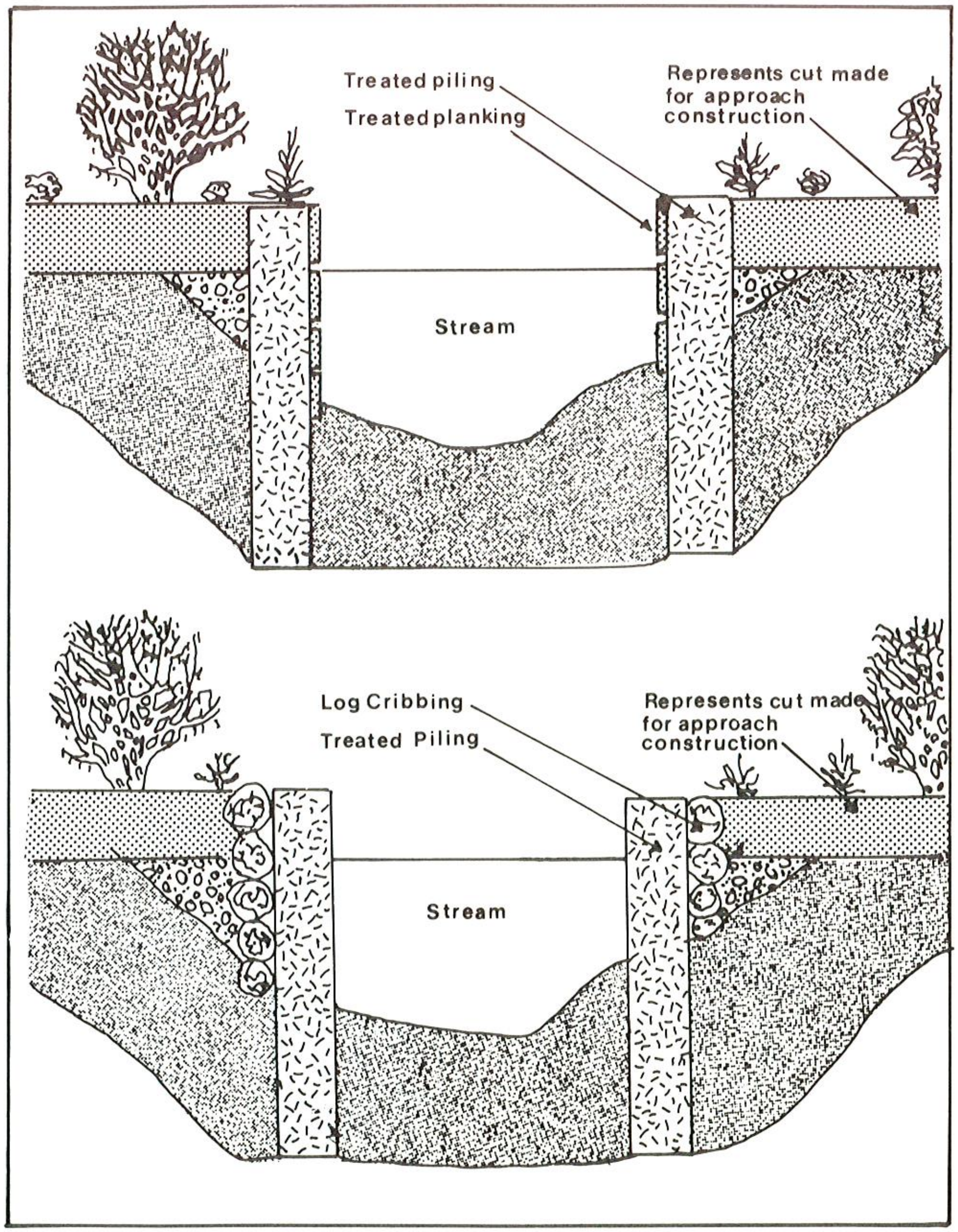



Figure 3A. STREAMBANK RESTORATION TECHNIQUES. These illustrations demonstrate the use of treated pilings and planking or cribbing on streams where stream bottom may not support the use of gabions.

SOURCE: Alberta Energy and Natural Resources, Fish and Wildlife Division, Habitat Branch. 1982a.

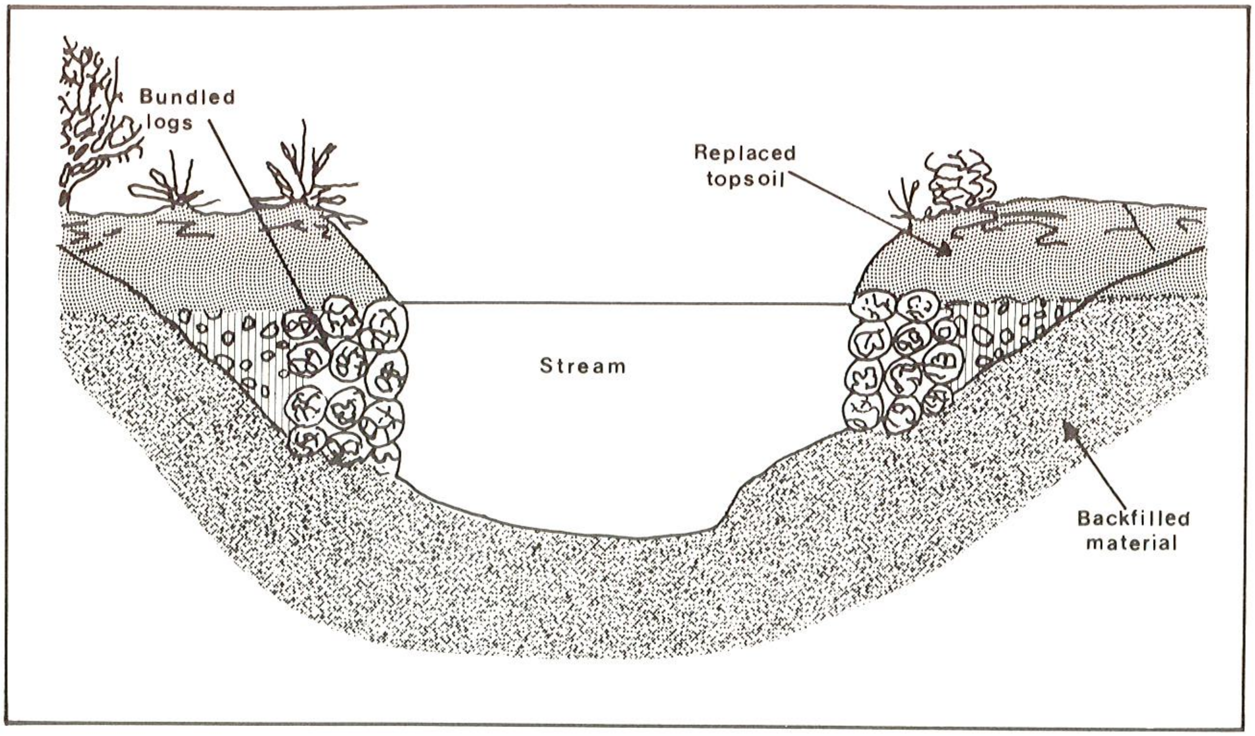



FIGURE 3B. This illustrates the use of bundled logs which can be anchored to provide stability. Gabions can also be used with anchors and offset to provide overhangs.

SOURCE: Alberta Energy and Natural Resources, Fish and Wildlife Division, Habitat Branch. 1982a.

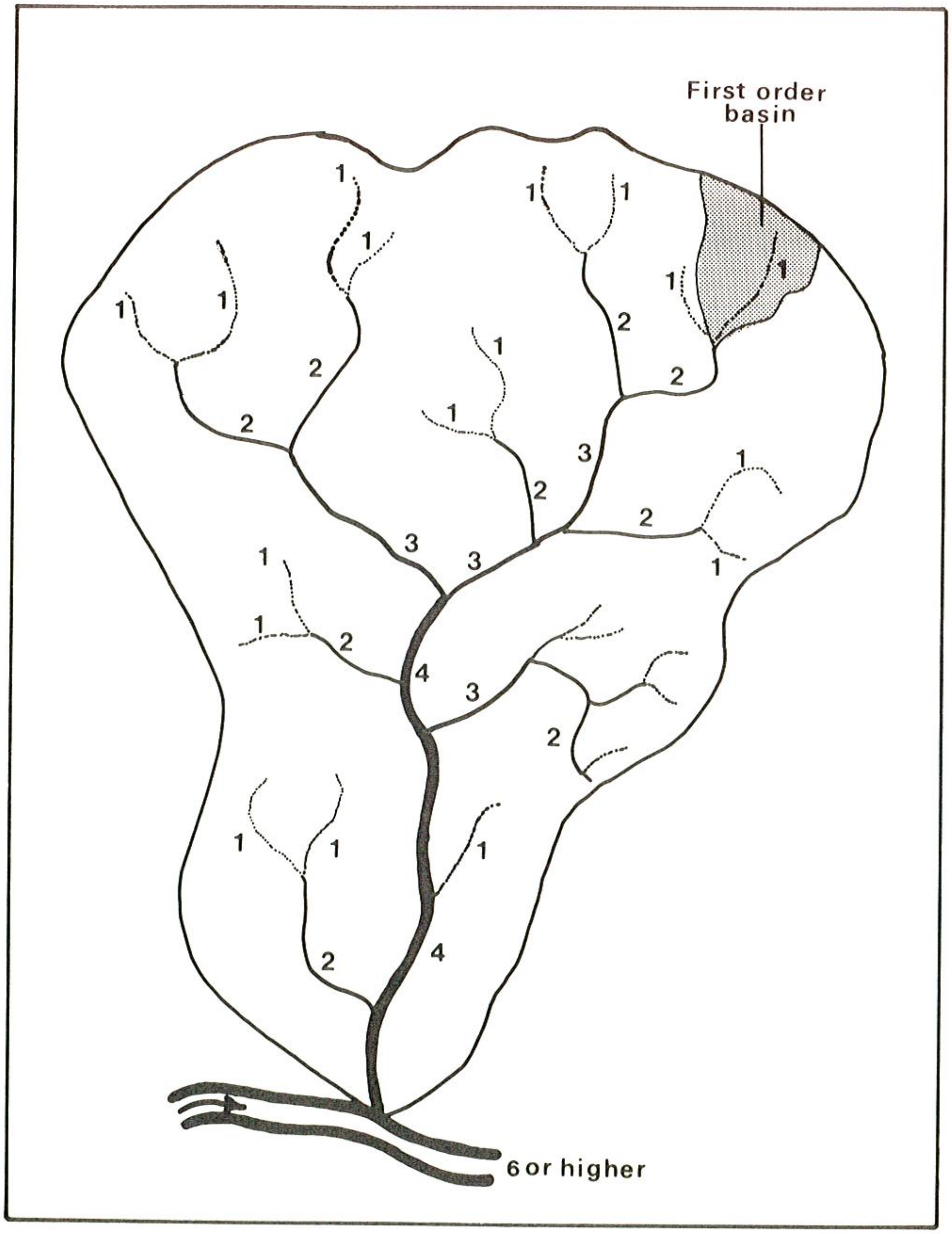
APPENDICES

## APPENDIX A

## STREAM CLASSSIFICATION

| WATERCOURSE CLASSIFICATION | PHYSICAL DESCRIPTION | PORTION OF YEAR WATER FLOWS | CHANNEL DEVELOPMENT | LAND USE IMPACT | FISHERIES CONCERNS | MAP CLASSIFICATION (STRAHLER SYSTEM) (1:15000 scale) |
|---|---|---|---|---|---|---|
| Large Permanent | - major streams or rivers<br>- well defined flood plains<br>- valley usually exceeds 400 m in width | - all year | - unvegetated channel width greater than 5 m | - water quality often reflects all up-stream land use impacts and natural erosion processes | - resident fisheries | - 4th order and above (see Figure) |
| Small Permanent | - permanent streams<br>- often small valleys<br>- bench (flood plain) de-velopment | - all year but may completely freeze in the winter | - banks and channel well defined<br>- gravel and rubble usually present in channel<br>- channel width 0.5 to 5 m | - water quality<br>- fisheries popula-tions sensitive to siltation | - significant insect populations<br>- spawning and seasonal habitat during higher flow periods<br>- resident fish popula-tions in larger streams | - 2nd to 3rd order |
| Intermittent | - small stream channels<br>- small springs are main source outside spring runoff and heavy rain-fall | - during wet season or during storms<br>- dries up dur-ing season of drought | - distinct channel development<br>- usually channel is non-vegetated<br>- channel width to 0.5 m<br>- some bank development | - deposition of sediment during flow periods will damage fish and invertebrate hab-itat and affect higher order streams into which it flows | - production area for important food sources<br>- drift invertebrate populations in pools and riffles<br>- blockages prevent fish passage for spawning | - 1st order |
| Ephemeral | - often a vegetated draw | - flows only during and immediately after rainfall or snowmelt | - little or no channel development<br>- channel is usually vegetated | - sediment production during flow periods as a result of soil disturbance | - only as influence on water quality downstream | |

SOURCE: Adapted from Alberta Energy and Natural Resources, Alberta Forest Service, British Columbia Forest Products Limited, 1981.




THE STRAHLER SYSTEM FOR STREAM ORDER. Scale 1:15 000.

SOURCE. Strahler, 1952.

# APPENDIX B

## STREAMFLOW RECORD SOURCES

Streamflow Records

1. Regional Chief
   Water Survey of Canada
   Water Resources Branch
   Environment Canada
   Bag 2909
   Postal Station "M"
   Room 854
   220-4th Avenue S.E.
   CALGARY, Alberta
   T2P 2M7

2. Director, Water Resources Branch
   Environment Canada
   OTTAWA, Ontario
   K1A 0E7

3. Watershed Management Section*
   Forest Land Use Branch
   Alberta Forest Service
   Alberta Energy and Natural Resources
   9920 - 108 Street
   EDMONTON, Alberta
   T5K 2M4

   * Records are generally less than five years.

4. Flow Forecasting Branch
   Alberta Environment*
   10th Floor, Oxbridge Place
   9820 - 106 Street
   EDMONTON, Alberta
   T5K 2J6

   * Has most records published by Water Survey of Canada.

## APPENDIX C

### Stream Crossing Sizing Methods

Bridges and culverts should be designed to pass the largest peak flow expected during the design life of the crossing.

If the crossing structure is too small (e.g. under designed) it can wash out, resulting in lower water quality, aquatic habitat damage, traffic flow interruption and costly repairs or replacement. Similarly, over designing a crossing can result in unnecessary costs and possible environmental damage associated with the expanded construction activity. Economic and environmental trade-offs between over and under designed crossings has not been quantified.

Many methods have been developed to estimate peak flows and crossing size requirements. None is exact and at best represent only a rough estimate or guideline toward selecting an adequately sized crossing. This appendix does not discuss in detail the use of these methods; however, a 1984 draft report entitled "Sizing Crossings for Eastern Slope Streams," reviews several common methods for sizing crossings. The findings of this draft report on methods to estimate 25-year peak flows are:

Recommended:

1. Return Period Calculation
2. Extrapolation of return period estimate from a similar basin.

Acceptable:

3. Fish and Wildlife Sizing Technique
4. Rational formula
5. Burkli - Ziegler formula

Not Recommended:

6. Kinematic Wave Program
7. Manning's Equation
8. Talbot's Formula

The first three methods were found to be the best overall of those examined for estimating peak flows. A brief review of these three methods is presented.

1. Return Period

Return period is defined as the average period of time between two occurrences of an event that equals or exceeds a given size. For example, the 25-year storm is expected to occur, on average, every 25 years. This does not mean that a 1 in 25-year storm will occur every 25 years, but that there is a 64% chance of the storm occurring within the next 25 years.

Return period calculations are based on available streamflow records and improve with the length of the record. Incorporation of a risk factor into the calculation will increase the cross sectional area of the crossing and reduce the risk of a washout.

2. Extrapolation of Return Period Data From a Similar Basin

When historic streamflow data is lacking for the watershed under investigation, data from a hydrologically-similar basin can be substituted. The return period calculations are converted to area based measurements (e.g. flow per unit area). The data can then be easily extrapolated to other basins.

3. Fish and Wildlife Culvert Sizing Technique.

This technique relies only on the stream's cross-sectional area (at bank full discharge) to estimate the size of crossing required. The level of bank full discharge is determined by observing the location of high water marks or more preferably the top of the unvegetated channel. Care should be taken in determining this level as high-water marks may not coincide with the stage that actually occurred at the time of peak flow. While this method is simple to perform, its only parameter, cross-sectional area, must be judged carefully.

None of the outlined methods can be considered foolproof, but rather they provide a better perspective on the general magnitude of the 25-year return period peak flow. These estimates must be further modified by the addition of recommended safety factors and tempered by personal knowledge of the area. Until more long-term data is available, rules of thumb, formulas and local experience will have to be used.

NOTE: For further information and discussion see Asquin, D.M. 1984.

# GLOSSARY

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**Abutment** - support for the superstructure of a bridge. It transfers the weight of the bridge and traffic to the ground, retains fill material and elevates the bridge to the required height.

**Apron** - protective material laid on a streambed to prevent scour.

**Bankfull** - condition of streamflow when the channel from the streambed to the top of the streambanks is completely filled with water.

**Buffer Strip** - strip of undisturbed land adjacent to a disturbed area which retards the flow of runoff water, causing deposition of transported material, thereby reducing sedimentation of receiving streams.

**Channel** - that area of a stream above the streambed and between the streambanks.

**Cover** - with reference to aquatic habitat, the plants, rocks and other materials used by fish for shelter and protection from adverse conditions and predation.

**Cross Drain** - ditch constructed horizontally to the disturbed slope for the purpose of retarding the flow, thereby reducing the sediment load.

**Debris** - logs, trees, limbs, branches, bark, and other woody material that accumulates in streams or other bodies.

**Discharge** - rate of flow, or volume of water flowing in a stream; usually expressed as cubic metres per second.

**Ditch Blocks** - barrier constructed across a drainageway to retard water flow and to form a small, sediment catch basin. Ditch blocks are usually constructed from timbers, piled up rocks or gabions.

**Diversion Ditch** - channel constructed across a slope to intercept surface runoff, changing the course of runoff into nearby vegetated areas.

**Fry** - young stage of fishes, particularly after the yolk sac has been absorbed.

**Gabions** - compartmented rectangular containers made of thickly-galvinized steel wire mesh of various sizes. The baskets are filled on site with stones. When installed, the gabion becomes a large flexible and permeable building block used to control erosion and stabilize slopes.

**Gradient** - general slope, or rate of vertical drop per unit of length of a flowing stream.

**Invertebrates** - in aquatic systems; includes insects, crustaceans, shellfish and worms.

**Habitat** - generally, the place where an organism lives. Pertains to the conditions found at such locations, including the physical, chemical and biological features such as substrate, cover, water and food.

**Hydraulics** - pertains to the mechanics and behavior of water (and other liquids) flow, particularly in or around pipes, streams, structures and the ground.

**Migration** - with reference to the stream environment, the movement of fish from one area to another within the stream for feeding, spawning or for overwintering.

**Obstruction** - any object or formation of debris which impedes or blocks water flow and/or fish migrations.

**Peak flow** - maximum instantaneous discharge of water expressed in cubic metres per second.

**Pier** - intermediate support used to join and support the ends of two spans.

**Planning** - determining of the goals and objectives of an enterprise, and the selection, through a systematic consideration of alternatives, of the policies, programs and procedures for achieving them. An activity devoted to clearly identifying, defining and determining courses of action necessary to achieve predetermined goals and objectives.

**Reclamation** - returning the land to a condition and productivity in conformity with the prior land use objective of maintaining a balanced ecological state which does not contribute substantially to environmental deterioration and is consistent with esthetic values.

**Recontouring** - grading disturbed land to an acceptable land form.

**Referral** - process whereby applications for permits, licences and leases are made to one government agency by an individual or industry for review and comment.

**Revegetation** - process of seeding, tree planting and fertilizing to establish vegetation in an area where the vegetation was previously removed.

**Riprap** - stones and rocks used to prevent erosion from occurring in a particular area.

**Salmonid** - of the Salmonidae family of fishes; including the Pacific salmon, trout and char.

**Scour** - erosive action of flowing water in streams or by ice. Usually refers to the erosion of the streambed in the vicinity of structures placed in the stream.

**Sediment** - solid material, both mineral and organic, that is in suspension, being transported, or has been moved from the site or origin, by air, water, gravity or ice.

**Span** - distance between abutments and/or piers of a bridge.

**Streambed** - bottom of the stream below the usual water surface.

**Streambank** - rising ground bordering a stream channel.

**Stream Reach** - section of stream of reasonably-uniform gradient, streambed, streambank and flow pattern.

**Stringer** - load carrying member of a superstructure resting on abutments and/or piers of a bridge. Stringers are often made of logs for timber bridges or steel and concrete for permanent structures.

**Substrate** - materials making up the streambed; usually described as bedrock, boulders, cobbles, gravels, sands and silts.

**Surficial Materials** - naturally-occurring, unconsolidated materials including soil which cover the earth's surface.

**Training Works** - devices used to protect streambanks, structures in the stream (bridges) and approaches against the erosive forces of flowing water.

**Watershed** - catchment area for a stream or river system, together with its land and water resources.

# LIST OF REFERENCES

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