

Forest Road Manual

Guidelines for the design,
construction and management
of forest roads

Tom Ryan, Henry Phillips, James Ramsay, John Dempsey

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and management of forest roads

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Photos provided by Paul McMahon, Pat Kelly and John Dempsey

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Figures prepared by John Dempsey

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Foreword

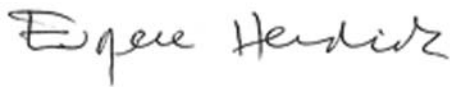
Private planting has increased significantly over the past two decades to now account for over 40% of the area under forests in Ireland. There are in excess of 16,000 owners, the majority being farmers with an average forest holding of 10 ha. This private resource has the potential to produce over 4 million m³ between now and 2015. For this potential to be realised, forest crops must be thinned on time. Thinning is a pre-requisite to maximising returns to the State on its significant investment in forestry and forest roads are a pre-requisite for thinning.

However, forest roads are not just for timber extraction. Their role is much more multifunctional than merely carrying loads of timber. When adequately designed and constructed, forest roads can enhance biodiversity, give access for better and more timely inspection and management, allow access for the fighting of forest fires and act as a fire break, and, subject to landowner approval, give access to the public to enjoy the many and varied recreational uses presented by forests.

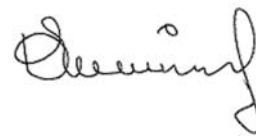
This manual is the first comprehensive guide to the design, construction and management of forest roads in Ireland that is available to all sectors of the industry – both public and private, foresters and landowners, engineers and contractors, as well as students of forest management and civil engineering.

The production of this guide was made possible by a project team which has a wide array of skills and many years combined experience in forest management, engineering and environmental matters. The resulting publication is testament to the professionalism of the authors in every facet of their work.

It is hoped that this guide becomes the standard work for the design, construction and maintenance of forest roads. Proper, fit-for-purpose roads are essential for the development of the professional harvesting and haulage infrastructure necessary to realise the full potential roundwood production from the forests of Ireland.



Eugene Hendrick
Director



David Nevins
Chairman

Section A: Introduction

A.1 INTRODUCTION

Forest cover in Ireland now accounts for 9% of land area or circa 650,000 ha. Afforestation has averaged 14,000 ha over the past three years. Total timber volume production is set to increase from 3 million m³ in 2001 to 4.5 million m³ by the year 2015. Much of this increase will come from the private sector who now account for about 40% of national forest ownership. Significant investment in forest roads will be required to access this roundwood. To date, due to the pattern of forest ownership, the State has been the major builder of forest roads. However, as private plantations mature and enter the thinning stage, forest roads will increasingly be required by private owners.

Little relevant information is available to private owners on the design and construction of forest roads. What is available is usually highly technical in nature and has not been written with forest owners in mind.

The *Forest Road Manual* covers all aspects in the planning, design, construction and maintenance of forest roads¹. It has been written for the entire forest industry.

A.1.1 FOREST ROADS

Forest roads are necessary to provide access to the forest for general management, maintenance, timber extraction and recreation. Apart from initial establishment, roads represent the single greatest capital investment by the owner. There is a need not only to provide a cost efficient road design and layout suitable for extraction but also to ensure that the forest road is compatible with environmental values.

Forest owners might neglect the timing of forest road construction as roading only assumes relevance when the crop is ready to produce timber. However, if planned at the time of crop establishment, many advantages ensue including:

- ▶ ease of layout and survey;
- ▶ alignment of road with the existing drainage system;
- ▶ unplanted road lines can act as firebreaks;
- ▶ reduces risk of windthrow as there is no opening up of the crop;
- ▶ improved opportunity to enhance biodiversity; and
- ▶ access.

The exception is on peat soils, where road reserves are only cut prior to road construction as the tree roots can provide a base for road formation.

The main stages in road construction are:

- ▶ **planning** – roading requirement, road density;
- ▶ **survey** – layout, alignment;
- ▶ **technical design** – specification, drainage, construction method, costing;
- ▶ **contractor selection** – based on detailed specification;

¹ Public roads are the responsibility of the Local Authorities and the National Roads Authority.

- ▶ **formation** – construction of the road base;
- ▶ **completion** – surfacing of the carriageway following a period to allow formation to dry;
- ▶ **final inspection** – ensuring the road was constructed correctly;
- ▶ **commissioning** – putting the road into use.

Once built, roads will require on-going maintenance by the forest owner, especially after harvesting operations and periods of heavy rainfall.

Forest roads in upland areas will be either contour, valley or connecting roads. Contour roads run at approximately the same elevation along their length and therefore will be, more or less, at a level grade. They are cut out of the hillside and are economical to construct. Valley roads are nearly always at a gradient, varying from almost level to the maximum permitted and are located to optimise timber extraction. Connecting roads are those which join up the system into an overall road network.



PHOTO 1: Old forest road network.

A.1.2 USE OF GUIDELINES

This manual is intended as a guidance document. While it outlines legal requirements and Forest Service standards, much of the information contained in it is advisory, indicating good forest practice.

READERS ARE DIRECTED TO OBTAIN COMPETENT PROFESSIONAL ADVICE ON FOREST ROAD WORK. THE AUTHORS ACCEPT NO RESPONSIBILITY FOR THE READERS ACTIONS/INACTIONS.

Each chapter covers a different aspect in road planning, design, construction or maintenance/repair. The reader may find certain information repeated in different chapters as the authors consider that it would be more beneficial to present key information in this manner. The object is to allow the reader find necessary information quickly without having to search various parts of the manual.

The flow diagram in section A.2 shows the general procedure to follow when planning, designing and constructing a forest road.

Where the reader requires further detail or information, a comprehensive bibliography is provided.

A.2 FOREST ROADWORKS QUICK REFERENCE GUIDE

NEW FOREST ROADS

What length is required to harvest the timber crop?	→	B.3 Forest Road Density and Economics
Is planning permission required?	→	B.9 Forest Road Planning B.9.3 Public Road Entrances B.9.4 Planning Issues B.1.2 Environmental Impact Assessment
How do you plan a forest road?	→	B.4 Forest Access B.9 Forest Road Planning B.10 Forest Road Survey/Layout
What design standards apply to a forest road?	→	B.7 Forest Road Design Standards B.8 Additional Equivalent Road Length C.10 Access to Forest Roads (from forest) C.11 Streams and Waterway Crossings C.12 Roads Curves, Junctions, Passing and Turning Places C.13 Interaction with Public Roads C.14 Loading Bays E.8 Extra Widening at Curves
Are there any environmental factors to consider during the planning, design or construction stages?	→	B.1 Environmental Considerations B.9.5 Archaeological and Monument Sites B.9.6 Fisheries and Wildlife B.9.7 Environmental and Social Concerns C.8 Quarries, Pits and Disposal Areas
What do technical terms like 'superelevation' or 'µm' mean?	→	A.7 Glossary A.8 Acronyms

How are forest roads constructed?



- C.1 Forest Road Clearance Work
- C.3 Forest Road Formation Methods
- C.4 Reversal Roads
- C.5 Forest Road Completion
- C.6 Forest Road Construction Problems
- C.9 Embankments

What is a development road?



- B.5 Development roads
- B.9.2 Existing Roads or Tracks and Development roads

What are engineered tracks and where can they be used?



- B.6 Engineered tracks
- B.9.2 Existing Roads or Tracks and Development roads

What type of forest roads are suitable for peat or wet soils?



- C.3.4 Geotextiles
- C.3.12 Stages and Methods of Formation – ‘Build on Top’ Embankment Roads
- C.3.13 Stages and Methods of Formation – ‘Reversal’ Embankment Roads
- C.4 Reversal Roads
- C.4.2 Type A Reversal Road Construction
- C.4.3 Type B Reversal Road Construction
- C.9 Embankments

What materials are suitable for use in constructing forest roads?



- C.7 Construction Materials/Grave/ Crushed Stone
- C.8 Quarries, Pits and Spoil Disposal Areas
- E.6 Specification for Road Material

How are stream or watercourse crossings constructed?



- C.11 Streams and Water Crossings
- C.11.3 Culvert Types
- C.11.8 Bridges
- C.11.9 Fords
- C.11.10 Irish Bridges
- E.8 Estimation of Waterway Areas

What type of drainage is required?



- C.2 Forest Road Drainage
- C.2.3 Sediment Traps
- C.2.4 Buffer Strips
- C.10.2 Drain Crossings
- C.10.5 Drainage Control on Sloping Sites
- C.10.6 Roadside Drainage Damage

What safety factors need to be considered?

B.2 Safety
E.3 Appropriate Signs for Use in Forest Roadworks

How important is access from the forest onto the forest road?

C.10 Access to Forest Road (From Forest)

EXISTING ROADS OR TRACKS

How often should roads be repaired or maintained?

D.2 Road Maintenance and Repair
D.2.1 Guidelines
D.2.3 Why Maintain and Repair Roads
D.2.4 Main Elements to Repair and Maintenance

What is Road Upgrading?

D.1 Road Upgrading;
D.1.2 Recognising the need for Upgrading

When should a road be closed to traffic?

D.3 Road Closure
D.3.1 Guidelines

A.3 GLOSSARY

ABNEY LEVEL	A hand-held level which measures slope angles.
ABSORPTION	The entry of fluid into a solid by virtue of the porosity of the latter. Often in conjunction with capillary action.
ABUTMENT	A support for an arch or bridge, etc., which may also support horizontal forces.
AGGREGATE	A general term for mineral particles which through the agency of a suitable binder can be formed into a solid mass.
ALIGNMENT	The geometric form of the centre line of the carriageway. A ground plan showing a route, as opposed to a profile or section, which shows levels and elevation.
ANGLE OF REPOSE	The angle from the horizontal which the sloping face of a bank of loose material assumes.

APRON	A layer of concrete, stone, timber or other permanent material placed at the entrance or outlet of a structure, such as a culvert, to prevent scour by water.
AQUATIC ZONE	A permanent or seasonal river, stream or lake shown on an Ordnance Survey 6 inch map.
BACKFILL	Earth or other material used to replace material removed during construction, such as in subdrain trenches or behind culvert and bridge abutments.
BASE	Surfacing material in the pavement in unbound roads
BATTER	(a) The uniform side slope of walls, banks, cuttings etc., (b) The degree of such slope, usually expressed as x horizontal units to one vertical, e.g. 5 in 1.
BENCH	(a) A ledge cut or formed in the batter of a cutting or bank to provide greater security against slip material depositing on the roadway, or to provide visibility on a curve. (b) A ledge cut or formed below the road formation to contain side cast fill.
BERM	A formed upstand of compacted fill material. Usually used to direct water run-off.
BLINDING	A thin layer of approved granular material to assist in binding a loose surface material, filling excess surface voids, or improving traction.
BORROW PIT	An excavation for obtaining fill material from outside the formation limits.
BOUND (ROAD)	A road completed with an impervious layer which does not allow the ingress of water through its surface, e.g. tarmacadam, asphalt and concrete.
BRASH MAT	A layer of branches and/or tree tops.
BUFFER ZONES	An area adjacent to an aquatic zone and managed for the protection of water quality and aquatic ecosystems.
CALIFORNIA BEARING RATIO (CBR)	A test carried out to determine the strength of a road surface, sub-base or base course. In simple terms it gives an expected performance percentage when compared to a good road aggregate.
CABLE (EXTRACTION)	The extraction of timber from the forest to roadside or a landing through a system of winches and suspended cables.
CAMBER	(a) The degree of cross fall on a road from centre line to side.

	(b) The curved cross sectional profile given to the formation and to the carriageway to aid water runoff.
CAPPING LAYER	A layer of rock or other suitable material placed on poor sub-grades to prepare them to receive the base completion material. Generally used on peats and very weak mineral soils, e.g. silty clays and clayey silts.
CARRIAGEWAY (roadway)	That portion of the road devoted particularly to the use of vehicles, inclusive of shoulders and auxiliary lanes.
CATCHMENT AREA	That area determined by topographical or equivalent features upon any part of which rain falling will contribute to the discharge of the stream at the point under consideration.
CENTRE LINE	The basic line, at or near the centre or axis of a road or other work, from which measurements for setting out or constructing the work can conveniently be made.
CLINOMETER	A survey instrument used to measure slope angles.
CONTOUR	An imaginary line along the side of a slope that connects points of the same elevation
CORDUROY	Brush, timber or logs laid over a low bearing surface to spread the load.
CROSS SECTION	The profile of the ground more or less at right angles to a traverse or main directional line.
CROSSFALL	The slope at right angles to the main alignment direction.
CULVERT	One or more adjacent pipes or enclosed channels for conveying a watercourse or stream below formation level.
DESIGN SPEED	A speed fixed for the design and correlation of those geometric features of a carriageway that influence vehicle operation.
DISCOUNT RATE	The percentage (interest) rate per annum at which future sums are discounted in order to express them as equivalent present day values.
DISCOUNTING	The process of reducing future sums of money or timber volumes to take into account the delay in time before they are spent or received.
DRAINAGE	The provision of channels to remove excess water or to lower the water table to a level below the road and to prevent the ingress of water in the future.
EARTHWORKS	All operations involved in loosening, removing and depositing or compacting earth, soil, or rock: or the material when so placed.

EMBANKMENT	A raised mass of soil or rock used to carry a road over low areas.
ENGINEERED TRACK	An engineered, level, cambered formation (foundation) of 4 m width, capable of supporting harvesters and forwarders without causing rutting.
EROSION	The process by which soil particles are detached and transported by water and gravity to some down-slope, or down-stream deposition point.
EXCLUSION ZONE	Areas in which forest roadwork and its ancillary activities are not permitted.
FORD	A relatively shallow place in a stream or watercourse where the bed may be crossed by traffic. The ford can be natural gravel or concrete.
FORMATION	The final surface of the ground, excluding any side slopes after completion of the earthworks on which the pavement is founded.
FORMATION WIDTH	The entire width of new formation excluding batters.
FORWARDER	A purpose built forest machine, wheeled or tracked, designed for the extraction and/ or transport of timber by carrying the load of timber clear of the ground.
GABION	A rectangular basket constructed of wire mesh packed with stones or boulders used for protection of river banks etc.
GEOTEXTILE	A synthetic fabric utilised in soil stabilisation and reinforcement of roads.
GRADIENT (or GRADE)	Expressed as the fall or rise of 1 vertical unit per number of horizontal units of a pipe, road, etc. The slope can also be expressed as the number of degrees from the horizontal or as a percentage.
GRAVEL	Coarse grained material, smaller than 60 mm, which remains on a 2 mm sieve.
HARVESTER	A purpose built forest machine, wheeled or tracked, complete with crane and harvesting head used to fell, delimb and cross-cut trees.
IGNEOUS ROCK	Rock resulting from molten magma pouring out into the earth's surface like basalt or being exposed by erosion like granite.
IMPERVIOUS	Impassable or impenetrable. Usually means in roading work that there is no way for water to pass through.
INTERSECTION	The place at which two or more roads cross.

IRISH BRIDGE	A set of parallel culverts laid across a stream and overlaid with a concrete slab.
LOG STEP	A bolt or series of bolts of timber placed at the exit point of the extraction rack to facilitate the removal of mud from forwarders and other forest machines, prior to entering onto the forest road.
METAMORPHIC ROCK	Rocks that have been transformed from intense pressure, e.g. marble from limestone or chalk, gneiss from granite, quartzite from schist, schist from shale, etc.
MORAINES AND ESKERS	Glacial deposits formed on the retreat of the ice age.
OPTIMUM MOISTURE CONTENT (OMC)	That moisture content of a soil at which a specified amount of compaction will produce the maximum dry density.
PASSING BAY	A widened length of carriageway at which vehicles can pass each other.
PAVEMENT	Constructed layers of a road surface which reduce/disperse loads to levels which are within the bearing capacity of the sub-grade.
PIT-RUN GRAVEL	The material obtained from a natural deposit of gravel without separation or addition of other material.
QUARRY	An open-surface working from which stone is obtained.
RAVELLING	The loosening of stones or particles forming the surface course of a pavement.
REVTMENT	A facing of stone or other material laid on a sloping face of earth to maintain the slope in position or to protect it from erosion.
RIPARIAN ZONES	The area directly adjacent to an aquatic zone, representing the intermediate between the aquatic and terrestrial environments.
RIP RAP	Loose stone deposited to protect against scour.
ROAD RESERVE	The strip of land immediately affected by the roadworks. In an existing plantation it corresponds to the tree clearance width.
SCREE	Loose rock plucked from a rock mass by frost action.
SEDIMENT	Any material which settles in a liquid, such as the material which is carried and dropped by a river or drain, often called silt.
SEDIMENT TRAP	Structures used to monitor the sediment produced from an area during construction and/or reduce the quantity of sediment entering a waterway.

SEDIMENTARY ROCK	Rocks formed by laying down of particles transported by wind, water or ice.
SETTLEMENT	A downward movement of the soil or of the structure it supports by the reduction of the voids in the underlying ground.
SHOULDER	That portion of the road continuous and flush with the pavement on either side of the road which is not used by the travelling traffic.
SIDECAST	Placement of spoil to a side of the excavation.
SOAK PIT	A large hole maybe filled with rock or stone to create a large surface area in the surrounding ground so that surface run-off can soak away.
STRIPPING	The removal of the upper layer of soil or overburden (including contained roots, humus or stones; or the material so removed).
SUBBASE	The material in the pavement in unbound roads below the upper surfacing layer.
SUB-GRADE	The parent <i>in situ</i> material immediately below the formation.
SUPERELEVATION	The transverse or inward slope of road surface on curves/corners.
THEODOLITE	A survey instrument used to measure horizontal and vertical angles.
TRAVERSE	A line of bearing and distances used in road surveys to determine location.
UNBOUND (ROAD)	A road completed with a pervious layer that allows the ingress of some moisture through its surface.
VOIDS	The volume not occupied by solids including the volume occupied by air and water.
YIELD CLASS	A measure of the potential volume growth per hectare of a forest crop based on the maximum mean annual volume increment using 2 m ³ intervals between the classes.

A.4 ACRONYMS AND ABBREVIATIONS

The following is a list of abbreviations used in this manual excluding those used in formulae and explained in the text at their place of use.

CBR	California Bearing Ratio
COFORD	National Council for Forest Research and Development
GPS	Global Positioning System
FÁS	Foras Áiseanna Saothair – Training and Employment Authority
HAS	Health and Safety Authority
HDPE	High Density Polyethylene
LCA	Landscape Conservation Area
LGP	Low Ground Pressure
m	Metre
mm	Millimetre
mc	Moisture Content
MCV	Moisture Condition Value
NRA	National Roads Authority
OMC	Optimum Moisture Content
OS	Ordnance Survey
r.o.w.	Right of Way
SAC	Special Areas of Conservation
SPA	Special Protection Areas
WAV	Water Absorption Value
µm	Micro metre = one millionth of a metre

Section B: Planning and Design

B.1 ENVIRONMENTAL CONSIDERATIONS

The construction of forest roads represents one of the more visible forestry operations and can have a number of environmental impacts including landscape, water, soil, habitat and social/community. This *Forest Road Manual* includes practices and guidelines to ensure that all phases in the construction of forest roads are carried out in a manner that is compatible with environmental values and sustainable forest management.

TABLE 1: Environmental values for various road construction phases.

PHASE	AIM
Planning	Potential environmental risks and construction difficulties are identified at road planning stage to ensure adequate design standards consistent with minimising environmental impacts.
Design	New and upgraded roads designed to a standard capable of carrying anticipated timber haulage traffic for a crop rotation to meet environmental requirements and with safety.
Location	Roads located so as to minimise risks to environmental values and road construction to take account of environmental values during all stages of formation and completion.
Construction	Forest roads and access points to county roads constructed in planned engineering stages, to minimise disturbance to the site, and well in advance of timber harvesting and road haulage.
Drainage	Roads properly formed, consolidated, completed and drained to ensure that the impact of run-off on water quality is minimised.
Maintenance	Road surfaces and drainage works maintained to protect the road foundation, disperse water and minimise environmental impact.

B1.1 ENVIRONMENTAL VALUES

This chapter is taken from the Forest Service *Code of Best Forest Practice* and the reader is referred to that text for further information and explanation.

In order to plan and manage forest operations (including road construction) in a sustainable manner, it is necessary to identify certain forest values which need to be safeguarded. These values, which are shown in Table 2, can be broadly classified as environmental, economic and social, with associated constituent values.

TABLE 2: Sustainable values necessary in all forest operations.

ENVIRONMENTAL VALUES	ECONOMIC VALUES	SOCIAL VALUES
Soil	Sustained productivity	Rural development and farm forestry
Water quality	Commercial viability	Amenity and recreation
Landscape		Safety
Ecological and scientific values		Other community values
Cultural and archaeological		
Biodiversity		
Forest protection and health		

Environmental value - soil

Soil values relate to erosion, compaction, stability and displacement, and levels of soil fertility. Wet soils, particularly peats, can become badly compacted by machine passage. Soil displacement and slippage can occur during road construction with consequent impact on water quality. Damage can be reduced by carefully planning and supervising forest operations, including road construction.

Environmental value - water quality

Water values are concerned with protecting water quality, ecology and stability and controlling onsite and downstream impacts. An aquatic zone is defined as a permanent or seasonal river, stream or lake shown on an Ordnance Survey six inch map (1:10560 scale).

Establishment, harvesting and road construction impact on the hydrology, chemistry and level of sedimentation in aquatic zones, through compaction by heavy machinery, soil displacement and slippage, increased run-off through drainage, and contamination with fertilisers, chemicals and fuel.

The Forest Service's *Forestry and Water Quality Guidelines* form the basis for the protection of aquatic zones (pages 9-10 cover roads, culverts and water crossings). Further guidance is provided in *Forest Harvesting and the Environment Guidelines* in relation to road planning, construction and consolidation (pages 10-14).

Environmental value - landscape

Forestry and the Landscape Guidelines, published by the Forest Service provide a sound basis for best forest practice in relation to the landscape. How a forest will look and its composition relative to the landscape must be determined at the initial stage of development, with planting areas, species selection, location of ridelines, firebeaks, roads etc. decided upon accordingly.

Development may be restricted as a result of section 204 of the Planning and Development Act 2000 where a Local Authority may designate an area as a landscape conservation area (LCA).

Environmental value - ecological and scientific values

Ecological and scientific values are concerned with conserving communities of rare or unusual fauna or flora, unique landforms and geology, and areas dedicated to research. Forestry practice and conservation are not mutually exclusive. While most forests are managed within commercial objectives, the balance between these and conservation will depend on structure and composition, and where the forests are located in relation to the heritage area.

Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) are protected by European Union and national legislation. Where these occur within or adjacent to forests, forest management activities, including road construction, must be undertaken in consultation and agreement with Dúchas, The Heritage Service (now encompassed as part of the Department of Environment, Heritage and Local Government).

Environmental value - cultural and archaeological

Ireland has been inhabited for almost 10,000 years. As a result, the country is rich in the physical remains of human activity. Many of these sites occur on forest land or lands likely to be developed for forestry.

The National Monuments Acts and Amendments 1930-1994 provide for legal protection from unauthorized interference or damage to identified and newly discovered sites. Activities leading to disturbance are forbidden. The Record of Monuments and Places (RMP) is based on information previously recorded in the Sites and Monuments Record (SMR) and County Inventories. This contains an index and map of monuments and other archaeological features which are registered, and others likely to be of significance but not yet registered. All sites listed are protected under the National Monuments legislation.

The Forest Service's *Forestry and Archaeology Guidelines* provides guidance (pages 4-5) on procedures to follow to protect existing features and those discovered during forest operations.

Environmental value - biodiversity

Biodiversity describes the variability among living organisms and the ecosystems of which they are a part. Three conceptual levels of biodiversity are recognized – ecosystem, species and genetic. Forests are complex ecosystems and important sources of biodiversity.

Sustainable forest management implies maintaining or increasing non-forest biodiversity such as additional flora through the retention of existing habitats (e.g. hedgerows, scrub) and the treatment of open spaces and edges. Insect, bird and mammal diversity can all be enhanced through appropriate management practice and measures such as the retention of over mature trees and deadwood. Riparian zones also contribute to fish and other aquatic life.

The *Forest Biodiversity Guidelines* published by the Forest Service, focus on how best to conserve and enhance biodiversity through appropriate planning, conservation and management (see page 10 for machine operations).

Environmental value - forest protection and health

Risks to forests arise from already identified indigenous pests and diseases, and exotic pests and diseases against which Ireland's island status offers some protection. Other threats include fire, wind and atmospheric pollution.

Forest management practices can reduce the risk of windblow, for example through the correct timing of road construction, but cannot anticipate storm damage.

B.1.2 ENVIRONMENTAL IMPACT ASSESSMENT

Environmental Impact Assessment (EIA) is a process for predicting the effects of a proposed development on the environment. The mitigation of negative impacts may then be considered in the design process by the avoidance, elimination or the reduction of their sources together with the enhancement of positive effects.

The European Communities (Environmental Impact Assessment) (Amendment) Regulations, 2001 (S.I. No. 538 of 2001) set out the requirements for EIA for forestry. The construction of forest roads is not subject to EIA, although there is provision for the introduction of sub-thresholds and examination on a case by case basis where it is deemed that the development could have a significant impact on the environment.

B.1.3 INITIAL ENVIRONMENTAL EVALUATION

Although forest road construction is not subject to EIA, it is still necessary to undertake an Initial Environmental Evaluation (IEE) at the planning stage. An IEE consists of two components:

- ▶ Screening procedure; and
- ▶ Mitigation measures.

Screening procedure

The purpose of the screening is to ensure that no activity within the scope of the different phases of forest road construction has the potential to impact significantly on the environment.

For the purposes of screening, account should be taken in particular of the direct and indirect effects of the planned road construction on the following factors:

- ▶ Human beings, fauna and flora;
- ▶ Soil, water, air, climate and the landscape;
- ▶ Material assets and the cultural heritage; and
- ▶ The interaction between the factors mentioned in the previous three bullet points.

Examples of screening checklists are shown in Forms 1 and 2 on pages 20 and 21 of this manual. Other examples are provided in the Forest Service *Code of Best Forest Practice* (pages 37-39).

The screening should be undertaken by a competent person during road planning and prior to the commencement of any construction activity.

Mitigation measures

If in the opinion of the road designer there is the potential or likelihood for any negative environmental impact, then mitigation measures should be proposed to minimise the potential impact. These mitigation measures should be additional to the normal compliance with environmental guidelines issued by the Forest Service and the guidelines set out in the Forest Service *Code of Best Forest Practice*.

Where mitigation measures are proposed, it will be necessary to ensure that these are complied with in the design and construction phases. Monitoring to ensure that the mitigation measures are implemented is included in Form 1 on page 20 of this manual.

B.1.4 RISK PRIORITIES

Risk rating is a procedure that requires knowledge of two factors: the likelihood of a hazard occurring and the consequence (or severity of impact) should the hazard occur. In quantitative terms, this relationship can be shown as:

$$\text{Risk} = \text{Hazard} \times \text{Consequence}$$

Hazard refers to the probability of erosion and stream sedimentation increasing from a given section of road. Consequence refers to the potential impacts on resource, social and economic values that are likely to occur in the immediate area of, or downslope or downstream of the road, if the erosion and sedimentation events occur.

There are four levels of risk rating: very high, high, moderate and low. Each is determined according to a combination of ratings for hazard and consequence, as shown in Tables 3, 4 and 5.

TABLE 3: Hazard rating.

High	The road is located on terrain with visible or suspected evidence of landslides or mass wasting. It is not limited to any particular side slope, although the steeper the ground, the greater the potential for avalanches and debris torrents. Soils may also be highly erodable.
Moderate	The road is located on stable terrain. Minor problems may develop. Erosion is limited to small scale slumping and ravelling. Cut and fill slope erosion and surface erosion are generally shallow.
Low	The road is located on stable terrain. Normal road construction and harvesting practices will not significantly decrease terrain stability. Periodic drain maintenance will likely be required. Soils are generally well compacted.

TABLE 4: Consequence (or severity) ratings.

ON-SITE DOWNSLOPE/ DOWNSTREAM VALUES	FORECAST THE CONSEQUENCE OR SEVERITY OF THE DAMAGE OR LOSS TO A SPECIFIC VALUE, SHOULD EROSION AND SEDIMENTATION OCCUR		
	HIGH	MODERATE	LOW
Water supply	Areas having very high water values, which, if damaged would have a serious long-term effect on water quality	Areas having very high water values, but less sensitive than those with high ratings	Areas not rated as moderate or high
Fish habitat	Areas having high to very high fishery values	Areas having moderate fishery values	Areas having low fishery values
Wildlife habitat and migration	Areas having critical importance to wildlife	Areas having high wildlife values but less sensitive than those with high ratings	Areas not rated as moderate or high
Forest site productivity	Areas having high potential to grow merchantable timber, which if damaged would have a serious long-term effect on regeneration	Areas having moderate potential to grow merchantable timber	Areas not rated as moderate or high
Human life, private property	Areas having rural development, domestic dwellings or industrial development, highways and railways	N/A	Areas that are uninhabited and undeveloped
Utilities	Areas having water mains, electric transmission, gas and oil lines or fibre optic cable	N/A	Areas with no utilities
Landscape	Areas having very high values for viewing and landscape sensitivity	Areas having high values for viewing but less sensitive than those with high ratings	Areas having non-visible development or low landscape sensitivity
Recreational	Areas having very high value for recreation	Areas having high value for recreation but less sensitive than those with high rating	Areas without, or having low, physical, biological, cultural or historic features

TABLE 5: Risk rating.

HAZARD RATING	X	CONSEQUENCE RATING	=	RISK RATING
High	X	High	=	Very High
High	X	Moderate	=	High
Moderate	X	High	=	High
High	X	Low	=	Moderate
Moderate	X	Moderate	=	Moderate
Low	X	High	=	Moderate
Moderate	X	Low	=	Low
Low	X	Moderate	=	Low
Low	X	Low	=	Low

FORM 1: Example screening checklist for initial environmental evaluation.

Receptor	Score *	Nature of Impact	Mitigation Measure
People			
Flora/Fauna			
Soils			
Water			
Landscape			
Archaeology/Cultural Heritage			
Material Assets			

* Evaluate on a scale from -3 to +3, where -3 refers to major negative impacts, and +3 refers to major positive impacts

Assessment Signature: _____ Assessment Date: _____

Completion Signature: _____ Completion Date: _____

Mitigation Measure(s) Implemented:

Signature:

Date:

FORM 2: Example screening checklist for forest road initial environmental evaluation.

Activity	Impacts on environment				Impacts on built environment				Impact on human beings			
	Soils, Geology	Surface Water and Ground Water	Air and Climate	Flora and Fauna	Urban Structures	Buildings and Structures	Landscape	Cultural Heritage	Health, Smells, Noise and Vibrations	Quality of Life and Recreation	Economic Life and Employment	Use of Natural Resources
Tree Clearance												
Formation												
Drainage												
Water Crossings												
Completion												
Maintenance												
Upgrading												

Note: Likely potential impacts are evaluated on a scale from -3 to +3, where -3 refers to major negative impacts, and +3 refers to major positive impacts.

B.2 SAFETY

Safety is a major concern for those involved in forest roadworks. The construction of new forest roads and the upgrade of existing forest roads come under the control of the Safety, Health and Welfare at Work (Construction) Regulations 2001. As a result, the client (forest owner/agent) must ensure that competent people are employed for the design and construction of forest road works.

THE CONTENTS OF THIS CHAPTER ARE INCLUDED FOR GUIDANCE PURPOSES ONLY. READERS ARE DIRECTED TO OBTAIN PROFESSIONAL ADVICE ON SAFETY MATTERS. THE AUTHORS ACCEPT NO RESPONSIBILITY FOR THE READERS ACTIONS/INACTIONS.

B.2.1 GUIDELINES

- ▶ Appoint a competent designer.
- ▶ Co-operate with the designer in providing details of potential hazards.
- ▶ Have a hazard identification and risk assessment carried out on the site at design stage.
- ▶ Appoint a competent contractor.
- ▶ Ensure that all safety related information is passed on to the contractor.
- ▶ Co-operate fully with the contractor, especially in respect of other activities that may be ongoing in the vicinity of the roadworks.
- ▶ Obtain safety relevant information from the contractor at the completion of the work.

B.2.2 SAFETY MANAGEMENT

It is a requirement of the Safety, Health and Welfare at Work Act 1989 that all businesses must have a safety statement. These documents are intended to state the business policy on safety, identify the person(s) responsible for managing safety and, perhaps most importantly, to identify potential hazards, assess their risks and state the means of controlling them.

Safety statements should be site specific² and therefore it is necessary to complete a hazard identification/risk assessment for each worksite. This assessment may have to be repeated during a job as site conditions may vary at different stages as work progresses.

The Safety, Health and Welfare at Work Act 1989 has many associated regulations which also affect the way work is carried out. The Construction Regulations 2001 are the most notable of these for forest road construction. These require a client (forest owner/manager) to appoint competent project design and construction supervisors whose job it is to ensure that safety is taken into account and managed. These regulations also set out many standards that contractors must observe.

The construction regulations set out requirements for safety plans for construction projects. The designer will prepare an outline plan detailing perceived hazards and risks and may suggest methods of managing them. This plan is given to the construction supervisor to follow up on as work progresses where he must note in more detail how safety will be managed. At the end of

² *It is best to identify hazards based on activities (e.g. delivering machines to site, working on steep ground, excavating trenches, crossing watercourses, etc.). These will be unique from site to site.*

the project this plan is returned to the client so that it is available to others who may need information about the 'structure'.

More complete details, if required, are available from the Health and Safety Authority (HSA) whose website address is www.hsa.ie.

B.2.3 CODE OF PRACTICE FOR MANAGING HEALTH AND SAFETY IN FORESTRY OPERATIONS

In addition to the regulations already mentioned, the HSA have drafted a *Code of Practice for Managing Health and Safety in Forestry Operations*. This new code, which became operational in 2003, provides practical guidance as to the observance of safety legislation. When planning and carrying out forestry operations the law requires a number of health and safety duties to be carried out, including:

- ▶ preparing written risk assessments;
- ▶ selecting suitable equipment for the job;
- ▶ protecting public health and safety;
- ▶ setting out safe working procedures;
- ▶ ensuring operators are competent; and
- ▶ supervising and monitoring the work.

The code identifies the following groups as all having duties in managing safety in forest operations and outlines their responsibilities³:

- ▶ the landowner role;
- ▶ the forestry work manager (FWM) role;
- ▶ the contractor role; and
- ▶ the sub-contractor role.

The code also specifies the need to designate an individual as a site safety co-ordinator to ensure safety standards are being met.

B.2.4 SAFETY PLAN FOR FOREST ROADWORKS

The safety plan is the document by which safety is managed on site. The principal topics that should be covered by the plan are listed below. Its exact contents are dependant on the specific site and the nature of the work.

Site description

Forest roadwork sites range from flat, lowland sites on peat, mineral soil or rock to steep, upland sites with similar soil composition.

The upland sites are by their nature generally more exposed and subject to harsher weather conditions than their lowland counterparts.

³ It is possible to belong in more than one group depending on working arrangements.

Scope of works

Forest roadwork may include:

- ▶ the repair and maintenance of existing forest roads;
- ▶ the widening and strengthening (upgrade) of existing forest roads;
- ▶ the construction of new forest roads; and
- ▶ the construction and repair of bridges and culverts in the course of the works.

Envisaged risks to safety and health of persons at work

Risk assessment carried out for forest roadwork indicates that each of the main areas of work pose certain risks to construction personnel, forest operators and members of the public.

These work areas include:

- i) survey and design;
- ii) road excavation;
- iii) road completion;
- iv) special construction works (large culverts and bridges).

Detailed hazard identifications/risk assessments must be prepared to cover each activity for each site and included as part of the plan.

Safety statement

Contractors involved in forest roadwork must have their own safety statements. These statements, which must be updated by contractors on a regular basis, should include a safety and health policy, responsibilities, risk assessments and controls.

Safety files

All documents associated with the management of Health and Safety on site must be maintained in a Site Safety File and a copy of relevant material forwarded to the client on completion of roadwork on the site.

Plant operator competency/worker training

All persons working on forest road sites must be in possession of a valid FÁS Safe Pass registration card or a HSA recognised equivalent qualification.

Plant operators must also possess a FÁS Construction Skills Certificate (or HSA recognised equivalent qualification) relevant to the machine they are operating after 1 June 2003.

Signage/traffic management

Adequate signage and traffic management measures must be implemented. This is particularly important when work must be carried out adjacent to the public road network. A suggested signage layout is included in the appendices along with diagrams of suitable signs.

Personal protective equipment

Safety helmets, reflective vests and steel toe capped footwear are required to be worn by all persons when present on site. All persons operating, or in the vicinity of, heavy plant must wear ear muffs. Additional protective equipment may be required in some operations.

Working hours

Contractors must agree procedures for supervisory cover where it is intended to work outside of normal working hours, e.g. Saturday and Sunday working.

General operatives/supervisory staff skills

All staff working on site are required to possess a valid FÁS Safe Pass certificate to show that they have been trained in general site safety awareness.

Manual handling

Machine operators and those involved in pipe laying are required to be trained in manual handling.

Engineering procedures/first aid

Machine contractors must ensure that a first aid kit and a fire extinguisher are available for their use at all times.

All site personnel must familiarise themselves with their surroundings and in the event of an accident be able to direct emergency services to a suitable rendezvous point.

A site specific Emergency Contact List must be available at all times on site containing contact details of local emergency services and key forest management/supervisory staff.

Special activities

Special activities such as rock drilling and blasting, requiring the use of a specialist contractor, are outside the scope of this plan. A safety plan and detailed method statement must be prepared in advance of this work.

Accident recording

Each business should maintain an accident register. Forest owners/managers should record any accidents and dangerous occurrences, on their property, in this register. Contractors should be required to notify the forest owner/manager of such instances.

Accident reporting

Contractors are legally obliged to complete HSA Accident Report Forms IR1 and IR2 and to notify the Health and Safety Authority of any accident occurring on site.

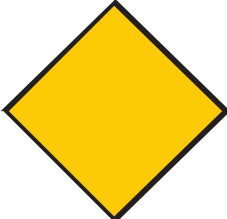
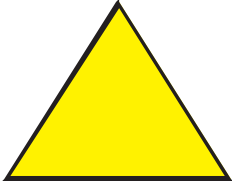

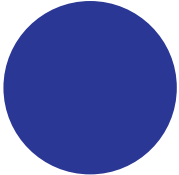

B.2.5 GUIDELINES FOR SAFETY SIGNS TO BE USED FOR FOREST ROADWORKS

This chapter is intended for guidance only. It is only concerned with temporary work signs. To aid this guidance, a page showing suitable signs for use on forest works is included in Appendix E3.

Types of sign

There are five basic types of signs which may be used in conjunction with forest roadworks. One of these is covered by the Department of Environment Standards, the rest conform to an EU standard (Directive 92/58).

Signs, with standard symbols and texts are readily available in a range of suitable sizes from most suppliers of safety equipment and clothing. 'Specials' can normally be manufactured in a few days. The size of signs for forest roadworks use must be large enough to be readily legible by persons in approaching vehicles.

<p>Roadworks These signs are diamond shaped They have an orange background They have a black symbol</p>	
<p>Warning Signs (e.g. Caution) These signs are triangular shaped They have a yellow background and black border They have a black symbol Accompanying text is in black on a yellow background</p>	
<p>Prohibition Signs (i.e. DO NOT ...) These signs are circular shaped They have a red ring and crossing bar over a white background They have a black symbol beneath the crossing bar Accompanying text is white on a red background</p>	
<p>Mandatory Signs (i.e. MUST DO ...) These signs are circular shaped They have a blue background They have a white symbol Accompanying text is white on a blue background</p>	
<p>Information Signs (e.g. FIRST AID) These signs are rectangular shaped They have a green background They have a white symbol Accompanying text is white on a green background</p>	

B.2.6 SUGGESTED USAGE FOR FOREST ROADWORKS

There are no specific requirements for the use of any particular sign in relation to forest roadworks. The guiding principle in sign selection is to minimise the risk presented by hazards. What follows therefore is a suggested sign usage for forest roadworks but the reader must take care to ensure that signs used are suited to the specific site.

Work adjacent to public roads⁴

Wherever forest roadworks meet public roads, roadworks signs should be erected on the public road, on each side approaching the work.

If the forest roadwork reduces the public road carriageway then the road width reduction signs should also be used (for guidance, see illustration in Appendix E.3.1). In this case, consideration needs to be given to the use of cones and barriers also. (If traffic is heavy and/or width reduction is substantial the traffic control procedures must also be employed.)

Approaches to site

At the start of roads/paths/tracks leading to worksites, it is advisable to erect a caution sign and possibly combine it with a mandatory 'keep clear' sign. This may be more important in frequently used properties or areas subject to walking paths, cycle tracks, pony trekking or other such activities.

Site entrances

Caution signs combined with mandatory 'keep out' or prohibition 'do not enter' signs should be erected at each entrance to a site (includes crossing roads, tracks and paths).

Mandatory 'Wear Personal Protective Equipment' signs should be erected at the principal entrance(s) to worksites.

Openings across roads/paths and broken or removed bridges/culverts

'Danger' caution signs combined with prohibition 'do not pass' should be erected wherever a road or path has been cut through or wherever a bridge or culvert has broken or been removed.

Barriers and hazard 'zebra' tapes (red and white or yellow and black diagonal bands) should also be used in these instances.

Other locations

Erect caution signs at specific hazards such as overhead power cables, underground services, open excavations, deep water, etc.

Mandatory or prohibition signs can be combined with these cautions if necessary.

In addition to signs, the use of cones, barriers and/or zebra tape should be considered if they help control the hazard but do not rely entirely on these methods.

⁴ Local authorities should be contacted at the road planning stage whenever a junction from the forest to a county road is planned.

Diagrams of appropriate signs for use on forest roadworks and for the correct use of signs on public roads are included in the appendices.

B.2.7 HAZARD RECOGNITION GUIDE

The following constitute a list of hazards that may exist on sites of proposed road works or may occur during the course of work. The list is not exhaustive and is included for guidance only.

Steep slopes/Valleys/Ravines/Gorges

Soft ground/Bog/Swamp

Deep drains/Trenches/Drains close to roads

Deep water/Rivers liable to sudden flood

Embankment roads/Roads on deep fill

Severely rutted/Pot holed roads

Timber bridges/Narrow bridges/Damaged structures/Load restrictions

Narrow roads/Substandard junctions/Poor alignments/Steep gradients/Access restrictions/Sight restrictions

Moving plant on and off site

Operations alongside public roads

Turning/Reversing gravel delivery trucks and/or other plant

High spoil banks

Overhead power lines/Overhead telecommunications lines/Underground services/Wells

Quarries/Quarrying

Landslides/Falling rocks

Buildings/Ruins

Harvesting operations in progress/Timber extraction traffic/High timber stacks/Scattered timber

Windblow/'Hung up trees'

Other site users/Public access

Pipe/Beam handling

Working alone

The following page shows a sample hazard identification/risk assessment form (Form 3).

FORM 3: Hazard identification/risk assessment form.

OPERATION _____		LOCATION _____				ACTIVITY _____		
HAZARD	CONSEQUENCE	RISK CONTROLS			PERSON(S) RESPONSIBLE	RESULTANT RISK		
		Severity	Likelihood	No. of People Affected				

Assessment completed by _____ Date _____

B.3 FOREST ROAD DENSITY AND ECONOMICS (INCLUDING HARVESTING)

Road density is the number of linear metres of road per hectare. For any given site there is an optimum road density that minimises the combined cost of construction, maintenance and timber extraction. In calculating the optimum density, it is essential to have reliable estimates for:

- ▶ volume and quality of timber to be harvested over the rotation;
- ▶ cost of road construction;
- ▶ cost of road maintenance; and
- ▶ extraction method and 'off road' movement cost.

The optimum density is only used as a guide to the appropriate roading for an area. There are many factors which may cause deviation from the optimum and these will be examined later in this chapter. Also, optimum road density does not take account of all the costs and benefits, e.g. recreation, hunting, access for fires etc., so it may be necessary in some circumstances to undertake a more complete cost benefit analysis before proceeding with road construction.

Road density is closely related to the planned harvesting and extraction methods. In Ireland, the most common extraction method is forwarder, although there are some sites which due to slope and/or ground bearing capacity can only be extracted by skyline (cable extraction). There are other methods of extraction that can be used but the two mentioned are the most economical in relation to road density. Typically for forwarders, roads are spaced at 800 m centres providing an average haul of 200 m. For cable extraction, road spacing, and therefore density, is determined by the maximum haul distance (length of cable). Typically in Ireland maximum haul distance for cable equates to 350 m.

B.3.1 GUIDELINES

1. Calculate the volume of timber to be served throughout the rotation by the planned road.

This volume varies from block to block depending on factors such as site conditions, species, yield class and silvicultural practices but will be independent of road density. Volumes can be calculated using yield models, e.g. Forestry Commission Booklet 48 *Yield Models for Forest Management* and should be reduced to allow for stocking and unplanted/unproductive areas.

2. Calculate the average road construction cost per linear m

The cost of road construction will vary with site conditions and the requirement for any special construction works, e.g. culverts, bridges etc. This cost per m³ of timber increases as road density increases.

3. Calculate the average off road movement cost per m³ of timber (to take the timber from inside the forest to the road).

The movement cost depends on the type of extraction planned, being smallest for forwarder and largest for cable extraction. This cost decreases as road density increases.

B.3.2 EXPLANATION OF ROAD DENSITY

As can be seen from Figure 1, road and movement (extraction) costs are combined to determine a total cost per m³ of timber. The lowest total cost gives the optimum density which should be the desirable level of roading for a forest block. This occurs when the roading cost and movement (extraction) costs (per m³ of timber) are approximately equal. This value may be calculated using the following formula:

$$\text{Opt. Den.} = \sqrt{\frac{Ve(100m)}{R}} \quad \text{m/ha}$$

where
 V = discounted timber volume (m³/ha)
 e = network efficiency factor (see below)
 m = timber movement (extraction) cost (€/m³/100 m hauled)
 R = road construction cost plus annualised maintenance cost (€/linear m)

Note: Discounting is the process of reducing future sums, usually money but in this instance timber volumes, to take into account the delay in time before they are received. A discount rate of 4 -6% is generally used in discounting for road density calculation

Road Density Example

Road construction year = 2003

Timber volumes to be harvested are as follows:

$$2004 = 30 \text{ m}^3,$$

$$2009 = 30 \text{ m}^3,$$

$$2014 = 60 \text{ m}^3,$$

$$2019 = 60 \text{ m}^3,$$

$$2024 = 220 \text{ m}^3.$$

Network Efficiency Factor = 0.44 (two way haulage)

Road cost = €26.50 per linear m

Average annual maintenance cost = €0.20 per m

Off road movement cost = €1.20 per m³ per 100 m hauled

Discount Rate = 5%

No. of years for discounting = 2024 – 2003 = 21

Discounted Timber Vol. (V)

$$= \frac{30}{1.05^1} + \frac{30}{1.05^6} + \frac{60}{1.05^{11}} + \frac{60}{1.05^{16}} + \frac{220}{1.05^{21}}$$

$$= 26.6 + 22.4 + 35.1 + 27.5 + 79.0 = 192 \text{ m}^3$$

Annualised Maintenance

$$= \frac{0.20(1.05^{21}-1)}{0.05 \times 1.05^{21}} = \frac{0.357}{0.14}$$

$$= €2.56 \text{ per m}$$

Optimum Density

$$= \sqrt{\frac{192 \times 0.44(1.20 \times 100)}{26.50 + 2.56}} = \sqrt{348.85} = 18.68 \text{ m per ha}$$

Note: This example is shown on the Optimum Road Density Calculator printout included later in this chapter.

It is necessary to discount timber volumes back to an equivalent present day volume as costs are expressed in present day values and this is the most convenient way to handle them.

All forest road networks have an efficiency factor. It is not always possible to haul timber in a direct line to the road. Also there will be areas in the vicinity of sharp bends and junctions that are over served (they can be hauled in different directions). Furthermore, it will not always be possible to haul to a road equally from both sides. The recommended efficiency factors (e) are:

- ▶ 0.44 for two way haulage (Timber can be hauled from either side of the road)
- ▶ 0.91 for one way haulage (Timber can be hauled onto the road from one side only)

Software packages and spreadsheets are available to calculate optimum densities. A road density spreadsheet is available from the COFORD website (www.coford.ie/roadman/spreadsheet) and a sample of output is shown in Figure 2.

It can also be seen from Figure 1 that total cost does not significantly change for slight deviations away from the optimum density. It is therefore acceptable to deviate away from optimum values by up to 15%.

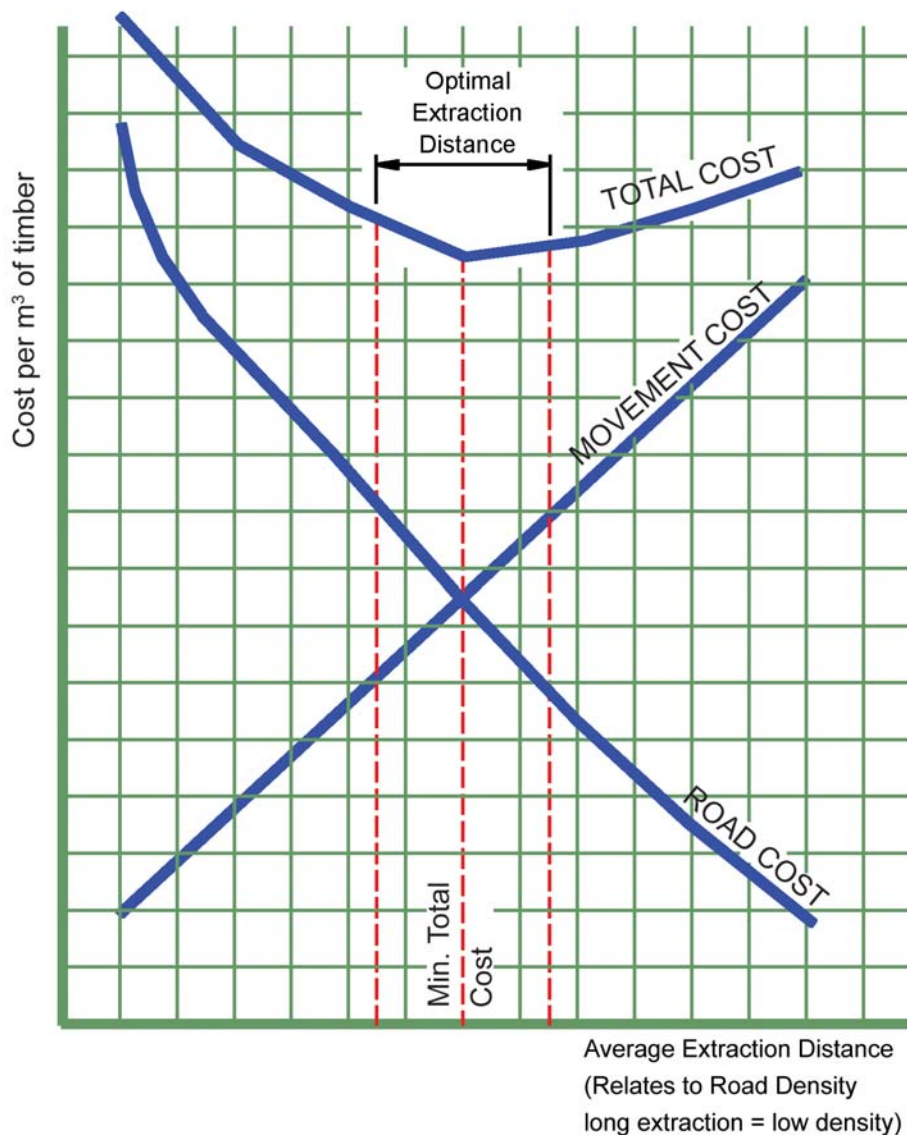


FIGURE 1: Chart showing the cost effects of road density.

In particularly difficult sites or unusual forest configuration (e.g. long narrow strip), the final road layout may not approach the optimum theoretical density. It may also be necessary to depart from optimum roading density on sites in environmentally sensitive areas. Extra road may also be necessary to minimise harvest impacts on some sites. Each of these cases would have to be examined individually and decisions taken on the relative merits of the issues involved.

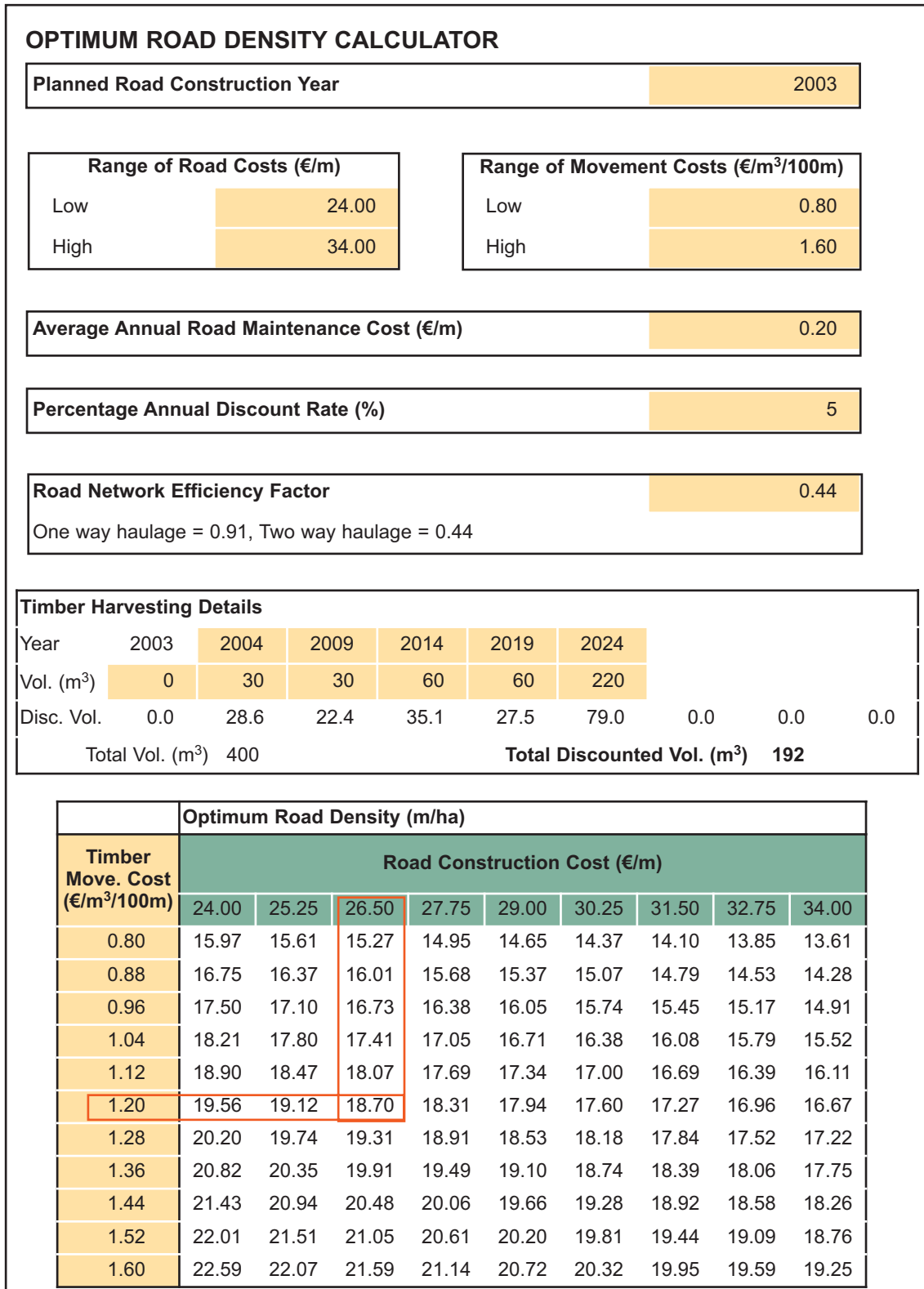


FIGURE 2: Sample output from road density spreadsheet.

Elements of road cost

There are a number of factors that contribute to the overall cost of a forest road and include:

- ▶ right of way (r.o.w.) development/purchase;
- ▶ road drainage;
- ▶ methods of road formation and construction;
- ▶ culverting;
- ▶ road completion (surface dressing) works;
- ▶ large waterway crossings (waterway area being greater than 1.5m²) or other structures;
- ▶ annual maintenance; and
- ▶ operational overheads (planning development charges, design costs, holidays etc.).

Not all of these would be included in optimum road density calculations as they would likely be incurred regardless of the constructed density and therefore do not influence movement cost. They would however have to be considered as part of a cost benefit analysis.

The excluded costs from the density calculations are the r.o.w. costs, and the overheads. Bridges and large culverts have traditionally been included in the calculation but will have a very negative effect on short lengths of road as they add a considerable cost per linear m. It can be argued that like a r.o.w. development cost, they are an extra to the road and do not contribute to a reduction in movement costs. It is left to each forest road developer to make their own decision on this.

Elements of extraction cost

The cost of timber extraction comprises the following:

- ▶ setting up on site (machine delivery/skyline set up/removal, etc.);
- ▶ machine upkeep (fuelling, operator maintenance, etc.);
- ▶ travelling from road to timber (empty movement);
- ▶ loading;
- ▶ travelling loaded to forest road (full movement);
- ▶ unloading and stacking; and
- ▶ overheads (machine management, downtime, etc.).

When calculating optimum road density, the only part of the extraction cost that is considered is the off road movement cost as the travel distance is related to the road density. The other elements of extraction cost are independent of road density and are not considered at this time. If undertaking a full cost benefit analysis, the full cost of extraction and harvesting will need to be considered.



PHOTO 2: *Extracted timber at roadside.*

B.3.3 COST BENEFIT ANALYSIS

No matter what the optimum road density may be, a forest owner may have to consider carrying out a cost benefit analysis. In this instance, all the roading and extraction costs across the rotation need to be compared against the benefits. The main benefit will be the timber revenue from the property but other benefits may occur from the improved access. Examples of the other benefits may include:

- ▶ Leisure activities (pony trekking, orienteering, etc.);
- ▶ Improved property protection (better fire fighting access, etc.); and
- ▶ Improved access to other lands.

In addition, the road may qualify for grant aid from the Forest Service and this should be considered.

B.4 FOREST ACCESS

Access to a forest property is gained either directly from a bordering county road or via an access route which could be a non county public road, a right of way over someone else's land or a route constructed on the forest owners adjoining lands.

Access from a bordering county road is covered throughout the manual.

Access via a non county public road or right of way are not within the scope of this document as they may be subject to various limitations.

Access over the forest owners adjoining lands should be constructed to the same design criteria as applies to forest roads.

B.5 DEVELOPMENT ROADS

Development roads are constructed to enable vehicle access for managing forests. These roads are normally constructed before planting although some may be built prior to canopy closure. Their purpose is to save time in reaching the workplace. They are also very important for safety reasons, forest protection and for fire fighting vehicles. Most development roads will ultimately become part of the harvest road infrastructure.

Development roads should be constructed to the same design criteria as harvest roads and will be subject to the same construction standards.

At design stage, for a development road, consideration must be given to its intended future use and decisions documented. If it is not intended to include a particular development road in the eventual harvest road infrastructure then this must be clearly indicated to subsequent users.

B.6 ENGINEERED TRACKS

Engineered tracks are defined as an engineered, level, cambered formation (foundation) of 4 m width, capable of supporting harvesting machines without causing rutting to the formation. These should not be mistaken for silvicultural extraction ‘racks’.

Under this definition cambered formations on poor ground are precluded and alternatives such as specially prepared brushed paths or extra roading should be considered on poor bearing capacity sub-grades. Generally then tracks are only allowable on solid, hard ground that is prevalent on hill slopes.

Engineered tracks are used to supplement the existing road network and should only be considered where harvesting costs will be excessive without them.



PHOTO 3: Forwarder using an extraction rack to access the forest road.

B.6.1 GUIDELINES

1. Engineered tracks should only be constructed on ground with good bearing capacity.
2. Engineered tracks should not be used as an alternative to roads unless it is too difficult to provide a road economically.
3. Engineered tracks are never to be used by road vehicles.
4. Engineered tracks will normally be only unsurfaced formations.
5. Engineered tracks must be provided with proper water runoff control measures.
6. As engineered tracks will almost always be on mountainous sites, their junctions with forest roads must be carefully located so as not to interfere with roadway drainage.

B.6.2 DESIGN CONSIDERATIONS

In most forests the careful planning and selection of extraction racks dispenses with the need for tracks and it is advisable to investigate all alternative options before deciding on track construction. The reason for avoidance of tracks where possible is simply that the risk of erosion increases enormously if track design and construction is not carefully managed. Indeed on many sites the construction of tracks is impossible because of poor or unsuitable ground conditions.

Tracks are often constructed to change the harvesting extraction process from cable to ground (vehicular) and therefore the allowable gradients have to be increased to assist in this process. The maximum gradient for tracks is increased to 16% and the minimum turning radius is decreased to 8 m. However the environmental consequences of increased gradients are paramount. Consequently good water control, frequent culverting, designed formation cross slope and access to the track for harvesting vehicles are primary concerns to the designer. The junction of the track to the forest road should be blocked off by the installation of a mound to prevent unauthorised traffic (i.e. cars and lorries). A loading bay should be located close to the junction to prevent forwarder traffic on the road.

When a crop is clearfelled a decision should be reached on whether the track should be closed and the ground reinstated.

B.6.3 TRACK CONSTRUCTION ON STEEP CROSS SLOPE

- i) Strip topsoil and organic matter off 5 m wide strip.
- ii) Form a level formation by digging 2 m out of the **solid** and filling the lower side of formation until a level bench 4 m wide is formed.
- iii) Compact the levelled formation by constant tracking with the excavator.
- iv) Form a 250 mm cross fall by excavating extra material and banking up the lower side of the track so that the cross fall is towards the normal slope of the hill.
- v) Again shape the material and recompact until deformation ceases.
- vi) Lay culverts as per the general culvert specification. The spacing of culverts will be determined by the designer taking account of the longitudinal gradient and the erodability of the mineral formation material.
- vii) The track should be inspected following storms and periods of bad weather to ensure no erosion occurs.

B.7 FOREST ROAD DESIGN STANDARDS

This chapter sets out the geometric design standards for forest roads. These must be interpreted for the individual set of site conditions encountered. At the conclusion of the design stage specification documents for each site should be prepared.

The purpose of road design is to provide the optimum road geometry to accommodate the planned vehicle sizes and traffic. Optimum road design should minimise the cost of construction, transportation, maintenance and impacts on other resources, and provide for user safety and a stable road with appropriate alignments and travel speeds.

B.7.1 GUIDELINES

1. Standard forest roads are designed to carry vehicles conforming to maximum legal weights and dimensions applicable to public roads. However economic and external factors will sometimes result in the design of a road to less than full standard.
 - ▶ e.g. intractable limitations in either public road or right-of-way access routes, terrain (heavy rock outcrop, deep peat) may limit what can reasonably be provided; and
 - ▶ departures from full road standard must not be lightly undertaken, each case being carefully evaluated on its merits. Such departures must be clearly documented by competent designers.
2. New and upgraded roads should be designed to:
 - ▶ comply with the standards set out later in this chapter;
 - ▶ accommodate the anticipated frequency, type and speed of traffic;
 - ▶ take cognisance of soil and sub-grade conditions;
 - ▶ provide for road drainage and water quality requirements; and
 - ▶ incorporate landscape and environmental values.

It is a characteristic of all forest roads that they are subjected to low-intensity, slow-moving traffic so that some risk of partial structural failure can be taken, where this would not be acceptable on a public highway. However, these risks must be limited to situations where road user safety is not endangered. Safety considerations preclude risk-taking with bridges and embankments.

The designer must bear in mind at all times that the primary purpose of forest roads is for timber extraction.

While some forest roads are constructed to facilitate development and general control of large blocks (development roads), the bulk of road construction will be for extraction purposes. Indeed, where development roads are provided it is almost invariably intended that they should, perhaps after future strengthening, become part of the extraction network. The provision of a forest road is therefore the first element of the harvesting process and represents a significant capital investment.

Forest roading sites are classified by soil type and by cross slope.

B.7.2 SITE CLASSIFICATION

Soil types are either:

- i. Mineral Soils
- ii. Shallow Peats (depth less than 2 m)
- iii. Deep Peats (depth 2 m or greater)

Cross slopes being:

- i. Flat to Gently Sloping (gradient less than 1 in 7)
- ii. Sloping (gradient 1 in 7 or greater)

Combining these, gives the following five site classifications for forest road design:

- i. Mineral Soils - Flat to gently sloping
- ii. Mineral Soils - Sloping
- iii. Shallow Peat - Flat to gently sloping
- iv. Shallow Peat - Sloping
- v. Deep Peat depth (greater than 2 m)

B.7.3 ELEMENT AND STANDARDS OF A FOREST ROAD

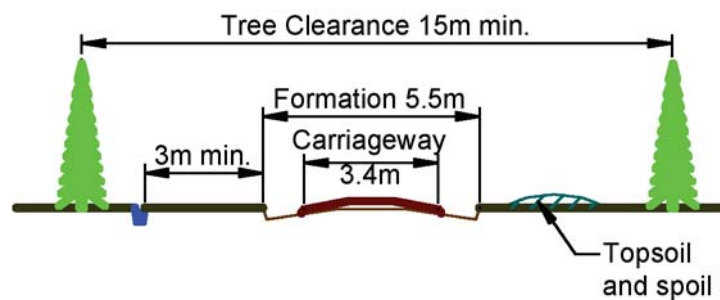


FIGURE 3: Typical forest roads cross sections for flat to gently sloping mineral soil site.

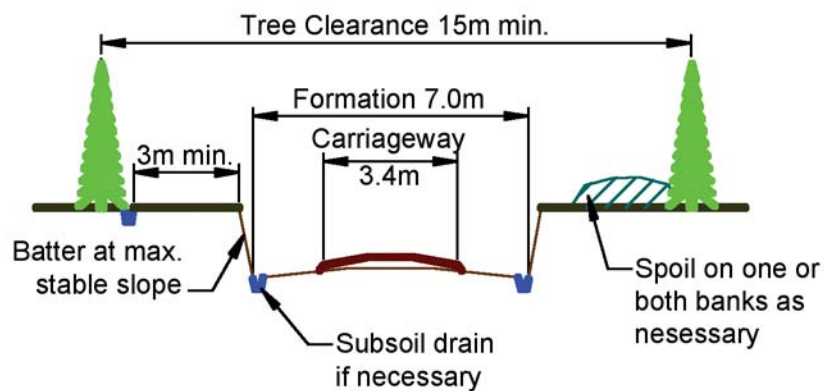


FIGURE 4: Typical forest roads cross sections for cuttings in mineral soil sites.

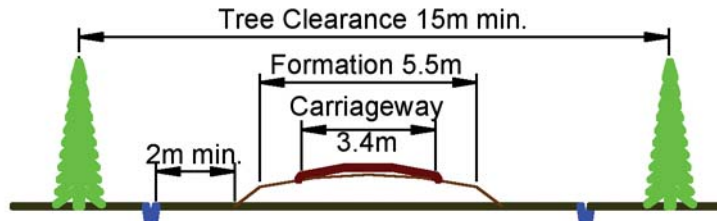


FIGURE 5: Typical forest roads cross sections for embankments.

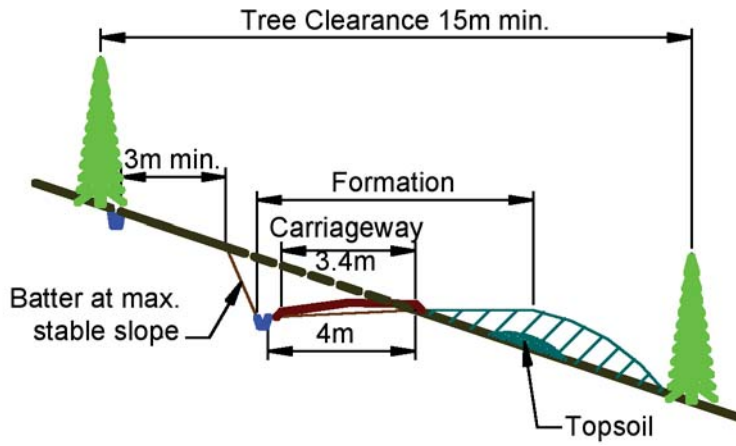


FIGURE 6: Typical forest roads cross sections for sloping sites.



PHOTO 4: Forest road cutting.



PHOTO 5: Forest road on a sloping site.

Road reserve

The strip of land immediately affected by roadworks. In an existing plantation it corresponds to the tree clearance width.

Standard tree clearance width shall be a minimum of 15 m.

Tree clearance width for Reversal Roads shall be a minimum of 20 m.

The roadway

The area between the extreme limits of earthworks.

- ▶ In side-hill construction, its width is from the edge of the excavated section to the toe of the fill section.
- ▶ In a cutting, it is the width between the top edges of the cutting plus width occupied by any spoil on the verges.
- ▶ In a full embankment (excluding reversal), it is the width between the bottom edges of the embankment.
- ▶ In a reversal road, the width depends on the method of construction. Outer edge could be either the toe of the embankment, the borrow pit/drain or the spoil.

Formation (road foundation)

The area between the usable limits of earthworks.

- ▶ In side-hill construction it is the width between the toe of the excavated section and the top edge of the fill section.
- ▶ In full cutting it is the width between the bottom edges of each side.
- ▶ In full embankment it is the width between the top edges of the embankment.

Flat to gently sloping (cross slope 1 in 7 or less)	Min. formation width = 5.5 m
Sloping - Mineral soils (cross slope 1 in 7 or greater)	Formation width varies - Minimum of 4 m from toe of excavation must be out of solid ground
Sloping - Peats	Min. formation width = 7 m
Cuttings less than 600 mm deep	Min. formation width = 5.5 m
Cuttings greater than 600 mm deep	Min. formation width = 7 m
Embankments (all sorts)	Min. formation width = 5.5 m

Carriageway

The section of the formation strengthened for the passage of vehicles. This strengthening may take the form of:

- ▶ Compaction of the natural formation (or sub-grade), where its composition is such as will give adequate strength.
- ▶ Placing and compacting a layer of imported base material on the compacted formation, followed by a compacted layer of imported surfacing material.
- ▶ Placing and compacting a layer of surfacing material only.

Straight sections of road	Min. carriageway width = 3.4 m
Along curves and at junctions	Surface to within 500 mm of formation edges to provide for vehicle track-in.
On embankments	Min. carriageway width = 3.4 m Carriageway width on substandard embankment formations must be at least 4.0 m

Drainage

The provision of channels, to remove excess water and prevent ingress of water in the future.

The provision of adequate drainage is the most important activity in road making. On it depends the strength and stability of the entire roadway. The ease with which effective drainage can be provided is a major consideration in the precise location of the roadway.

Three types of drain are commonly used:

- i. **Subsoil drains**, to lower a high water-table, are provided at some distance (min. 2 m) from each side of the roadway prior to excavation or building of an embankment. Where it is intended to build an embankment road, particularly on peat sites, these drains should be provided as long as possible (many years, ideally) before construction of the embankment is undertaken.
- ii. **Interceptor (or cut-off) drains** provided approximately parallel to roadway prior to excavation to catch run-off from higher ground. In undisturbed ground the cheapest way to do this is by excavating two or three drains parallel to the roadway so the closest drain is a minimum of 3 m from the estimated position of the top edge of the excavation.
- iii. **Roadside drains** at the edge of the formation. In general the angle between the toe of the cutting and the edge of the cambered formation will be adequate to control the run-off from the formation area itself. Occasionally a deeper drain may have to be provided where a high water-table persists in the formation, especially in cuttings. **The distance between the edge of subsoil or interceptor drains and the formation edge must always exceed 1.5 times the drain depth.**

Sub Soil Drains	Min. 2 m from edge of roadway	450 mm to 750 mm deep on mineral sites. 750 mm deep on peat sites.
Interceptor Drains	At least 3 m from top edge of excavation.	Deeper than existing plough furrows.
Roadside Drains	At formation edge.	300 mm to 400 mm deep.
Culvert Spacing	This depends on road gradient and susceptibility to soil erosion. Usual interval range is 40 to 100 m. Culverts must in all cases be provided at the lowest point of longitudinal section and at each end of superelevated sections.	

Camber

The curved cross-sectional profile given to the formation and to the carriageway to aid water runoff.

Camber is expressed either as the rise of the crown over the edge (e.g. 200 mm camber) or as a gradient (e.g. camber of 1 in 12.5 or 8%).

The softer and finer grained the formation material the greater the camber required. Formation camber limits will vary from approximately 200 mm to 300 mm. In side-hill (cross-slope) conditions the bulk of the camber is applied sharply near the toe of the excavation to facilitate formation drainage while camber over the fill section is reduced to allow for the gradual consolidation which will occur in this part of the roadway.

5.5 m wide formation	200 - 250 mm camber
6.5/7.0 m wide formation	225 - 300 mm camber
Carriageways	100 mm camber

Superelevation

The transverse or inward slope applied to the formation surface to counteract centrifugal forces acting on vehicles traversing curves.

If superelevation is excessive at bends, the risk of trailers overturning is greatly increased. Therefore, superelevation should be kept low on acute bends.

The transition from a cambered to a superelevated section should be uniform and gradual over a distance of approximately 30 m.

Superelevation - 1 in 25 (4%) min to 1 in 15 (6.7%) max.

Gradient (or grade)

The rise or fall of a road with respect to the horizontal.

Gradient is expressed either as one vertical unit in so many horizontal units or as a percentage, e.g. 1 in 20 gradient or 5% grade. Its value may be prefixed + for uphill and - for downhill in the direction of access.

It may occasionally be necessary in forest road design to depart from gradient standards but any deviations must be for sound physical or economic reasons.

Straight Sections	Max. gradient - 1 in 10 (10%) Min. gradient - 1 in 100 (1%)
Curved Sections	Max. gradient - 1 in 12 (8.3%)

A minimum gradient of 1 in 100 (1%) is necessary to effect drainage of the formation area. Artificial drainage gradients can be achieved on flat sites by varying the camber. This is most easily done by using a self-powered grader.

A table of gradients and equivalent grades is included in Appendix E.4.

Curvature

The bends on a forest road (measured by their radii).

The minimum standard radius of curvature is 20 m and naturally a larger radius should be employed where physical and economic factors so permit. In difficult situations it may not always be feasible to make a standard curve but in large blocks it should usually be possible to avoid the use of hairpin bends.

Formations and carriageways need to be widened at curves so as to allow for vehicle 'track in'. Tables showing extra widening requirements are included in Appendix E.8.

Desirable min. radius for curves = 20 m

Absolute min. radius for hairpin bends = 12 m

Road junction

The intersections between two or more forest roads or between a forest road and a public road.

Where conditions permit, all road junctions should be right-angled bell-mouth type as shown in Figure 7. Skew junctions of the type shown on Figure 8 may be used otherwise. Junctions with public roads must always be designed in consultation with Local Authority Engineers.

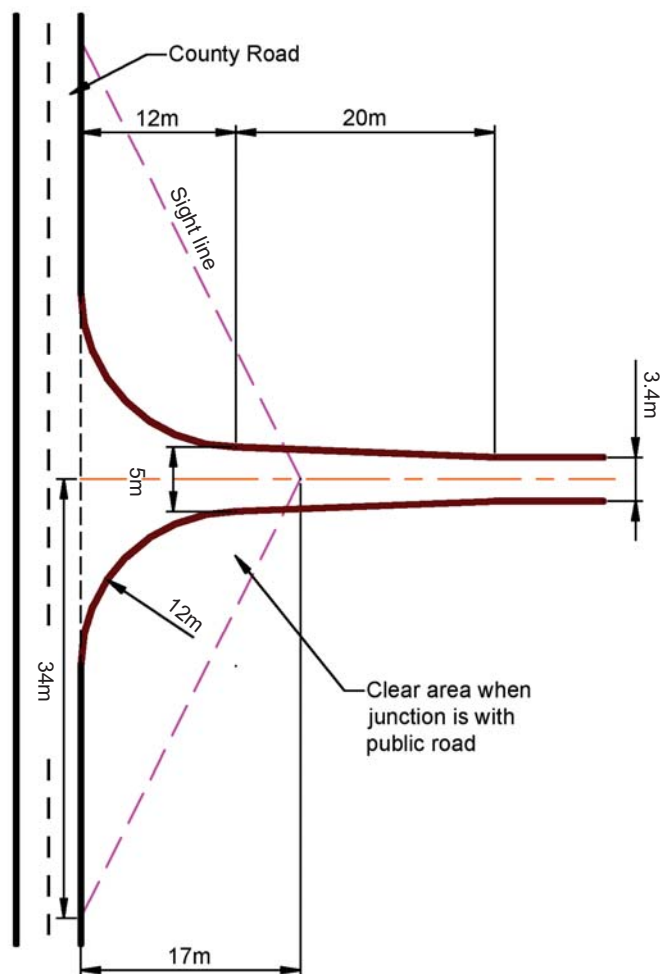


FIGURE 7: Typical forest road junctions.

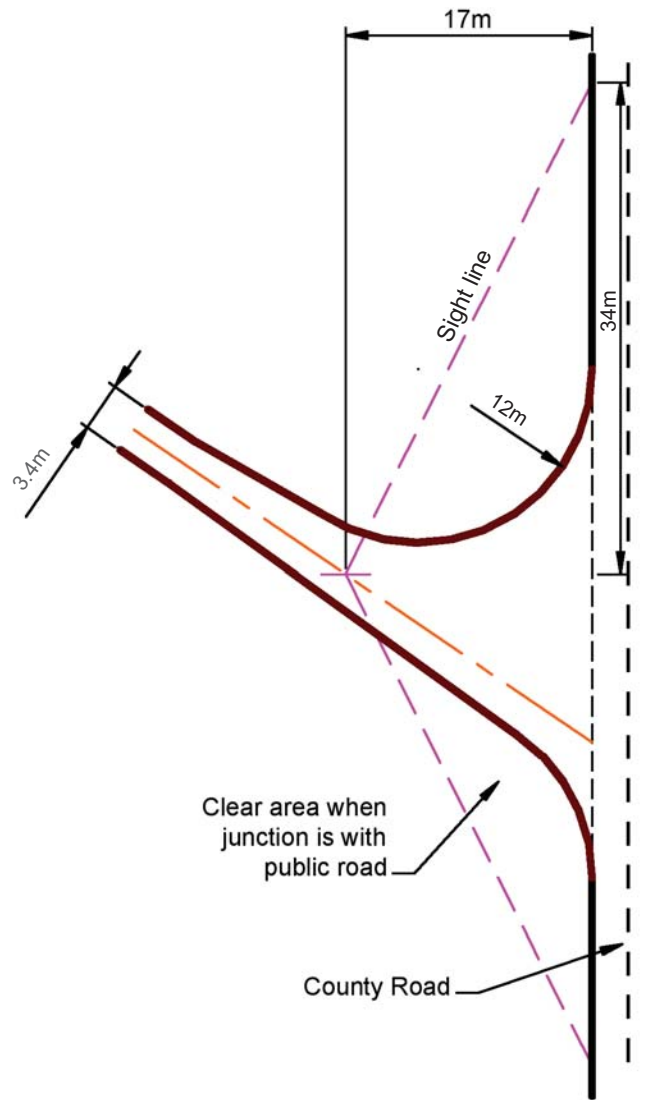


FIGURE 8: Typical forest road skew junctions.

Passing places

The bays provided at intervals along a forest road to allow trucks pass each other.

Passing places are similar to longitudinal loading bays and are obtained by widening the road at intervals enlarged to approximately 20 m long by 4 m deep. The distance between passing places can be up to 300 m.

Fortuitous extra widening, such as at borrow pits and junctions, will also serve as passing places. On embankment roads passing places will be provided where turning places for construction traffic have to be constructed.

Turning places

The circles or T-junctions provided at or near the ends of cul-de-sac roads.

Turning places can take either the form of a circle, approximately 12 m radius, an ellipse, 26 m long by 22 m wide or a T - junction.

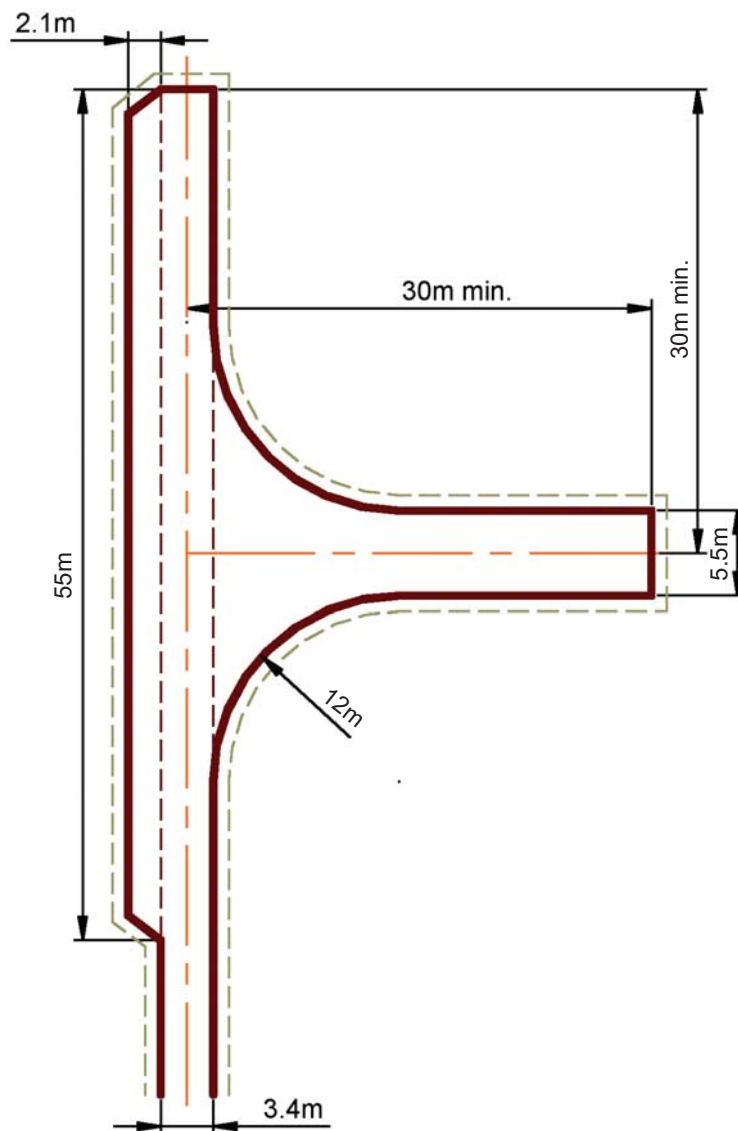


FIGURE 9: Typical forest road 'T' type turning place.

T-junctions, the end and side legs of the T being at least 30 m long and 5.5 m width each, are the most commonly constructed turning areas. It is desirable to place the leg of the T to the right hand side of the road from the direction of access so that when a lorry is reversing the driver can have a clear sight of the leg that is being turned into.

Careful attention to the selection of turning places at the survey and layout stage will usually give a satisfactory result but *ad hoc* solutions may be required in difficult cases.

Loading bays

The short road lengths of forest road used to provide access from a public road in small blocks or where greater road lengths would be uneconomic.

It is recommended that bays should comprise of a standard bell-mouth entrance, short section of road and turning place with surrounding cleared area for stacking. The precise layout of the bay

will depend on the site characteristics but care should be taken to screen it from public view as far as possible. Longitudinal bays immediately adjoining the public road are the least favoured but, where unavoidable, should consist of hard-standing for trucks with adjoining cleared stacking ground, the metalled area being not less than 20 m long by 5 m deep.

Particular attention should be directed to the elimination of damage to and fouling of the roads and ancillary drains, culverts etc. either during construction or subsequent use of loading bays.

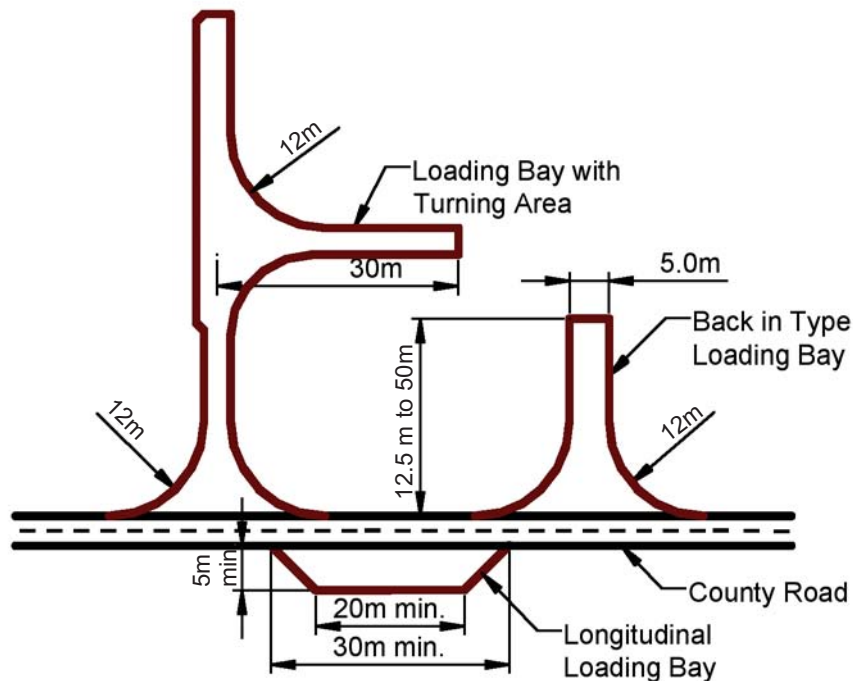


FIGURE 10: Typical loading bays.

Parking places

Small surfaced bays provided for work vehicles to park in without obstructing roads and turning areas for trucks.

Parking bays will be in the form of a surfaced rectangular area either 5 m deep by 10 m long or 3 m deep by 15 m long. They should normally be placed close to loading bays but care must be taken to ensure they do not interfere with timber stacking areas.

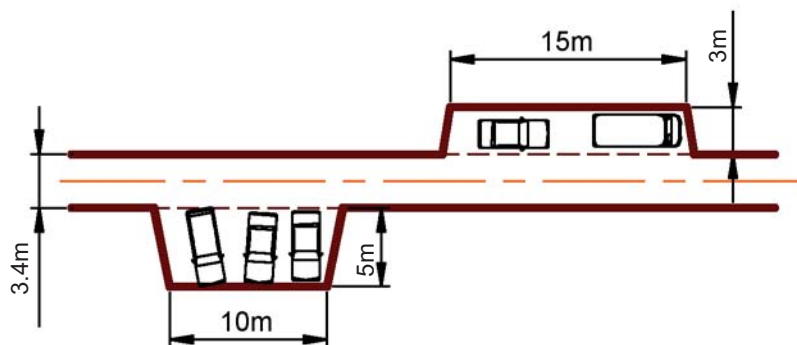


FIGURE 11: Typical parking places.

Tracks

Tracks, in forestry, tend to fall into two categories. These can best be described as:

- ▶ An engineered, level, cambered formation (foundation) of 4 m width (described as engineered tracks). Although not achieving road standards, they will safely carry timber extraction units (forwarders, skidders, etc.) and will not cause damage to the plantation or roads due to water run-off. Peat sites and wet, soft mineral sites are not suitable for these tracks as they would not have sufficient bearing capacity.
- ▶ Previously undisturbed ground, unplanted clearances, felled rows of trees, etc. over which timber extraction operates (called harvest tracks or racks).

Engineered tracks (from the first category) only, are those that are of concern to forest road building. The second category are purely a harvesting matter although care must be taken in their planning, layout and use so as to avoid damaging the environment, existing roads or possible future roadways.

Engineered tracks may be used in circumstances where it would be too difficult or too costly to construct a road to required standards. They should be intended solely for the use of harvesting vehicles and not for road vehicles. Engineered tracks do not get a completion metalling but it may often be necessary to install culverts and control drainage along them.

Maximum engineered track gradient	1:6 (16.7%)
Minimum radius of engineered track curvature	8 m
Engineered track formation width	4 m

B.8 ADDITIONAL EQUIVALENT ROAD LENGTHS

Equivalent road lengths arise from the extra work/quantities necessary due to road widening at junctions and loading bays. These additional equivalent lengths can be included in calculating work undertaken.

Standard bellmouth

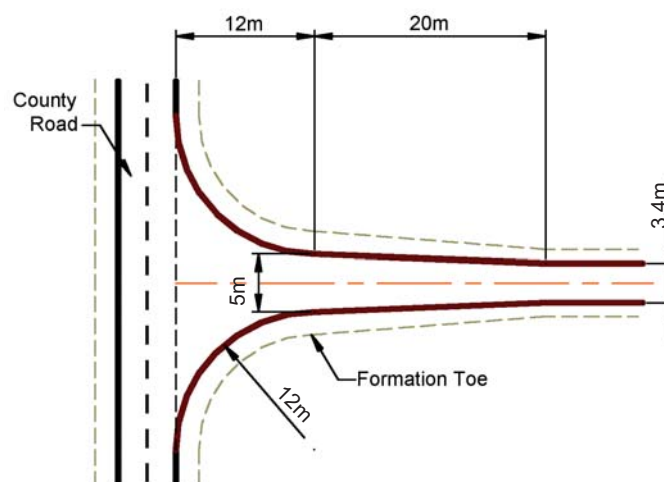


FIGURE 12: Standard forest road bellmouth.

Note: Measure road length from the edge of the county road.

$$\begin{aligned} \text{Junction area} &= 20 \times \frac{1}{2}(5 + 3.4) + (5 \times 12) + \frac{1}{2}[(24 \times 24) - \pi(12 \times 12)] \\ &= 84 + 60 + \frac{1}{2}(576 - 452.4) \\ &= 205.8 \text{ m}^2 \end{aligned}$$

less standard road (3.4 x 32) leaves 97 m²

$$\therefore \text{equivalent length} = 97 \div 3.4 = 28.5 \text{ m}$$

As bellmouths often require greater depths of fill, the equivalent length should be rounded up to 30 m.

⇒ Additional Equivalent Road Lengths for Standard Bellmouth
= 30 m

Standard T turning area

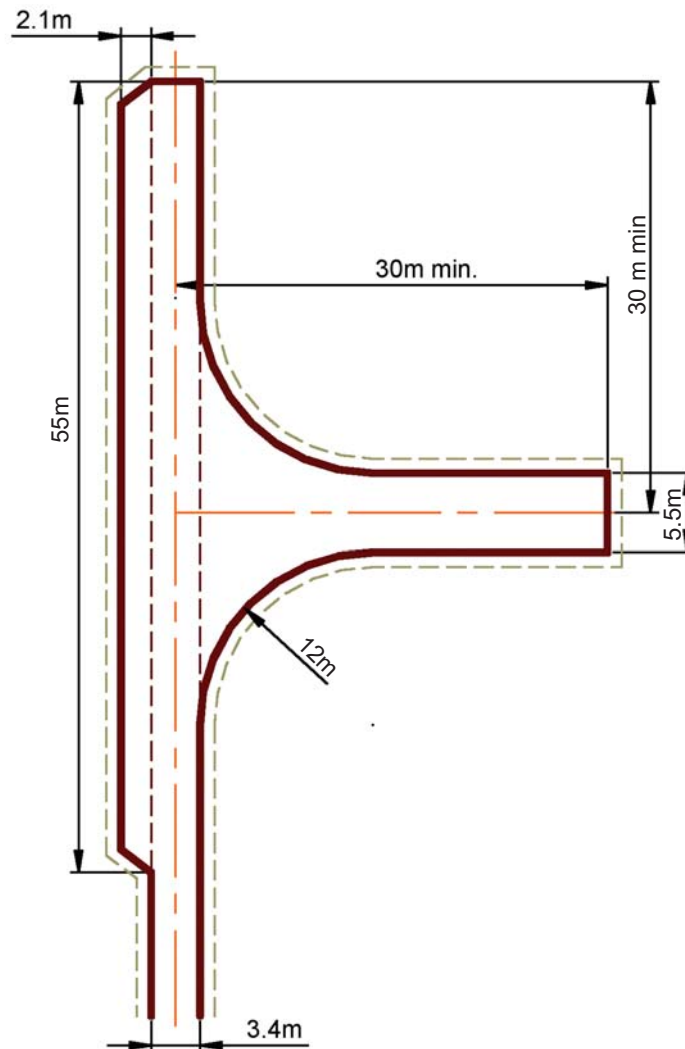


FIGURE 13: Standard forest road T turning area.

Notes: Turning leg should preferably be to the right as the truck approaches.

Measure road length to end of road and add the length of the turning leg (from road centre to its end).

$$\begin{aligned}
 \text{Turning area} &= (55 \times 5.5) + (30 \times 5.5) + \frac{1}{2}[(24 \times 24) - \pi(12 \times 12)] \\
 &= 302.5 + 165 + \frac{1}{2}(576 - 452.4) \\
 &= 529.3 \text{ m}^2
 \end{aligned}$$

less standard road $[(55 + 30) \times 3.4]$ leaves 240.3 m^2

\therefore equivalent length = $240.3 \div 3.4 = 70.7 \text{ m}$ - say 70 m

\Rightarrow Additional Equivalent Road Lengths for Standard T Turning Area = 70 m

Standard loading bay with internal turning area

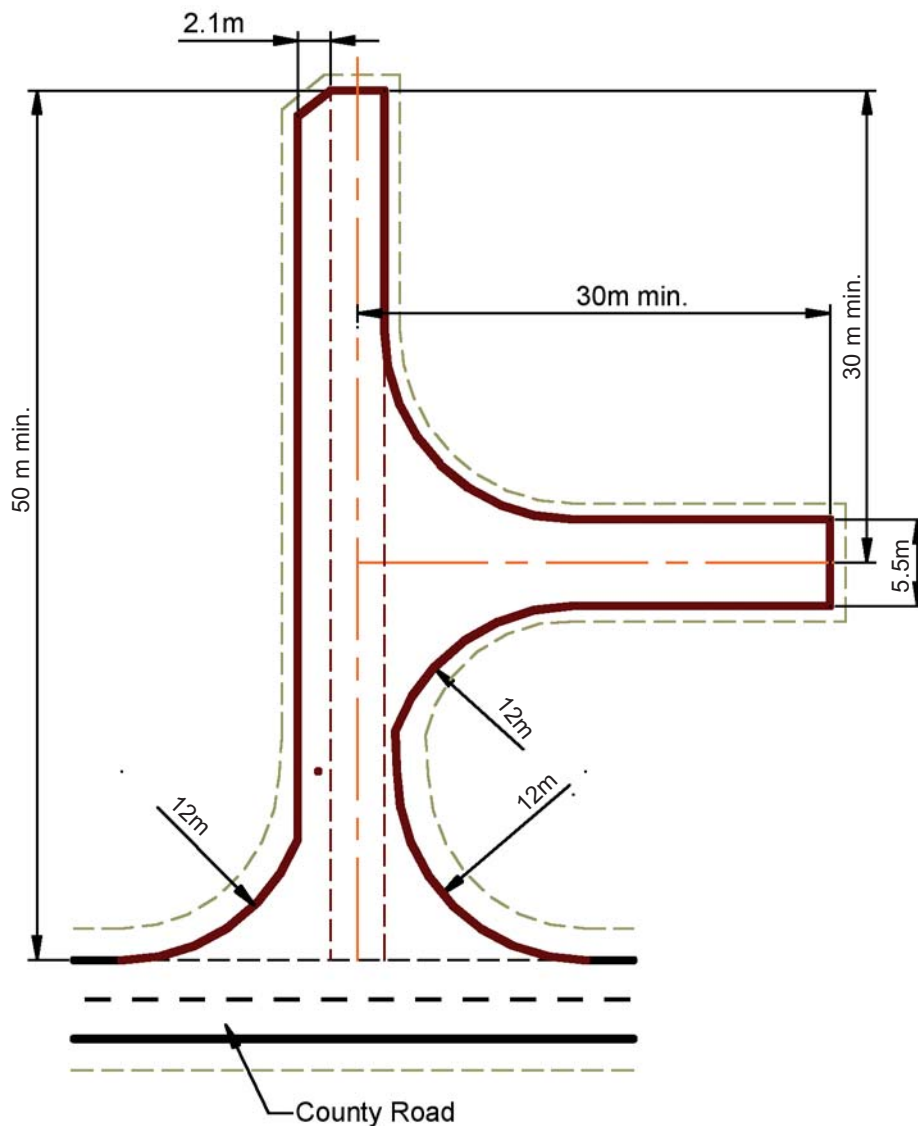


FIGURE 14: Standard loading bay with internal turning area.

Notes: Turning leg should preferably be to the right as the truck enters.

Measure road length from edge of county road to end of road and add the length of the turning leg (from road centre to its end).

While there may be some slight overlap between the standard bellmouth and the standard T type turning area the additional equivalent length (to be added to the depth in from the road) should be the sum of their equivalent lengths.

i.e. $30 \text{ m} + 70 \text{ m} = 100 \text{ m}$.

⇒ Additional Equivalent Road Lengths for Standard Loading Bay with Internal Turning Area = 105 m

Standard back in type loading bay

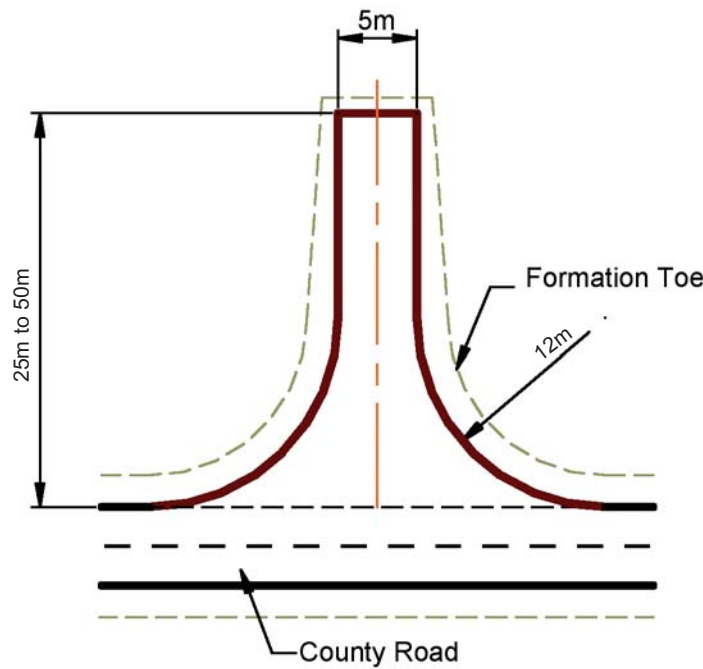


FIGURE 15: Standard back in type loading bay.

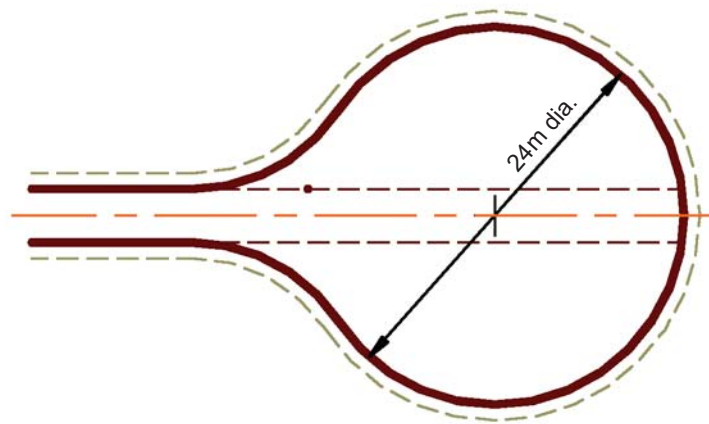
Note: Measure road length from edge of county road to end of the bay.

$$\begin{aligned} \text{Bellmouth area} &= (25 \times 5) + \frac{1}{2}[(24 \times 24) - \pi(12 \times 12)] \\ &= 125 + \frac{1}{2}(576 - 452.4) \\ &= 186.8 \text{ m}^2 \end{aligned}$$

less standard road (25×3.4) leaves 101.8 m^2

∴ equivalent length = $101.8 \div 3.4 = 29.9 \text{ m}$ - say 30 m

⇒ Additional Equivalent Road Lengths for Standard Back in Type Loading Bay = 30 m

Standard circle turning area**FIGURE 16:** Standard circle turning area.

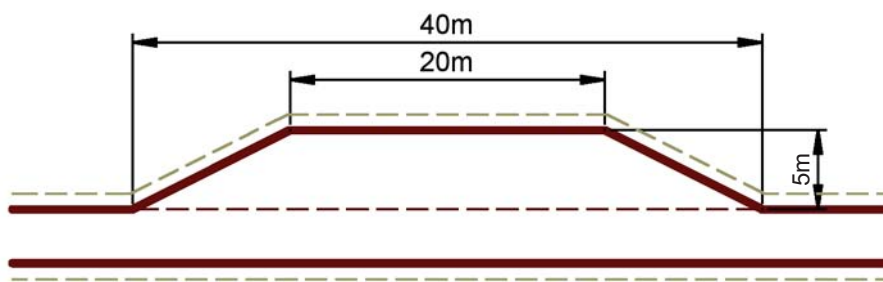
Note: Measure road length to the centre of the turning circle.

$$\begin{aligned}\text{Turning area} &= \pi(12 \times 12) \\ &= 454.4 \text{ m}^2\end{aligned}$$

less standard road (24 x 3.4) leaves 370.8 m²

∴ equivalent length = 370.8 ÷ 3.4 = 109.0 m - say 110 m

⇒ Additional Equivalent Road Lengths for Standard Circle Turning Area
= 110 m

Standard passing place**FIGURE 17:** Standard passing place.

$$\begin{aligned}\text{Passing area} &= 5 \times \frac{1}{2}(40 + 20) \\ &= 150 \text{ m}^2\end{aligned}$$

this does not include any standard road length

∴ equivalent length = 150 ÷ 3.4 = 44 m - say 45 m

⇒ Additional Equivalent Road Lengths for Standard Passing Place
= 45 m

B.9 FOREST ROAD PLANNING

The recommended time for road planning is prior to the commencement of planting. This will reduce the cost of planning by making site inspection and initial alignment much easier and enable the site and road drainage system to be planned together. It also prevents the opening up of the crop prior to thinning, reducing the risk of windthrow. The exception is on peat soils, where tree roots can provide a base for road formation but it is advisable to leave a 5 m wide unplanted strip beside the road site.

Having decided upon the road density for the forest block, the next step is to plan a system of roads as soon as possible, even though construction work may not be carried out for a number of years. Good planning will ensure access to the maximum volume of timber with the minimum length of road. Not only should the road density be correct, but the roads should be in the right place to facilitate harvesting and minimise environmental impact.

The three basic steps in road planning are:

- ▶ thorough site inspection of the area;
- ▶ initial road alignment on 6" map; and
- ▶ confirm alignment by walking road lines and amend as necessary.

Forest road planning is the first phase of a forest road construction project. At this stage the need for a road has been identified and the forest owner/agent must now identify the criteria which must be met to achieve the desired objectives.

The objectives to be achieved by a forest road must be clear. The primary purpose of a forest road is that it must be capable of safely carrying timber haulage vehicles. It must also provide satisfactory access to the forest property and work areas and have minimal impact on its surrounding environment.

Potential environmental risks and construction difficulties are identified at this stage, to ensure adequate design standards consistent with minimising environmental impacts and construction difficulties.

To achieve appropriate standards, forest road designers will normally be engineers with considerable forestry experience.

B.9.1 GUIDELINES

1. Roothing plans to be prepared well in advance of harvesting and transport operations to enable the roads to be located on alignments and grades that provide the required standard of access without compromising environmental values.
2. Roads to be kept to the minimum total length consistent with management objectives, located in the best landscape position possible, constructed under suitable weather conditions and well consolidated before use.
3. Roothing plans to be based on detailed surveys and environmental care principles that ensure that all environmentally sensitive locations are identified and appropriate design and construction techniques adopted.
4. Establish if the area to be rooded lies within or contains:

- ▶ an area identified as being environmentally sensitive in a County Development Plan,
- ▶ a part or whole of a Special Area of Conservation (SAC), Special Protection Area (SPA) or proposed Natural Heritage Area (pNHA),
- ▶ an aquatic zone (see *Forestry and Water Quality Guidelines*),
- ▶ archaeological sites and monuments (see *Forestry and Archaeology Guidelines*) or
- ▶ important habitats retained for biodiversity (see *Forest Biodiversity Guidelines*).

If any of these areas are affected by the road plan then the planner must liaise with the relevant Regional Fisheries Board, Local Authority or prescribed body as appropriate.

5. Identify if the road plan could create any local social/community impacts.
6. Identify the site conditions:
 - ▶ soil types;
 - ▶ ground conditions;
 - ▶ ground slopes;
 - ▶ watercourse locations;
 - ▶ areas to be harvested;
 - ▶ likely method of timber extraction; and
 - ▶ landscape;

as these will have a bearing on construction methods and environmental impacts.

It is recognised that not all issues will be fully definable at the outset and like any good planning process they must be monitored, reviewed and updated as necessary throughout the planning, design and construction phases of the forest road.

B.9.2 EXISTING ROADS OR TRACKS AND DEVELOPMENT ROADS

One further matter to bear in mind at this stage is the presently intended purpose of the road. Is it intended to be a development road or a harvest road? The answer to this will have some bearing on how issues are dealt with but it must also be remembered that most development roads will ultimately become part of the harvest road infrastructure.

Consideration should be given at the planning stage to the future use of any existing sub-standard roads and tracks. Decisions will usually take the form of:

- a) retention, and possibly extension, as a forwarder network instead of a new road; or
- b) retention in present form as a forwarder track to supplement a new road system; or
- c) network up-grading to full road standard and integration into a new road system.

The decision taken should be recorded to avoid the possibility of the plan's intention becoming obscured with the passage of time.

B.9.3 PUBLIC ROAD ENTRANCES DESIGN

In designing a forest road system, the designer must take care to ensure that it causes least impact to the public road network. Forest road entrances should be kept to a minimum and they should be located wherever possible on the better quality public roads.

B.9.4 COUNTY DEVELOPMENT/PLANNING ISSUES

Previously, under Local Government (Planning and Development) Regulations, 1994 (S.I. No. 86/1994), forestry was deemed as an agriculture activity and planning permission for internal forest road was only required where the entrance is from a public road with a surfaced dressed width greater than 4 m. This has now been replaced by the Planning and Development Act 2000. Section 4 (1)(i) of the act states that '*development consisting of the thinning, felling and replanting of trees, forests and woodlands, the construction, maintenance and improvement of non-public roads serving forests and woodlands and works ancillary to that development, not including the replacement of broadleaf high forest by conifer species*' is exempted development and does not require planning permission. Section 204 of the act allows for the designation of landscape conservation areas and this would restrict exempted development.

The Minister for the Environment and Local Government issued the Planning and Development Regulations, 2001 (S.I. No. 600 of 2001) to implement the Planning and Development Act, 2000 in its entirety.

Parts of the regulations and related provisions of the 2000 act were brought into force on 21 January 2002, including the provisions on exempted development. The remainder of the Regulations were brought into operation on 11 March 2002. The Local Government (Planning and Development) Acts, 1963 to 1999 (and the Regulations made under that Act) were then repealed.

Under provisions of the 2000 Act, the Minister for the Environment may introduce additional control regulations and has signalled that forestry may be subject to regulation in the future.

While planning permission is not required for forest road construction, it is recommended that in all instances where forest roads are constructed with a public road junction, consultations must be held with Local Authority Engineers as there are strict standards to be met in order to comply with minimum safety requirements.

County development plans set out areas in which certain types of development are either prohibited or restricted. Normally this will not effect forest road construction unless it is for a development road to establish a new plantation. The Local Area Engineer should be able to provide advice about this.

Sight distance requirements for public roads

Sight distance requirements are related to specific public road conditions and must take account of traffic volumes and speed. The sight distance for National routes may be greater than for Regional or county roads. The sight distance for National roads should be in accordance with the requirements of the *NRA Road Geometry Handbook* (TD 41/95) as updated by the *Design Manual for Roads and Bridges* (DMRB). The sight distances can be in the order of 90 m for national routes and 70 m for regional roads. Normally, the Local Authority will specify its requirements for an entrance during consultation.

B.9.5 ARCHAEOLOGICAL AND MONUMENT SITES

Archaeological sites in Ireland are legally protected from unauthorised interference or damage by the National Monuments Acts and Amendments 1930-1994.

Throughout the country there are many archaeological and monument sites along with natural heritage areas and special areas of conservation. The Office of Public Works (OPW) (which has responsibility for built heritage) keeps a register of these sites along with accompanying maps (Record of Monuments and Places (RMP)). All sites listed in the RMP are protected under the National Monuments legislation. Property owners/agents wishing to construct forest roads must contact their nearest OPW office to check that their proposed development will not interfere with any of these areas.

B.9.6 FISHERIES AND WILDLIFE MATTERS

As part of the road planning process, watercourses and catchments in the vicinity of the proposed works must be identified. These may feed rivers of fisheries importance. The local regional fisheries board must be consulted about the proposed road scheme at this stage so they can advise on the appropriateness of the work or provide suggestions to minimise potential impact(s).

Similarly, the local Department of Environment, Heritage and Local Government wildlife officer (formally part of Dúchas) should be consulted to ensure that minimal impact on flora and fauna can be achieved.

B.9.7 ENVIRONMENTAL AND SOCIAL CONCERNS

Many of the environmental and social concerns have been dealt with in the preceding paragraphs. The other environmental issues to be aware of are effects on the landscape and effects on air quality. Roads, especially when planned late, i.e. not at time of planting, can have an impact on the landscape although this impact is likely to be temporary as the forest will fill in and embankments/cuttings will green up over time. Forest road construction will not impact heavily on air quality but dust may become a problem in prolonged dry spells. Quarrying operations can also cause considerable dust and may also be a nuisance from a noise point of view.

Social considerations take account of the impact that road construction has on the local population living in the vicinity of the work or on the approaches to it. These impacts will normally be of a temporary nature and the most common nuisance will be the traffic generated by the road work. Machinery noise will then be probably the next biggest impact. A further consideration to take account of at this stage is to examine the possibility of using as much local resources as possible. This helps reduce transport impacts and also maximises the inputs to the local economy.

B.9.8 SOIL TYPES

Identifying the type of soil in the area to be roaded is very important as it will greatly influence the method of road construction and will also have a major bearing on the timber extraction for the property.

The erodibility of the soil, its susceptibility to damage and its silt content will influence the likelihood of watercourse pollution and hence the measures required to combat this.

B.9.9 GROUND CONDITIONS

Ground conditions are concerned with localised features on the site. Areas of rock, marsh, callows, deep peat, etc. need to be identified as road construction in many such areas can be very difficult. In addition to the difficult construction conditions, it is often more difficult to incorporate mitigation measures to minimise a road's impact on its environment in these areas.

Landscape features such as ravines, ridges and saddles also need to be located at this stage to aid good road planning.

Ground condition will also effect extraction and so it is important to take account of this at road planning stage. Other ground condition obstructions such as banks, cliff faces, and boulders can have a major adverse affect on timber extraction.

B.9.10 GROUND SLOPES

Contour maps of the site should be consulted early as they provide clear indications of areas that will be difficult to road. There are limits to road gradients and steeper cross slopes involve considerably more work. The tree clearance required for steep cross slopes needs to be greater and the resulting visual scarring on the hillside, although temporary in nature, will also be far greater.

Once again, ground slopes influence timber extraction methods and costs and this need to be taken account of when planning a road.

B.9.11 WATERCOURSE LOCATIONS

It is important to identify at an early stage all watercourse locations. This can largely be achieved by reference to 1:10560 scale ordnance sheets.

The Forest Service has published guidelines concerning water and these must be observed during forest road construction.

Roads must not follow watercourses, crossings must be kept to a minimum and crossing structures (bridges, fords, etc.) must not impede the waterflow.

Early identification of watercourses allows the road designer to plan for the most appropriate road drainage and dispersal of road surface water in a manner that will prevent pollution.

The source of collection points for water supply schemes must also be identified. Forest road planners must consult with the Local Authority and with residents in the vicinity of the forest property for further information on water intakes, e.g. group water schemes and private dwelling water supplies, as not all schemes are council operated.

B.9.12 AREAS TO BE HARVESTED

For a forest road to be successful, it must adequately serve the forest area to be harvested. The catchment area for harvesting needs to be clearly identified. However, it is also very important that road building is not carried out in a piecemeal fashion. Thus, it is normal and recommended practice to design and construct forest roads to serve a full forest property/forest block.

The road engineer/designer has to understand all harvesting systems to ensure the road is sited so as to optimise the harvesting costs. Ground haulage systems are best served by roads

located to reduce the average haul distance whereas cable systems are best served by roads located to maximise the length of cable used.

B.9.13 LIKELY METHOD OF TIMBER EXTRACTION

Forest roads are mostly constructed for harvesting purposes. The cost of extraction is influenced by a number of factors but the two greatest are probably the road density and the type of extraction machinery that will likely be used. Optimum road density is also dependant on the type of extraction (cable, forwarder, horse or skidder) and so it is very important to ascertain this at planning stage. Also, as noted in earlier paragraphs, many factors influencing extraction method also influence road construction and so a reasonable balance needs to be found.

B.9.14 OTHER FACTORS THAT MAY BE CONSIDERED AT PLANNING STAGE

At planning stage, a road designer may well consider other issues, most of which will develop as the planning stage passes into the design stage. These issues could include resources, such as what road construction equipment and road surfacing material is available in the area.

The designer should begin to address Safety and Health issues at the planning stage. A designer must identify hazards associated with the site and the construction work. A small sample of hazards could include overhead power lines, steep drops, boggy ground, loose boulders, fast flowing or deep water and substandard road junctions to name but a few.

The property owner/agent may also want the road designer to provide necessary information for a road grant application, where applicable. Although it will not be possible to submit this until the design has been carried out, much of the information required should have been obtained at this planning stage.

B.10 FOREST ROAD SURVEY/LAYOUT

At all stages of forest road planning and design, it must be remembered that the primary purpose of a forest road is to provide access for harvesting and timber extraction. This must be achieved at an economic cost (including optimum density) while taking account of environmental values during all stages of formation and completion.

B.10.1 GUIDELINES

Roads should be located so that they:

1. avoid strictly protected areas, scientific research areas and designated archaeological and cultural sites;
2. minimise the number of stream crossings and interference with natural drainage;
3. keep earthworks to a minimum by matching wherever possible, road alignment with topography of the site;
4. avoid environmentally sensitive areas;
5. avoid steep (>60%) and unstable slopes and areas prone to landslips;
6. avoid disturbance to streams, buffer strips and riparian vegetation;

7. avoid entry of sidecast material into streams or drainage channels; and
8. permit surface run-off to be discharged away from streams or drainage channels as far as is practicable.

B.10.2 CONSIDERATIONS

Before deciding the location of a forest road, it is necessary to examine the various pieces of information gathered at the road planning stage and weigh up their influences.

Once the areas to be served by the road (normally harvest areas) have been identified, it is normal to try to site the road on the best available soil types as this will generally give a more cost effective road which will also require less maintenance and upkeep. Wet soils, callows, deep peat and rock outcrops are to be avoided if possible on the proposed road line. While doing this the designer must take account of other ground conditions and slopes so as to minimise their impact on the construction stage.

Roads should be located at least 50 m from an aquatic zone (defined as a permanent or seasonal river, stream or lake shown on an ordnance survey 6" map) wherever possible. The layout should also aim to direct off road traffic away from streams. Road crossings of aquatic zones must be kept to a minimum and wherever they are necessary, an appropriate bridge or culvert must be constructed. Similarly the landform needs to be considered to ensure that the proposed road will have minimal visual impact, if any. It is important to minimise the visual impact of roads crossing over ridges and also be aware of the visibility of road features, cuttings and fills. These should not be allowed to create an artificial landscape. In general, the road alignment should reflect the natural features and qualities of the landscape.

In addition to finding a balance between these various physical issues, the designer needs to take account of the other constraints mentioned in the earlier road planning chapter. The designer must ensure that the chosen road location is suitable to ensure there will be no impact on fisheries, wildlife, archaeology, heritage, water quality etc. Quite obviously, this demands good experience and excellent judgement.

The Forest Service has published a suite of guidelines which should be consulted when planning the construction of a forest road. These guidelines are:

<i>Forestry and Water Quality Guidelines</i>	Pages 9 and 10
<i>Forestry and Archaeology Guidelines</i>	Pages 2 and 4
<i>Forest Biodiversity Guidelines</i>	Page 8 (machine operations)
<i>Forest Harvesting and Environment Guidelines</i>	Pages 10 to 14 and page 9
<i>Forestry and the Landscape Guidelines</i>	No specific forest road guidelines
<i>Code of Best Forest Practice</i>	Sections 13, 14 and 17

These guidelines can be accessed on the Forest Service web site (www.dcmnr.gov.ie).

Note: This web address is subject to change from time to time.

B.10.3 SETTING OUT

Following economic and environmental considerations, a designer will prepare tentative or provisional road location lines on a map which he will then inspect on the ground. The designer may have to amend the route before a final selection of the chosen location.

TABLE 6: Authorities and their responsibilities.

National Parks and Wildlife Service, formally Dúchas, now the Department of Environment, Heritage and Local Government	Sensitive wildlife habitats
National Monuments and Historical Properties Service, formally Dúchas, now the Office of Public Works	Archaeological sites and monuments
Local Authorities	Public road junctions
Local Authorities	Drinking water supplies
Local Authorities	Outstanding landscapes and high amenity areas
Regional Fisheries Boards	Fisheries

At this stage a designer will need to consult further with interested parties such as Local Authorities, fisheries boards, the heritage section of the Department of Environment, Heritage and Local Government, neighbouring landowners etc. to ensure that impacts are mitigated and any permissions required are obtained. After this the designer will mark out the design on the ground.

In most cases, fairly simple tools are used in setting out forest roads. These include a scale rule, protractor, measuring tapes, magnetic compass, abney level (or clinometer) and ranging rods. The road line will normally be marked out with pegs at 30 m maximum intervals, but marker tape will often be used where construction work will follow on soon after layout. The assistance of a chainsaw operator will often be required to clear a path through the trees.

During this setting out stage, regular ground probings will be taken to assess the depth of organic matter. Additional trial holes will be dug at frequent intervals to determine the nature of the sub-grade and height of the water table. Results of these probings and trial holes are recorded on a site investigation report. This report will accompany a road layout map which must also be prepared at this stage. The layout map will normally be plotted on six inch ordnance sheet (1:10560 scale) and to comply with mapping standards this mapping should be to an accuracy of 2.5 m. The map will be required for grant applications, contracting purposes and for subsequent forest management/planning.

Distance and bearing measurements are commonly used in surveying forest road positions. However, when using a compass, the user must check the angle of declination (difference between true north on the 6" OS map and magnetic north on the ground). This is achieved by checking the observed bearing of long straight features against their map bearing. All subsequent observations can be modified by this difference so that they coincide with the map. Bearings should be observed in both directions whenever possible. Measurements should always start from a point of ordnance detail and should similarly finish at a point of ordnance detail in order to check on the accuracy of the survey.



An abney level is a light hand held device used for checking gradients. The user views a distant 'eye level' height object through the level scope while turning a measuring dial with attached levelling bubble that can be viewed simultaneously in the scope. When the bubble reaches the level mark the user then checks the measuring dial for the angle of inclination. The object



viewed should be at the same height above the ground as the abney level is (i.e. eye level). This can be achieved in a number of ways. The user can sight on to an assistant who walks ahead/follows behind. Alternatively the user can fix markers at eye level as they move along and sight back to them. As with bearings, inclinations should be checked in both directions whenever possible.

Clinometers can be used as an alternative to abney levels as they are also used to measure inclinations.

Ranging rods are useful for temporarily marking reference points during layout or for projecting straight alignments over longer distances. The measuring tapes most commonly used would be 50 m long polypropylene tapes. Users must remember that maps show plan (2D) distances and so adjustments must be made to measurements taken on steep ground. (A 1 in 4 slope adds 3% to the plan distance.)

In exceptional cases, where properties are large and mountainous, advanced layout methods such as global positioning systems (GPS) or laser rangefinders may be used. However as these cases are rare and the equipment expensive, little use of these methods are made in Ireland. Also, specialist assistance would be necessary to utilise these methods effectively as they involve graphical three dimensional layout design which would then be set out on site and adjustments made for localised difficulties. It is therefore not proposed to discuss these methods further in this manual. These systems are nevertheless very useful for measurement and mapping of completed layouts and constructed roads.

B.10.4 MAPS AND REPORTS

Sample maps and site reports are shown on the following pages.

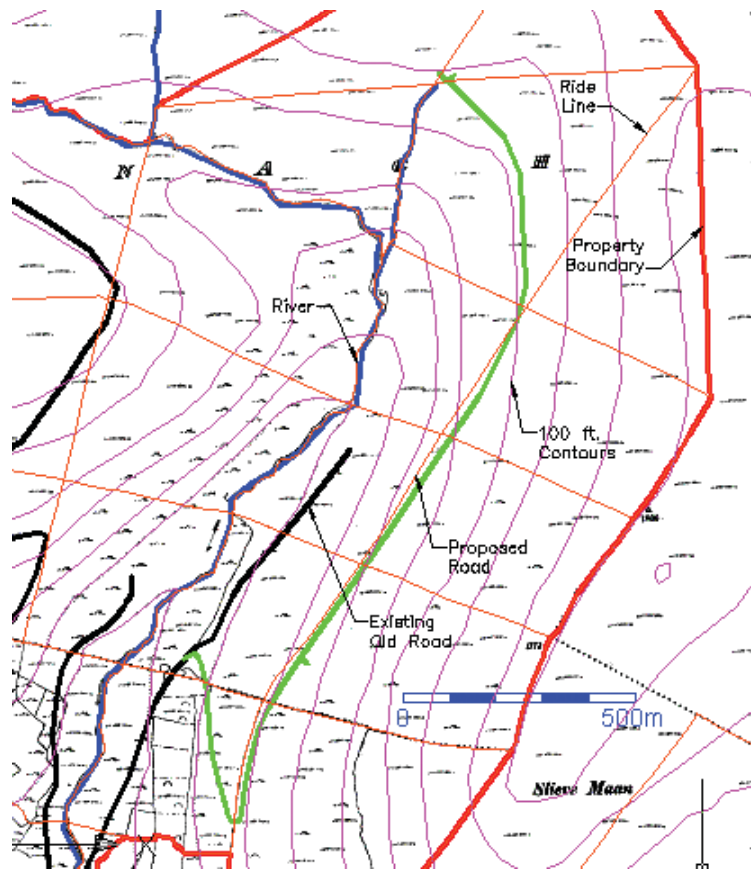


FIGURE 18: Proposed layout on mountain site (hairpin bends required to overcome gradients – road climbs steadily at approx. 1 in 12).

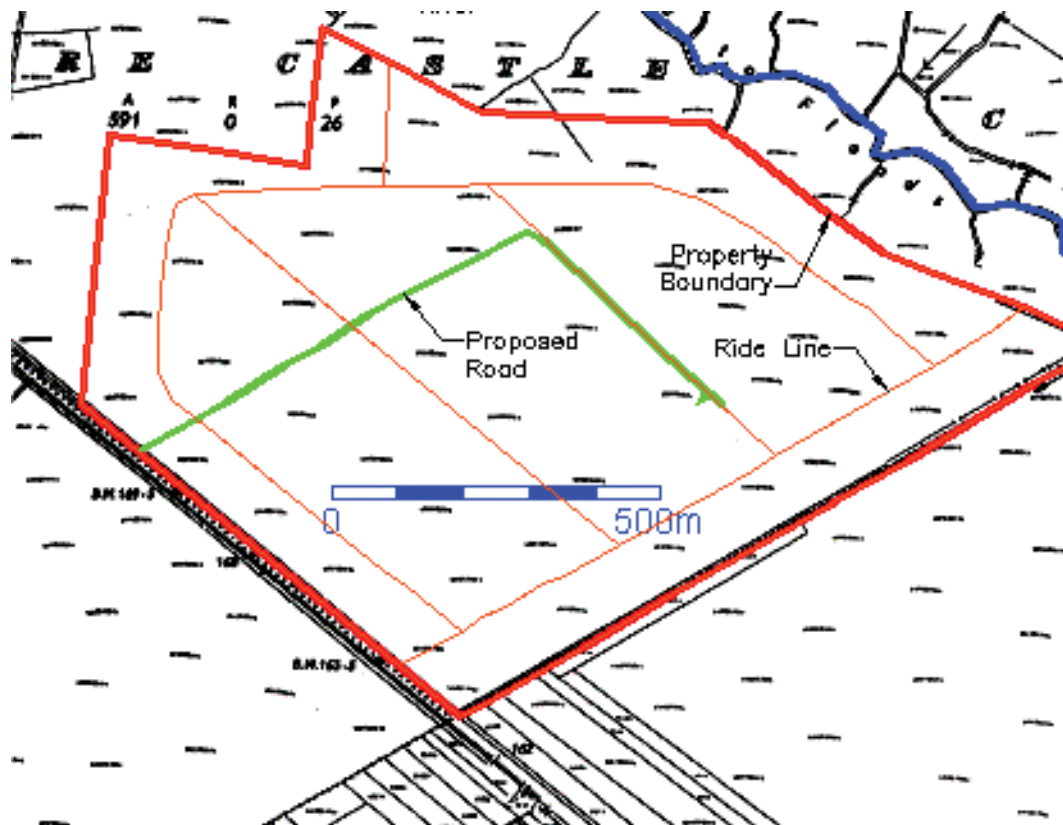


FIGURE 19: Proposed layout on flat peat site (road follows old track).

FORM 4: Sample site investigation report.

SITE INVESTIGATION REPORT	SHEET No. 1 of 3
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Forest Owner: Coillte Production Year 2004

Property/Townland: Buffy

OS No. Galway OS 67 Date of Survey 7/12/2001

Road Type: New Upgrade T/A Row

Programme Requirements:

Survey 1,670(m) Form. 1,670(m) Comp. 1,670(m)

Upgrade Form. _____(m) Upgrade Comp _____(m)

Engineered track _____(m)

Engineering Specification Compliance? Yes No

Hazards Identified? Yes No

Environmental Guidelines observed? Yes No

County Development Plan Checked? Yes No

If any 'No' above, attach a report explaining reasons for deviation

Distance (m)	Peat (mm)	Mineral (type)	Rock (type)	Culvert Ø (mm)	Slope +/- 0°	Comments
20	200				3.8	
70	400				4.7	
120	1000				3.8	
140	1000			450	3.3	Stream Crossing
170	1200				4.4	
220	1200				4.3	
270	400				3.6	
310	0	Clay			3.8	Transition
340	0	Clay		600	00	Stream Crossing
Continued on Additional Sheets (not shown)						

Will planning permission be required? Yes No

Signed _____

Date: _____

Section C:

Construction and Features

C.1 FOREST ROAD TREE CLEARANCE WORK

C.1.1 GUIDELINES

1. The road alignment is to be cleared before commencing road formation work.
2. Any stumps, logs and other forms of organic debris are to be removed clear of the roadway to ensure that they are not buried in the load bearing portion of the road unless they are being used as a fascine layer to help spread the load on soft ground.
3. Where necessary, topsoil should be stockpiled in a manner suitable for rehabilitation works with organic and mineral soil stored separate.
4. The area cleared should be kept to the minimum required for effective construction, and to allow sunlight and air movement onto the road surface for effective drying. This will normally be 15 m width but may need to be increased for certain types of work.

C.1.2 TREE CLEARANCE

In established plantations, the standard width of clearing will be a minimum of 15 m, except for reversal roads where the minimum will be 20 m. Additional width may be required in deep cuttings where soil may have to be deposited on both banks.

The required tree clearance must be confirmed with the designer as in some instances, the centre lines of the road and the tree clearance may not coincide. This is particularly so in the case of reversal roads.

Inadequate tree clearance causes a number of problems including:

- ▶ It creates difficulties during construction;
- ▶ It results in poor drainage and greater maintenance costs;
- ▶ Overhanging boughs cause trucks to drive on the road edges which causes damage and is dangerous; and
- ▶ Reduced sight distances at bends are hazardous.

Where excavation of the formation is intended, all unsaleable trees and lop and top are to be removed from the roadway to avoid their incorporation in embankments and spoil banks, with subsequent risk of collapse. Where an embankment road on undisturbed ground is intended, they may be utilised as a fascine layer.

Saleable timber should be removed from site if possible before the commencement of road formation work. Care needs to be taken at this stage to avoid causing severe rutting to the ground as this may effect the quality of the subsequent road. Where saleable timber is not removed before commencement of the road work, it should be stacked off the road site between standing trees. It is preferable to place these stacks on the upper side of the road.

Timber must never be extracted over an unsurfaced road formation. Doing so will rut the formation resulting in future water ingress and a weaker road. If the formation is rutted, regrading it will minimise this damage but surfacing (completion layer) must be delayed to allow the formation time to reconsolidate.

Where road-lines are set out prior to development of the area, a similar clear reserve (15 m) should be left and provided for in the cultivation plan.

C.2 FOREST ROAD DRAINAGE

Forest road drainage is an important aspect of forest road construction and maintenance.

Without good drainage a road will lose considerable strength and as a result will not achieve its design life. A 'wet road' may be as little as 25% as strong as a similar well drained road.

Proper drainage will minimise a roads impact on the environment. Without good drainage, there can be considerable sediment loss into the environment.

Culverts and bridges are covered in later chapters of this manual.

C.2.1 GUIDELINES

1. Adhere to drainage measures set out in *Forestry and Water Quality Guidelines*:
 - ▶ Preparation of a map containing a broad terrain classification, details of aquatic zones and sources of water supply;
 - ▶ Delineation of aquatic zones and buffer zones;
 - ▶ Roads should be located at least 50 m from an aquatic zone, where possible;
 - ▶ Roadside drainage is to be designed to discharge away from buffer zones and not allowed discharge directly into an aquatic zone. Sediment traps will be necessary;
 - ▶ Roadside drainage should not intercept runoff from higher ground;
 - ▶ Carry out construction in dry weather – ideally from April to October;
 - ▶ Do not remove gravel from a buffer zone;
 - ▶ It is essential to maintain roadside drains and sediment traps; and
 - ▶ Cement must not be discharged into an aquatic zone.
2. Where the intended route of a road must pass through waterlogged or impervious soils, these areas should be drained prior to commencement of construction.
3. When the formation area is fully stripped, the sub-grade should be shaped to a cambered profile, the degree of camber depending on the nature of the sub-grade material but within the range 200 – 300 mm.
4. Roads are to have a minimum gradient of 1 in 100 to facilitate drainage and water runoff.
5. Roadside drains should be provided to minimise the concentrations and velocity of runoff and ensure that water drains from the road surface.
6. Interceptor drains or culverts are to be spaced according to the road grade and have sufficient capacity to convey the peak flow from a storm.

7. Sediment traps to be provided where necessary to prevent direct discharge into streams.
8. Drainage from road sections to be discharged through a buffer strip before entering a stream.

C.2.2 DRAINAGE

The provision of adequate drainage, to remove excess water and prevent ingress of water in the future, is the most important ancillary activity in road making. On it depends the strength and stability of the entire roadway. The ease with which effective drainage can be provided is a major consideration in the precise location of the roadway. Except in very porous soils, cuttings should as far as possible be avoided.

Three types of drain are commonly used :

- i. Subsoil drains;
- ii. Interceptor (or cut-off) drains.
- iii. Roadside drains.

The standards for these drains have been set out in the previous section but more detail is included below.

Sub-soil drain

Lowering of the water table is particularly important in peat and gley sites. Drains should be provided well in advance of formation work particularly where it is intended to build an embankment road on the natural ground surface - a time interval of 1 year or more between preliminary and formation work is recommended where this can be arranged. On deep peats, drainage excavation staged over many years is necessary to improve the strength of the peat.

Subsoil drains will usually be from approximately 450 mm to 750 mm deep and be a minimum distance of 2 m from the edges of the roadway.

Interceptor (cut-off) drains

On sloping sites these are best provided by excavating two or three drains parallel with the road line, the closest drain being at least 3 m from the estimated position of the top edge of roadway excavation. On dry permeable wooded hillsides it is frequently unnecessary to provide any cut off drain.

Roadside drains

These are provided at the edge of the formation. In general the angle between the toe of the cutting and the edge of the cambered formation will be adequate to control the run-off from the formation area itself. Occasionally a deeper drain may have to be provided where a high water-table persists in the formation, especially in cuttings.

C.2.3 SEDIMENT TRAPS

Sediment traps (also known as sedimentation ponds or silt traps) are constructed to contain sediment that primarily arises during road construction. Their size is site dependant, but they will

generally be approximately 3 m long by 1.5 m wide by 1 m deep. They need to be cleaned and maintained on a regular basis until the sediment problem abates after 1 to 4 years.

Permanent sediment traps on highly erodible soils require detailed engineering design. Further information is available in the COFORD publication *Forest Drainage Engineering*⁵.

C.2.4 BUFFER STRIPS

Roadside drainage must not be allowed to discharge directly into natural watercourses. Instead it should be allowed to run out through buffer strips.

Buffer strips are zones of natural vegetation through which the water passes and in so doing deposits sediments. Buffer strips are preferred to sedimentation traps in forest road construction because the traps need constant monitoring and maintenance.

Buffer zone widths vary from 10 to 25 m depending on the terrain.

TABLE 7: Buffer zone requirements.

AVERAGE SLOPE SEADING TO AQUATIC ZONE	BUFFER ZONE WIDTH ON EACH SIDE OF THE AQUATIC ZONE	BUFFER ZONE FOR HIGHLY ERODABLE SOILS
Moderate (even to 1 in 7)	10 m	15 m
Steep (1 in 7 to 1 in 3)	15 m	20 m
Very Steep (> 1 in 3)	20 m	25 m

Source: Forest Service - Forestry and Water Quality Guidelines.

C.3 FOREST ROAD FORMATION METHODS

Forest roads and their junctions to county roads must be constructed in planned engineering phases well in advance of timber harvesting and road haulage and with the intention of minimising disturbance to the site.

The engineering phases are:

- i. road formation;
- ii. road drainage;
- iii. road completion.

Road drainage, which includes culverting, is normally undertaken in conjunction with road formation.

There are a number of road construction methods at formation stage depending on site conditions but they can be generally described as either of the following:

- i. excavated roads (on mineral soils and on organic soil to 2 m deep); or
- ii. embankment roads on peats over 2 m deep; or
- iii. reversal roads which can be either excavated or embankment type roads. They will be touched on briefly in this chapter and covered in more detail later in this manual.

⁵ COFORD. 1999. *Forest Drainage Engineering - A Design Manual*. COFORD, Dublin.

C.3.1 GUIDELINES

Buffer and exclusion zones

1. The outer perimeter of all buffer and exclusion zones as per *Forestry and Water Guidelines* should be clearly demarcated on the ground.
2. Machines should not enter these zones during road construction operations, except where it is unavoidable.
3. Fuel storage, maintenance, refuelling and repair work must not take place within 50 m of the nearest aquatic zone.

Methods of construction

4. Methods for the construction of forest roads and associated special construction works including the specification of machinery and ancillary equipment should be selected to promote efficient construction and minimise environmental impact.

Timing

5. Road construction should ideally be undertaken during summer periods when lower rainfall and drier soil conditions minimise the risk of erosion.

Carriageway

6. The formation/carriageway should be in accordance with the standards set out earlier in section B.7.
7. The carriageway is to be constructed by either:
 - i. compaction of the natural formation (or sub-grade), where its composition is such that it will give adequate strength; or
 - ii. placing and compacting a layer of imported base material on the compacted formation, followed by a layer of imported surfacing material; or
 - iii. placing and compacting a layer of surfacing material only.

Fills and embankments

8. Fills and embankments should be allowed time to consolidate.
9. The side-slope of embankments should be the natural angle of repose of the material, usually of the order of 1 vertical unit to 1.5 horizontal units.
10. All faces and slopes requiring stabilisation and drainage should be treated prior to the removal of equipment from the site.

Cuttings

11. The banks of cuttings should be battered wherever necessary to minimise erosion. This is particularly necessary where seepage through the banks is a problem.

12. In any instance of bank slippage, loose material must be removed as soon as possible to prevent sedimentation of watercourses.

Culverts and drains

13. All roadside drains, culvert drains and other drainage structures should be installed concurrently with the formation of the road. Sections of partially constructed road to be left uncompleted over winter or for other extended periods should be drained by cross drains.

Partially built roads

14. All partially built roads (or those being left to settle) must be closed to traffic until they are completed.
15. Where road construction is halted or suspended, adequate temporary stabilisation must be employed to deal with site earthworks drainage.

Contamination

16. The refuelling and maintenance of machines must not take place close to sensitive sites in order to prevent spillage of fuel and oils from entering streams and watercourses. *Forestry and Water Quality Guidelines* require this work to be carried out at least 50 m from the nearest aquatic zone on a dry, elevated site.

C.3.2 FORMATION WORK

This includes all earthworks, whether excavation or building of embankments, and drainage within the roadway.

C.3.3 TIMING OF WORK

Ideally, road construction is a seasonal activity confined to the period March to October. Within this period it is desirable to suspend roadwork during periods of wet weather. In the off-season the recovery of wet ground to workable condition is always very slow. However, it is obviously not always possible to suspend work with every break in the weather.

Building of embankment roads is best confined to dry conditions as the road cost increases and the quality decreases dramatically in prolonged wet periods.

C.3.4 GEOTEXTILES

Several proprietary geotextiles are available (generally composed of polypropylene) which serve either as a separation layer and/or to increase bearing capacity (similar to the function of a layer of fascines). They facilitate construction and may reduce the volume of fill necessary to carry construction traffic. They can be particularly useful on wet sites.

The lower cost geotextiles are commonly used for separation of construction material from the sub-grade. Occasional use of higher cost geotextiles/geogrids on deep peat sites is necessary for strengthening in the absence of natural fascine material.



PHOTO 6: Formation material being placed on a geotextile.

C.3.5 MACHINERY USED

Over the last twenty years, hydraulic excavators have taken over from dozers as the most popular method of constructing unbound roads. The principle reasons for this change are:

- ▶ improved technology;
- ▶ greater versatility – they can perform a greater range of tasks;
- ▶ less dependence on dry weather; and
- ▶ more sensitive to the environment.

Even where dozers are operating, it will be necessary to use excavators in the vicinity of streams and other water features.

As a general rule of thumb, more powerful machines, rather than those merely capable of doing the work, are the more economical. However, care must be taken not to use too large a machine, especially on soils with a low bearing capacity.

Mineral soil sites

On dry permeable sites excavation can be carried out by dozers in the 70-200 h.p. range. The machine size chosen will depend on the difficulty of site, hourly rates and availability. A machine with rear-mounted ripping attachment can greatly facilitate work on compacted soils, even where there is no rock or shale.

On sites with a high content of large boulders, excavators normally in excess of 20 tonne weight with a bucket capacity of approximately 1 m³ are preferred. Alternatively, use dozers in the 200-300 h.p. range where environmental considerations permit this.

On clay or gley soils in high rainfall areas it is generally best to use excavators of 15 to 20 tonne with 0.75 – 1 m³ bucket capacity, although very good output can be achieved by the use of dozers when sustained spells of dry conditions occur. To be assured of work continuity in such

areas excavators are a better choice, except in the limited number of cases where dozers can be brought in and taken out at short notice.

Peat sites

On upland peat sites where depth of peat does not exceed 600 mm and there is a sound mineral sub-grade, dozers in the 100-150 h.p. range will give good production provided site conditions remain dry. When site conditions are not good and sub-grade is impermeable, use excavators with 0.75 – 1 m³ bucket capacity.

Where peat depth exceeds 600 mm the recommendation is to use an excavator (preferably low ground pressure - L.G.P.) with 0.75 – 1 m³ bucket capacity.

C.3.6 SIDE-SLOPE OF EMBANKMENTS

These will be at the natural angle of repose of the material, usually of the order of 1 vertical unit to 1.5 horizontal. Edge material will often stand initially at a much steeper slope, gradually falling away as consolidation proceeds. Allowance must be made for this occurrence in designing the embankment width.

C.3.7 CULVERTS

Roadway culverts will be for two purposes, conveyance of run-off from uplands and the periodic removal of run-off from the formation before it can give rise to structural weakening or erosion.

Culverts for upland run-off

These will occur at existing drains or outlets created in the drainage programme. Culvert size will be determined as outlined in the chapter on culverts.

Culverts for formation run-off

These will be of 300 mm diameter jointed concrete pipes usually but the use of 375 mm to 450 mm diameter is recommended on easily eroded sub-grades.

Culvert spacing will vary from 40 m to 100 m depending on road gradient and susceptibility of sub-grade to erosion. The proximity of culverts increases with steeper road gradient and the erosion risk. The chapter on culverts contains a guide to culvert spacing.

In the case of roads in full cutting (particularly flat peat areas) it is usually difficult to achieve drainage outfall economically. Where this problem occurs it is best to provide side drains within the formation and use fewer culverts of larger diameter (e.g. 600 mm). Careful selection of culvert positions which will entail minimum length of outfall drain is a very important factor in these cases. (Construction of outfall drains for roads through fully grown plantations is very expensive.) It may also be necessary to provide a wider formation than the standard minimum in these situations.

C.3.8 ROCK OBSTRUCTIONS

Rock obstructions should be avoided wherever possible. Where unavoidable, they will generally be dealt with either by ripping, where rock type permits this, or by rock breakers. However, due to high costs inherent in these operations, every effort should be made at road planning stage to keep the incidence of this work to an absolute minimum.

In extreme circumstances, blasting may be necessary. In such instances, specialist contractors must be employed for this work.

C.3.9 DIFFICULTIES ARISING DURING COURSE OF FORMATION WORK

Despite site investigation carried out at the design stage, some unforeseen difficulties may arise on some sites during the course of formation work. Occasionally the magnitude of such difficulties may necessitate major departures from the approved specification. When it becomes apparent that such a situation is arising, the road designer should be informed immediately so that corrective measures can be introduced at the earliest stage possible.

C.3.10 STAGES AND METHODS OF FORMATION – EXCAVATION – FLAT TO GENTLY SLOPING SITES

Stripping the formation site

All organic soil, or peat, and tree stumps over the formation area are to be stripped and run to both sides. Some sub-grade material, at a lower level, may also be run to spoil with a view to exposing better bearing material. The decision to do this will depend on the balance struck between savings in road completion and the additional cost of excavation and possibly more difficult drainage.

Work Method - Mineral Soil Sites

Excavator: Machine is used as a backacter travelling backwards along the line of the road and working on the natural ground surface. Set up close to one edge of the formation (lower side where edge is a slight cross-fall) and excavate formation in chequer-board pattern dumping spoil at full reach of machine.

Dozer: Angle the blade and push top-soil in a scything action from one side of the formation area to spoil well clear of opposite side. Alternatively, using a straight blade, push top soil straight across formation to spoil, well clear of opposite side.

Work Method - Peat Sites

Excavator: With the exception of a very limited number of sites, all shallow peat sites will be either fully finished by excavator or stripped by excavator and have sub-grade finished to camber by dozer or by dozer and grader. Formation width will be 7 m. (When peat depth is less than 600 mm, a formation width of 5.5 m may be used at the discretion of the road designer).

Dozer: Where peat depth is less than 600 mm and there is a sound mineral sub-grade, the

peat may be stripped by a dozer (preferably LGP type) of approximately 120 h.p, always provided that site conditions are dry. A formation width of 7 m will be normal (When peat depth is less than 600 mm, a formation width may be 5.5 m may be used at the discretion of the road designer).

Excavation and cambering (all flat to gently sloping sites)

When the formation area is fully stripped, the sub-grade is shaped to a cambered profile, the degree of camber depending on the nature of the sub-grade material. For formation work, camber will range from 200 mm to 300 mm depending on soil type.

Work Method

Excavator: Generally the sub-grade is roughly shaped at the time of stripping of the organic soil to prevent deterioration and final grading and cambering is done subsequently by dozer or motor-grader. In difficult cases (e.g. gley soils), or where only a short section of road is being constructed, the final cambered shape is done by the excavator working on the sub-grade, when a certain degree of satisfactory longitudinal grading can be achieved also. As a rule, full completion of formation by excavator to satisfactory longitudinal and cambered profiles calls for a high degree of skill.

Dozer: Angle and tilt blade. With the machine travelling along at one edge of the formation drift excavated material to centre. Repeat until the desired camber is achieved over half the formation width. Reverse angle, tilt and repeat for other side of the formation. On clayey sites, form a cambered formation by side-casting to verges thus making a full undisturbed solid section. Longitudinal grading to give a uniform gradient is done simultaneously. A final back-blading by a skilled operator will greatly enhance the quality of finish.

Motor-grader: The most satisfactory method of achieving high quality, low-cost final grading and cambering is by use of a motor-grader, confining dozer or excavator to rough shaping only. Four-wheel drive and steer type graders are best for forest road work.

Compaction of formation

Construction plant will achieve a certain degree of compaction. However, where possible and at or near its optimum moisture content, the cambered formation should be further compacted by use of either a three-point, non-vibratory roller (of approximately 8 tonnes) or by a vibratory roller of 3 - 5 tonnes dead-weight towed by a motor-grader. The number of passes is usually 4 or 5, there being little strength gain beyond that point.

Note: Maximum strength can only be achieved at the optimum moisture content (approximately 10-15% for sandy/gravel type soils, 20-25% for clayey soils). While it will often be necessary to allow drying-out time to get near optimum, it will, in the Irish climate, rarely be necessary to add water to a sub-grade.

C.3.11 STAGES AND METHODS OF FORMATION - EXCAVATION – SLOPING SITES (CROSS SLOPES GREATER THAN 1:7)

Stripping the formation site

All organic soil, or peat, and tree stumps over the formation area are to be stripped and run to spoil clear of the down-hill side of the formation area.

Work Method - Mineral Soil Sites

Excavator: Use as described previously for flat to gently sloping mineral soil sites, except that in this case, the operator must first place some stripped material under the down-hill track to provide a level working platform for the machine. On very severe cross-slope the machine will sometimes work from the formation for safety reasons. This will not arise often as such difficulties are minimised by careful layout.

Dozer: Angle the blade and strip top-soil, beginning at the upper edge of formation and dump well clear of the lower edge. Where side-slope is too steep to permit slewing across the formation, strip parallel with direction of road, stepping outward in successive passes until the entire width is stripped. A certain amount of sub-grade material will be run to spoil with organic soil but this is preferable to having organic soil incorporated in the fill section of the formation. It may in any case result in the uncovering of superior base material.

Work Method - Peat Sites

Excavator: The majority of sites will be excavated by excavator. Work methods will be as for sloping mineral soil above. The formation cross-section will however be half cut and half fill, the fill section being buttressed by the vertical face of the peat at the lower edge.

Dozer: Where depth is less than 600 mm and there is a sound mineral sub-grade the peat may be stripped by a dozer (preferably LGP type) of approximately 120 h.p. always provided that site conditions are dry. Work stages and methods will be as for sloping mineral soil above.

Excavation and cambering (all sloping (greater than 1:7) sites)

When the formation area is fully stripped, the sub-grade is shaped to a cambered profile, the degree of camber depending on the nature of the sub-grade material.

Work Method

Excavator: Generally, if the exposed sub-grade is suitable for dozing, this method of completing formation work is adopted. Where the formation is finished by excavator it is first roughly formed at stripping stage. Subsequently the excavator, standing on the sub-grade, can shape the formation and do a certain amount of longitudinal grading. Depth of cut will be governed by the provision that a minimum of 4 m from the toe must be out of the solid. Where possible, final grading and cambering is best done by motor-grader.

Dozer: Angle the blade and tilt in reverse direction to the ground slope. Make first pass along the upper edge of stripped formation allowing the excavated material to drift outward. Make successive cuts along the same track until a bench at least 4 m wide from the toe of the excavation to the intersection with parent ground has been excavated. The fill section formed by the excavated material (the extent of which will depend on how much it has been necessary to remove to achieve the 4 m solid bench) is then struck off to roughly complete the cambered section. The face of the excavation is left untrimmed at the slope it assumes in course of work. Finally, camber the formation to the degree appropriate to the material. Note that the crown of camber should be approximately 2.5-3 m from the toe and only a nominal camber is given to fill the section to allow for consolidation. Alternatively, leave the roughly cambered finish for subsequent completion by motor-grader.

In gley sites, where there is a strong possibility of bank slip, the crown of the camber may be shifted outward at the designer's discretion in order to provide space for slip material without blocking of the carriageway. Slip material should, of course, be removed at the earliest opportunity.

Compaction of formation

If the sub-grade is undisturbed following formation and cambering, no compaction will be required. However, when compaction is required, compact the formation, where possible, by using either a three-point, non vibratory roller (approximately 8 tonne) or a towed vibratory rollers (3-5 tonne dead-weight). Vibratory rollers are most effective on sandy soils while cohesive, clayey soils respond well to dead-weight rollers. Soil moisture content should be as close as possible to optimum. Caution should be exercised in rolling the fill section of the formation, particularly where depth is considerable.

Note: Maximum strength can only be achieved at the optimum moisture content (approximately 10-15% for sandy/gravel type soils, 20-25% for clayey soils). While it will often be necessary to allow drying-out time to get near optimum, it will, in the Irish climate, rarely be necessary to add water to a sub-grade.

Levelling of spoil banks

As far as possible high obstructive spoil banks are to be avoided. They should be levelled over verges where they will provide useful timber stacking/processing ground. Gaps should be pushed through at regular intervals as required to facilitate off-road access (say 30 to 100 m intervals).

Access ramps

In the course of formation excavation, ramps should be provided, from the formation to higher verges, to facilitate off-road vehicles. They should be at reasonably frequent intervals (say 100 m) and advantage should be taken at local low spots in the excavation. On longitudinal road gradients, access ramps should be located just below formation run off culverts.

Access ramps should be excavated out of the solid bank and not constructed with fill material. A gradient of approximately 1 in 5 will be adequate on ramps, although they may need to be as steep as 1 in 3.

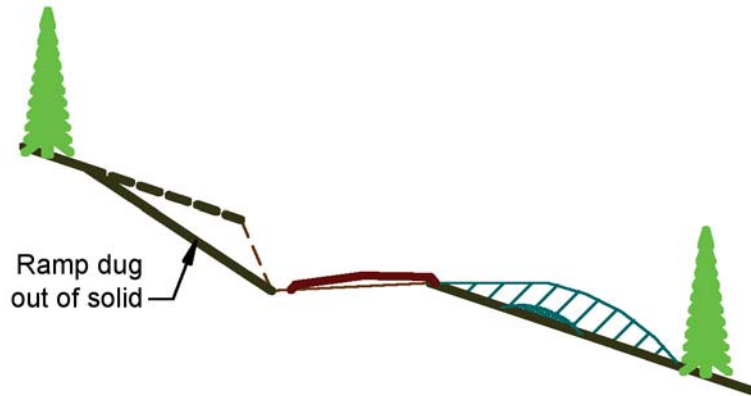


FIGURE 20: Section showing ramp location.

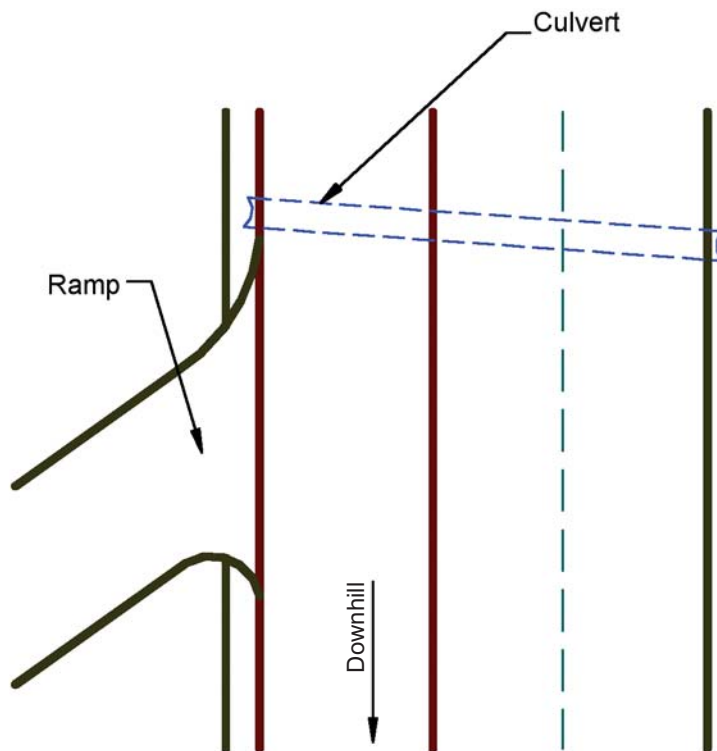


FIGURE 21: Plan showing ramp location.



PHOTO 7: *Formation on a steep cross slope.*

C.3.12 STAGES AND METHODS OF FORMATION - 'BUILD ON TOP' EMBANKMENT ROADS

Embankment roads are most likely to be constructed on sites where excavation would be prohibitively expensive. Unfortunately, these sites are also least likely to support dependable embankment roads. As a result, maintenance expenditure on embankment roads will usually be at a high level.

On deep peat sites it is always necessary to consider whether alternatives, such as long haul forwarding, might not be better than attempting to cater for full truck traffic. This is especially important when the access route also has severe limitations not readily rectified or where the area will not be intensively managed.

Site improvement

On embankment roads, the natural vegetation is left untouched as it contributes to the bearing strength of the site. Trees growing on the road line should be felled close to ground level and stumps left. Where available, closely spaced, felled poles (delimbed trees), covered with brash can be spread across the formation base width to help load distribution. Sods from drains (provided at preliminary stage) can be used to level up depressions. When the road site has been chosen some years before construction is due, it is recommended to carry out pre-construction drainage at the earliest possible stage and use the intervening time to make the formation area as strong as possible. Spoil from drains can be used to give a convex shape, drains themselves can be gradually deepened as drying out proceeds and planting of trees at close spacing will provide a matrix of stumps and roots as well as ready-to-hand supply of brash.



PHOTO 8: Build on top formation on poles and brash fascine.

Geotextiles

In the absence of timber, geotextiles are used in the base of embankments. Several proprietary geotextiles are available which serve the function of a layer of fascines. As structural geotextiles are expensive for forest roads they are used only on specific sites. However low cost separation geotextiles are commonly used. These help to reduce the volume of fill necessary to construct the embankment.

Formation material

The ideal material for embankment roads on sites with low bearing strength is light-weight fill such as clinker, but in practice the best available material to hand must be used. Haul distance has a strong bearing on delivered cost so that, where possible, it is best to use a number of small quarries or borrow pits along or close to the road.

Construction method

Where the time scale permits, embankment roads on peat depths greater than 1 m, should be built up slowly over several years. (On mineral sites an extended time of construction, while beneficial, is not as crucial for success). This approach, allied to periodic attention to lateral drains, will allow for maximum strength gain in both base and formation; ensure a better profile and minimise the risk of failure under eventual heavy loading. The rapid raising of embankments to full height may result in foundation failure. To avoid damage to the site, material should be delivered in small quantities and spread on the formation in shallow layers. Only sufficient material to carry construction traffic should be used in the first instance. The embankment can be further strengthened, gradually, by the addition of further layers of material. It is important to keep a cambered profile on each successive layer to obviate infiltration of water through hollows or ruts. Initial compaction is confined to that imparted by construction traffic but as the embankment height increases, compaction by rolling is desirable. The risk of failure is considerably reduced by using wide embankments, but economic considerations will dictate formations of approximately 5.5 m in width.

Embankment roads will require depths of fill material from 500 mm to 1000 mm. This results in 3 to 5 m³ of material per linear m of road. In circumstances where large quantities are to be used, lower grade material can be used for the capping layer. This can be surfaced with a good quality finishing material.

Settling in period

As indicated, an extended time of construction is essential for the successful building of embankment roads on sites of low bearing capacity. In addition, the completed road should be allowed to consolidate under its own weight and under management traffic for a considerable amount of time before it is subjected to heavy loading. The surface profile should be maintained as settlement proceeds, preferably by the re-distribution of existing formation material rather than by the addition of further material.



PHOTO 9: Shaping embankment material.

C.3.13 STAGES AND METHOD OF FORMATION - 'REVERSAL' OF EMBANKMENT ROADS

The term 'reversal' more or less describes the method of construction whereby mineral soil is taken from beneath the peat layer and is placed as an embankment on top of the peat. In order to carry out this operation successfully, the peat layer should rarely exceed 2 m depth - otherwise there will be difficulty in obtaining sufficient mineral soil.

The main advantages of this type of construction are as follows:

- ▶ it provides a very cheap method of construction, providing low cost fill on the site as against having to import it;
- ▶ it reduces, if not eliminates, the spoil heaps from the side of the road making timber extraction easier; and
- ▶ it raises the level of the road, enabling it, in wet areas, to be kept above the water table, and also facilitates the run off of surface water.

There are two main methods of reversal road construction and these will be dealt with in greater detail in the following chapter.

- i. Type A, where the road is built on top of the existing ground (sometimes known as Mark I);
- ii. Type B, where all organic matter is removed over the formation width and the road built on the solid (sometimes known as Mark II).

While the second (Type B) method will give a more sound road, there will be greater quantities of peat to be disposed of. For this reason, this method is generally only used on shallower peats.

Basic method

Deep drains are excavated on either or both sides of the road. The excavated peat is first run to spoil. The drain is dug as deep as possible and the excavated mineral material heaped on the formation area and allowed to dry. The drains are then backfilled with the spoil. After the excavated fill has had a chance to dry, it is shaped, graded and rolled.

Depending on the particular site, it may be necessary to operate the excavator on the formation area. In this case, borrow pits are excavated rather than drains.

C.3.14 STAGES AND METHODS OF FORMATION – TRANSITION FROM EXCAVATED TO EMBANKED FORMATIONS

There are many sites where the soil classification will change considerably along the length of the road. In these circumstances it may be necessary to change from an excavated formation to an embankment formation.

The transition will not normally be sudden. It is more normal to commence the embankment on a stripped formation (e.g. Type B reversal) before proceeding to embankment work on undisturbed ground. The length of the transition will depend on the site.

C.3.15 STAGES AND METHODS OF TRACK FORMATION – EXCAVATION OF TRACKS

It should be remembered that tracks are intended to supplement road systems. They should be used in situations where it would be too difficult or too costly to construct a road to the required standards.

It is not normal to surface dress tracks. In fact, they should be avoided if they need surface dressing (i.e. where the sub-grade is of low bearing capacity), since the cost of maintenance would be excessive.

On steep slopes, it is better, where possible, to locate roads on the lower ground and tracks on the higher elevations.

Stages of construction

- i. Strip organic soil/peat over a minimum 4 m wide strip.
- ii. Level and camber sub-grade over a 4 m wide formation. On steep cross slopes, at least 2 m of the track formation width must be dug out of the solid.
- iii. Grade and compact the sub-grade.
- iv. Culvert watercourses as necessary and install 'open top' culverts. These consist of poles, which are separated by a spacer, set into the surface of the formation. They are laid at a gradient of 6% to 7% so as to be self cleaning and are spaced at 20 to 100 m apart (see C.3.7).
- v. Excavate access ramps and slipways as are necessary for harvesting.

Method of construction

The methods employed for track construction are similar to those for road construction except that due to gradient, it may not be possible to use motor-graders or rollers.

C.4 REVERSAL ROADS - GUIDELINES FOR CONSTRUCTION

C.4.1 INTRODUCTION

This method of construction was introduced into Irish forestry in the mid-seventies. The term 'reversal' describes the basic method of construction, which entails taking the mineral soil from beneath the peat layer and placing it as an embankment on top of the peat, thus reversing the natural order of soil strata. This method has been adopted throughout most of the country since then with many variations, adaptations and developments.

The advantages of this type of construction are as follows:

- i. it provides a low cost method of construction, providing fill on the site as against having to import same;
- ii. it reduces, if not eliminates, the spoil heaps from the side of the road, making timber extraction much easier; and
- iii. it raises the level of the road, enabling it, in wet areas, to be kept above the water table, and also facilitates the run off of surface water.

Note: A reversal road must be allowed to settle and dry before completion commences and the construction for reversal roads should be over a 2 year period.



PHOTO 10: *Reversal road construction in progress.*

The reversal system of road construction has developed into two main methods, namely:

- Type A** Where the road is built on top of the existing ground;
- Type B** Where all organic matter is removed over the formation width and the road built on the solid.

C.4.2 TYPE A REVERSAL ROAD CONSTRUCTION

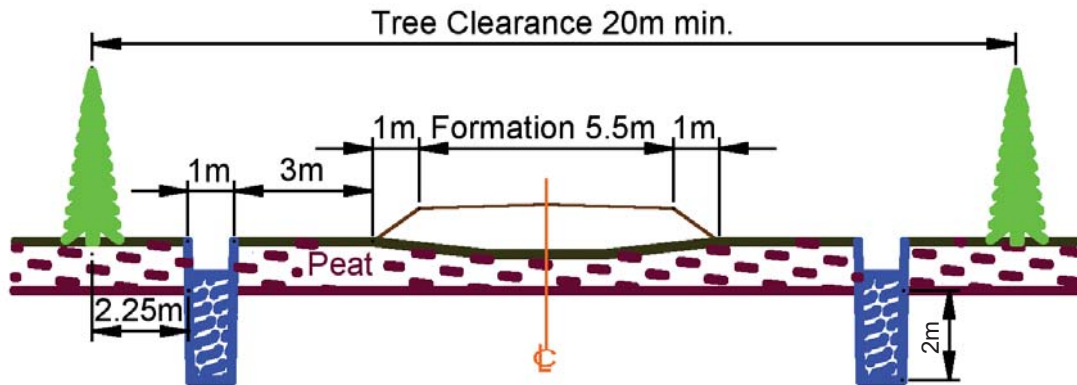


FIGURE 22: Type A reversal road section with double drain.

The minimum dimensions that are required are as follows:

- i. formation width 5.5 m (i.e. top of embankment);
- ii. base width of embankment 7.5 m;
- iii. width from edge of embankment to edge of drains to be not less than the depth of the drain - minimum width 2 m;
- iv. drain width 1 m; and
- v. 2 m from edge of drain to edge of trees.

Therefore the minimum tree-clearance possible is 17.5 m, but to allow for exceeding any of these minimum dimensions for any reason a tree clearance of 20 m is desirable.

C.4.2.1 Type A reversal road formation and drain dimensions

The minimum depth of fill required over the formation width is 700 mm. This is considered to be the minimum requirement to ensure a formation capable of supporting trucks and will ensure that tree stumps and brush are adequately covered, where the road is through an existing crop. Brush is of course left on site.

A quantity of 4 m³ of fill per linear m of road will provide this average minimum depth of 700 mm over a 5.5 m formation. This minimum quantity of fill is obtained by excavating drains 2 m into mineral soil. If any of the mineral soil is not suitable as fill, the drain will need to be deeper and/or wider.

If it is necessary to excavate a wider drain, borrow fill from the tree side of the drain and provide extra tree clearance so as to ensure that there is always at least 2 m between the edge of

the excavation and the edge of the trees; otherwise there is the danger of undermining the fringe trees and this can lead to the onset of windblow.

C.4.2.2 Type A reversal road drainage and extraction traffic

When it is necessary to reduce the water table, the level of back fill (stripped peat, tree stumps, etc.) to drains will be governed by the amount of the reduction required and the fall required to drain the area. Continuous drains are essential to reduce the water table, and roadside drains should be incorporated into the normal forest drainage system to ensure outfall.

Vehicular extraction across narrow drains should not cause any problems, as they are easily bridged. However to facilitate vehicles, a broken drain system can be used with gaps, 5 m wide, being left in the drains opposite the racks; the position of the racks being already decided. Plastic pipes can be used to bridge gaps to provide a continuous drain if necessary. Extra depth when excavating drains will provide the fill required to make up the formation where the gaps occur.

On good mineral sites where it is not necessary to reduce the water table, both drains can be filled in by borrowing material (peat, tree stumps, etc.) from between the drain and the trees. The backfilled drain can often be left in a condition to take vehicles and the resultant track on the far side of drain may facilitate timber extraction traffic. It may be necessary to provide a drain for surface water on this track, and remember that extra tree-clearance will also be necessary.

In cross-slope conditions it may only be necessary to leave the drain on the upper-side open to reduce the water table.

C.4.2.3 Type A reversal road methods of construction

General

A tree-clearance adequate to the dimensions and method of construction is essential, and therefore these decisions must be taken before tree felling commences. The limits of the formation, centre line of drains and limits of excavation beyond drain, where appropriate, should be flagged as a guide to the machine operator. A tracked hydraulic excavator is the machine used; size to be specified by the designer/engineer.

Machine straddling drain

The machine straddling the centre-line of drain, removes the peat or topsoil and tips it to spoil away from the side of the road, continues to dig into mineral to the depth required to give sufficient fill for formation, i.e. at least 2 m³ per linear m; this is spread over half the formation width. Ideally before moving on, disposing of the spoil back into drain and ensuring, where necessary, that a drain is maintained by pushing down spoil with the bucket when backfilling. This will provide a continuous drain on both sides of the road, which will act as subsoil, cut off and surface water drain. The procedure, usually, is for the excavator to travel down one side making half the formation and back the other side completing the formation.

The quality of the mineral soil making up the formation plays an important part in the method of construction:

- i. if the material is a good granular material, such as weathered shale, gravel etc., it can be put out, roughly shaped by excavator, graded and rolled immediately;

- ii. if the material is stiff boulder clay, roughly shape by excavator and leave to dry, if necessary, before grading and rolling;
- iii. if the material is very wet material, heap in centre between drains and leave to dry for up to 12 months. Then spread, shape, grade and compact. It may be necessary to have an excavator reshape the material during the drying period to assist the drying process.

Formation to be finished with a camber of 200 mm to 250 mm as per design standards. For fine grained soils a greater camber may be required.

Excavator working from centre line of formation

On some soft sites or for some other reason it may be preferable to work from the formation rather than straddle the drain with the machine. In such cases the excavator positions itself on the centre line of the road and digs the drain on either side. If the quality of the material excavated is soft it will be deposited behind the excavator. Otherwise it may be tipped in front of the excavator as the machine sits on the fill already placed, thus compacting it as work progresses. The peat or topsoil is disposed of in the drain in the usual way.

This method should give better production as it halves the travelling time in relation to the quantity of material put out, but it does mean wider drains.

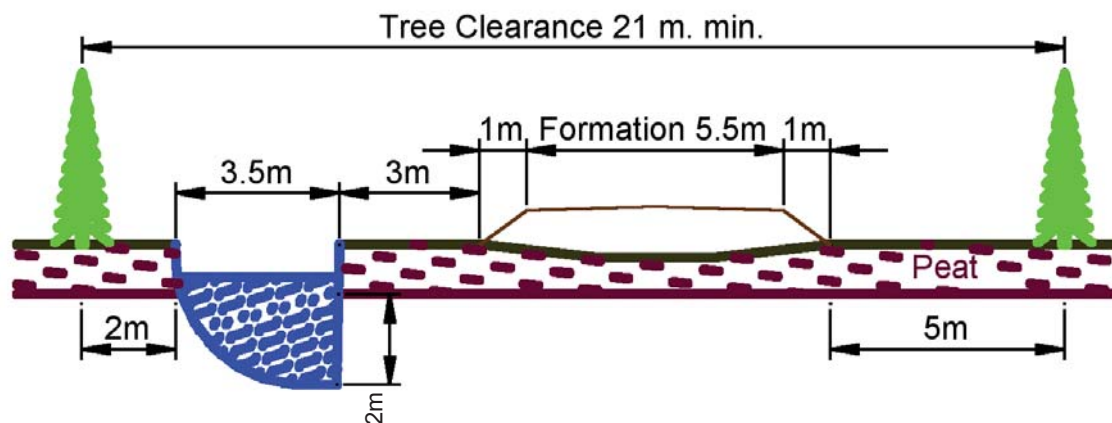


FIGURE 23: Type A reversal road section with single drain.

- i. All dimensions are the minimum required.
- ii. Width of trench will vary with depth of peat and required depth of excavation into mineral. The above is the minimum required for 1 m depth of peat and 5.5 m formation width, when the machine is working from centre line of formation.

Wider drains could prove more of an obstacle to vehicular extraction and may have to be specially bridged, but if the site is unstable, cable extraction may be the only means possible.

As before, any extra excavation on the tree side of the drain will mean an increase in the tree-clearance width so as to ensure that there is always 2 m between the edge of the cutting and trees. The drain, of course, should be located on the most advantageous side of the site.

Single trench method

To reduce movement time for the excavator, a trench on one side of the road should be considered. On sites with poor stability such as the midland peats, borrowing material from one side of the road might be the only solution. In cross slope conditions, especially on wet sites, locating the cutting on the upper side of the road is more advantageous as it will collect any run off from above the road both during and after construction and will tend to reduce the water table where most needed. A wider and/or deeper trench is inevitable and at least 3 m between the edge of trench and toe of formation is essential.

Borrow pit method

This method can be used on sites where there is no drainage problem, and it probably provides easier access for vehicular extraction than any of the other methods of construction. Pits can be opened on both sides of the road on a staggered basis or confined to one side.

Pits both sides

Where pits are opened on both sides of the road they should be approximately 2 m wide. Accepting all the other minimum dimensions already specified this would require a minimum tree-clearance of approximately 20 m. The length of the pits can be tailored to suit the extraction plan, ensuring that there is always a gap opposite a proposed extraction rack. These gaps between pits should be at least 5 m wide and be permanently defined by constructing ramps to the formation using deposited fill. Pits 2 m deep into the mineral will ensure 4 m³ of fill per linear m of the formation. The peat spoil and any other debris, such as stumps, boulders, etc. can be disposed of in the pits.

Pits one side only

When pits are opened on one side only the procedure is the same, except to ensure a spread of 4 m³ per linear m it is necessary to dig the pits deeper and/or wider. The extra depth is more desirable as usually the deeper you go the better the quality of the material. It is very important that the off road access for vehicular extraction be well defined by ramps.

3 x 3 m pits

Instead of using long narrow pits as described in both methods above, the alternative is to use a series of 3 m x 3 m pits between ramps. Thus it is possible to discard the peat spoil directly into the small pits without any danger of it mixing with the mineral soil that is about to be excavated.

Example 1: Calculate the depth required for borrow pits to raise 4 m³ material per linear m of formation

The arrangement shown in Figure 24 would work out as follows:

Every 3 pits would have to provide enough fill for 18 m of formation.

$$= 18 \times 4 \text{ m}^3 \text{ per linear m} = 72 \text{ m}^3$$

Depth each pit would have to be dug into mineral

$$= 72 \div (3 \times 3 \times 3) = 2.67 \text{ m}$$

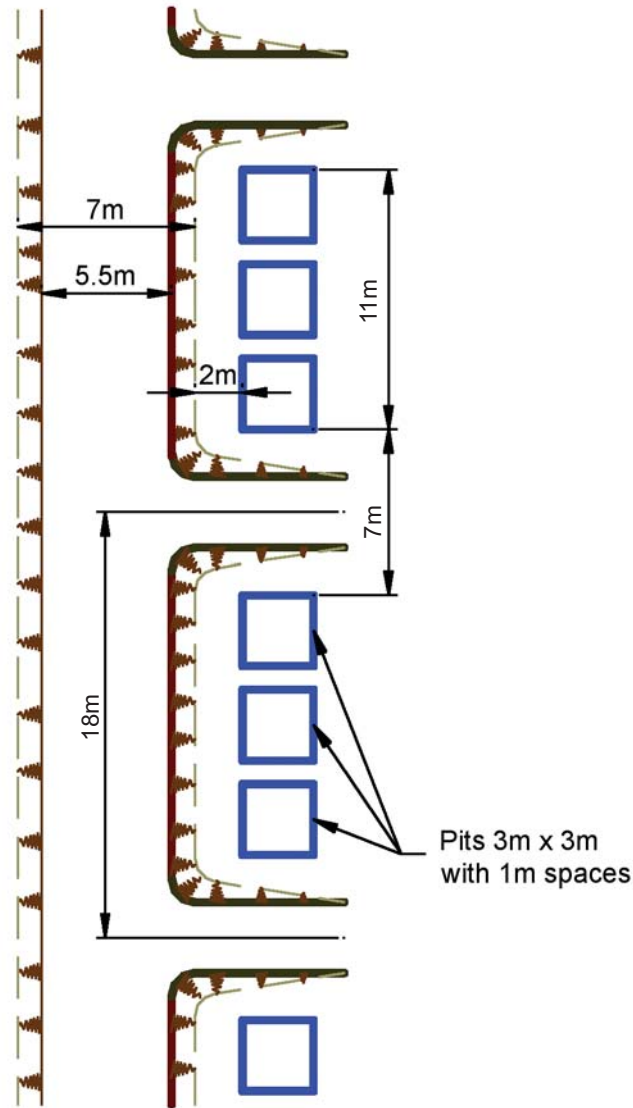


FIGURE 24: Plan of reversal road borrow pits arrangement.

C.4.2.4 Type A reversal road summary

Type A reversal road construction is very suitable for:

- i. Flat sites where there is a drainage problem, because even if it is not possible to reduce the water level, it does raise the formation level above the water table level.
- ii. On peat up to 2 m deep.
- iii. Where excavation of organic soil or peat, especially if the road is passing through growing timber with the subsequent stumps/tree stems/logs to be disposed of, could create a spoil heap which would be an obstacle to timber extraction.

C.4.3 TYPE B REVERSAL ROAD CONSTRUCTION

The main difference between this method and the Type A method, as already described, is that the organic matter is removed over the formation width, and the road built on the solid. This is a basic engineering principle and should result in a sounder road. However, excavation of topsoil over the formation width does create more spoil and, when the road is through an existing crop, tree stumps and brash have also to be disposed of.

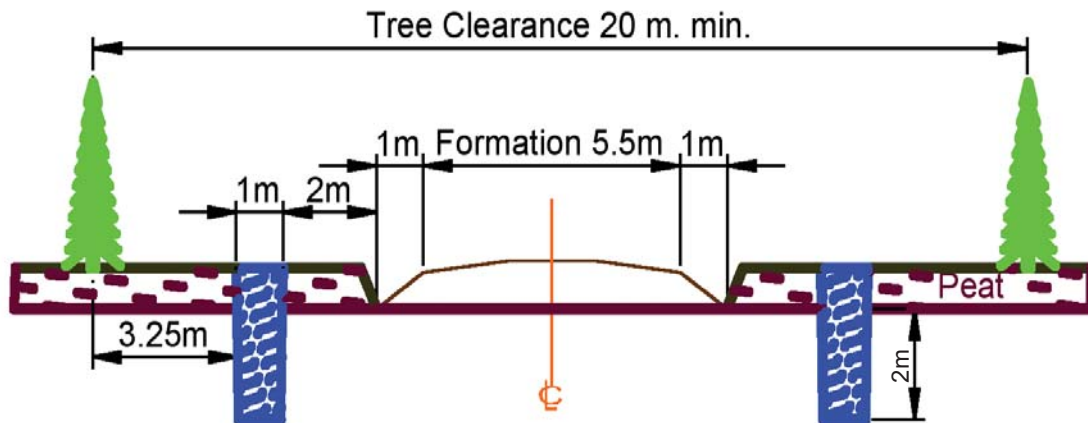


FIGURE 25: Type B reversal road section with double drain.

Formation	Peat stripped off 7.5 m width
	Finished formation 5.5 m wide
Tree Clearance	Minimum required 17.5 m width
	Desirable 20 m width

Depth of peat and formation level

The depth of organic matter to be removed governs the quantity to be removed, and this must also be taken into consideration. Ideally on flat ground or where the road has a flat profile, the formation level should be brought above the adjoining ground level, thus allowing surface water to run off freely and, at least allow for some subsoil drainage.

When the depth of peat is 500 mm or less there should be no problem. Ensuring that the finished formation level is brought even slightly above the adjoining ground level should mean that there is plenty of room to dispose of the peat spoil, and any surplus that might arise due to bulking will quickly become insignificant because of shrinkage or drying out.

Type B reversal roads in cross-slope

Type B reversal road construction is suitable for steeper cross-slopes than Type A reversal roads. The limit of slope is in the region of 1 in 5. On steeper slopes than this the fill required to level up the formation becomes excessive, although a combination of cut and fill plus borrowing of fill can be used.

The big advantage of this type of construction over the ordinary excavated road is that by raising the formation level it reduces the height of the banks, maybe eliminating it on the lower

side and reducing it to a manageable height on the upper side and thus more readily facilitates timber extraction.

Where the excavation is a continuous drain it will be more beneficial if placed above the road.

C.4.3.1 Type B reversal road methods of construction

General

As before, a decision on the method of construction is essential prior to tree clearance to ensure that there is adequate room. The limits of formation to be stripped, centre line of drains, etc., should be pegged out/flagged before construction starts.

Machine straddling of drain

The method is the same as for the Type A reversal roads except that in this case the formation is being stripped of its organic material, which is deposited in the drains. The aim is to keep the finished road level above the adjoining ground level. This becomes more difficult as the depth of peat increases.

Table 8 shows the excavation required per linear m to keep finished formation level at or above existing ground level, taking the minimum depth of fill to formation to be 500 mm.

TABLE 8: Material volumes for Type B reversal roads.

DEPTH OF PEAT	DEPTH OF FILL TO FORMATION	DRAIN WIDTH	DRAIN DEPTH	FILL	SPOIL	AMOUNT OF SPOIL THAT CAN BE ACCOMMODATED IN DRAINS
mm	mm	m	m	m ³	m ³	m ³
150	500	1.0	1.78	3.25	1.43	3.55
300	500	1.0	1.93	3.25	2.85	3.85
500	600	1.0	2.50	4.00	4.75	5.00
700	700	1.0	3.20	5.00	6.65	6.40
1000	1000	1.5	3.30	6.83	10.50	9.90
1250	1250	1.5	4.15	8.70	13.13	12.45
1500	1500	2.0	4.15	10.58	17.75	16.60

Note: Volumes quoted are net amounts per linear m.

Peat depths up to 500 mm

It can be seen from the above table that, ignoring bulking, the drains are well capable of taking the spoil. Brush and stumps will add to the volume and may be a problem in deeper peat. If drains are necessary to reduce the water table, there should be no difficulty in peats up to 300 mm deep.

Peat depths over 500 mm

Volume to be excavated becomes great if the formation level is kept at or near ground level, but there is little surplus spoil. Reducing the finished formation level below ground level will reduce the amount of fill to be excavated, but as the amount of peat spoil remains the same, the surplus spoil increases. Reducing formation levels may cause drainage problems on the road, especially the disposal of surface water.

Single Continuous Drain

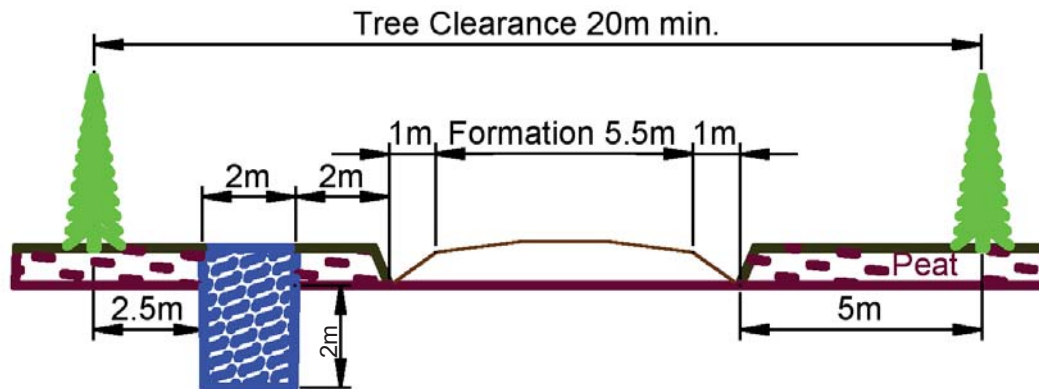


FIGURE 26: Type B reversal road section with single drain.

Formation	Peat stripped off 7.5 m width Finished formation 5.5 m wide
Tree Clearance	Minimum required 19.5 m say 20 m. Wider drain will require wider tree clearance to ensure that there is at least 2 m between edge of the drain and the trees.

Excavation is as before, except that now the fill is all taken from a drain on one side of the formation. To give the required quantity of fill the drain must be twice as wide. The wider continuous drain does present a greater obstacle to vehicular extraction.

TABLE 9: Material volumes for single drain Type B reversal roads.

DEPTH OF PEAT	DEPTH OF FILL TO FORMATION	DRAIN WIDTH	DRAIN DEPTH	FILL	SPOIL	AMOUNT OF SPOIL THAT CAN BE ACCOMMODATED IN DRAINS
mm	mm	m	m	m ³	m ³	m ³
150	500	2.0	1.78	3.25	1.43	3.55
300	500	2.0	1.93	3.25	2.85	3.85
500	600	2.0	2.50	4.00	4.75	5.00
700	700	2.0	3.20	5.00	6.65	6.40
1000	1000	3.0	3.30	6.83	10.50	9.90
1250	1250	3.0	4.15	8.70	13.13	12.45
1500	1500	4.0	4.15	10.58	17.75	16.60

Note: Volumes quoted are net amounts per linear m.

Flat sites using borrow pit method

Layout is the same as shown previously in Figure 24 (i.e. 3 No. 3 m x 3 m pits with 1 m between them and a 7 m gap every 18 m).

Formation	7.5 m stripped of peat. Finished formation 5.5 m.
Tree Clearance	Minimum required 19.5 m.

Fill is excavated from pits on one side of the road. Table 10 shows the excavation required per 18 linear m to keep finished formation level at, or over the existing ground level, taking the minimum depth of fill to formation to be 500 mm.

TABLE 10: Borrow pit volumes (per 18 linear m).

DEPTH OF PEAT	DEPTH OF FILL	DEPTH OF PITS	DEPTH TO WHICH SPOIL WILL FILL PITS	TOTAL FILL REQUIRED	TOTAL SPOIL	SURPLUS SPOIL
mm	mm	m	m	m ³	m ³	m ³
150	500	2.32	0.90	58.50	24.3	Nil
300	500	2.47	1.80	58.50	48.6	Nil
500	600	3.17	3.00	72.00	81.0	Nil
700	700	4.10	(4.20)	90.00	113.4	2.7
1000	1000	5.50	(6.00)	122.94	162.0	13.5
1250	1250	7.00	(7.50)	156.60	202.5	13.5
1500	1500	8.50	(9.00)	190.40	243.0	13.5

Note: Volumes quoted are net amounts per 18 linear m.

Peat depths up to 500 mm

No great difficulty in shallow peat depths except that there will not be sufficient spoil to fill pits and this may prove a hazard to vehicular extraction unless undisturbed gaps between pits are well defined.

Peat depths over 500 mm

The amount of material to be excavated becomes great and the depths of pits excessive, unless it is decided to settle for road levels below the adjoining ground level. This will reduce the amount of fill required and, of course, the depths of the pits, but it will not reduce the amount of peat spoil and therefore the amount of surplus spoil will be greater. This can be heaped over pits and will in fact define the location of same.

In general it is not practical to construct reversal roads Type B on sites that have a peat burden in excess of 2 m.

Cross slopes general

On sloping sites to finish the formation level with the mineral soil on the upper side of the cut will take the following amounts of fill per m run in relation to the given slopes:

TABLE 11: Reversal road fill requirements on sloping sites.

SLOPE	FILL REQUIRED	HEIGHT OF ROAD ABOVE LEVEL OF MINERAL SOIL ON LOWER SIDE
	m ³	m
1:7	3.0	1.07
1:6	3.7	1.25
1:5	5.1	1.50
1:4	7.1	1.90

Note: Calculations done for a free standing embankment with side slopes of 1:1.5.

This fill must be borrowed from a continuous drain or pits located on the lower side of the road. On the steeper slopes some cut and fill within the formation cutting can reduce the amount of fill borrowed.

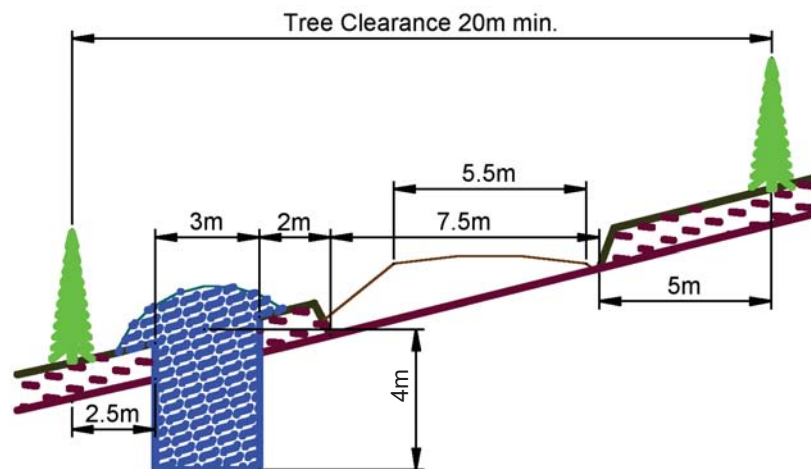


FIGURE 27: Reversal road section on sloping site.

Formation	7.5 m stripped of peat. 5.5 m finished formation width.
Tree Clearance	Minimum 19.5 m.

Example 2: Calculation of surplus spoil for Type B Reversal Road using Borrow Pit Method

Assuming 1 m depth of peat, the calculations over an 18 m length for the borrow pit method are as follows:

Cross slope of 1:5

Stripped formation width = 7.5 m

Finished level of formation = level of mineral soil on upper side of formation

Fill required per linear m for free standing embankment = 5.1 m³

Embankment supported by peat face on lower side, therefore fill required per m can be reduced by 0.5 m³/linear m.

Therefore total fill required over 18 m section = 18(5.1-0.5) = 82.2 m³

This material is taken out of 3 pits, each of 3 m x 3 m plan area

Depth each pit would have to be dug into mineral

= 82.2 ÷ (3 x 3 x 3) ≈ 3 m

(i.e. Pits need to be 4 m deep below ground level)

Peat spoil from 18 m length of formation = 7.5 x 1 x 18 = 135 m³

Peat spoil from pits = 3no. @ 3 x 3 x 1 = 27 m³

Total spoil/18 linear m = 162 m³

Capacity of pits = 3no. @ 3 x 3 x 4 = 108 m³

Implies that surplus spoil = 54 m³

This can be piled over pits leaving at least 5 m gap free of spoil every 18 m.

Example 3: Rework example 2 with narrower stripped formation

Same calculation taking that only 6.5 m is stripped of Peat

Fill required for 18 m length = 3.87 x 18 = 69.66 m³

Depth of pits = 69.66 ÷ (3 x 3 x 3) ≈ 2.6 m

Total depth of pits = 3.6 m

Spoil = 6.5 x 1 x 18 + 27 (spoil from pits) = 144 m³

Capacity of Pits = 3no. @ 3 x 3 x 3.6 = 97.2 m³

Surplus spoil = 144 - 97.2 = 46.8 m³

Example 3 gives an overall saving of 12.5% in the total amount to be excavated while giving the same finished formation width. The saving will not always be as high as 12.5% but the fact that there is a saving in this region would favour cleaning the narrower width especially when the peat is over 500 mm deep.

Peat depths up to 500 mm

On the steeper slopes in shallow peats dozing is probably the most economic method of construction. However on the flatter slopes if there are a lot of stumps, brash and/or boulders to be disposed of, the Type B reversal is preferred.

Peat depths over 500 mm

The deeper the peat and the steeper the slope the greater the excavation involved. The maximum depth of peat for which this method of construction might be used is approximately 1.5 m and the steepest cross-slope 1 in 4 or maybe less. To facilitate vehicular extraction the borrow pit method is preferable to the continuous drain method.

C.4.9 GENERAL OBSERVATIONS (REVERSAL ROADS)

- i. Reversal roads raise the road surface above the formation level ensuring the road is much drier than by other methods of construction.
- ii. The raised road profile over the water table minimises maintenance costs.
- iii. Generally the use of deeply excavated material on the formation substantially reduces the depth of imported material necessary to complete the road and results in major cost savings.
- iv. The reversal method of road construction is very adaptable and each individual site must be treated separately.
- v. In peats up to 2 m deep, the Type A method is the most suitable for flat areas with drainage problems.
- vi. The Type B method, removing all organic matter from the road site, provides a sounder road and therefore should be used whenever possible.
- vii. Both methods facilitate extraction much better than the excavated sunken roads, but care must be taken not to leave undefined pits or wide trenches full of peat which could prove a hazard to off-road vehicles.
- viii. Comparable costs for all the methods described are not available, but they relate to the volume of material handled. However, on average, production data for the machines engaged on this work is in the range from 3 to 7 m of formation per hour. The cost of completing the road will vary with the quality of the material available on the site.
- ix. Reversal roads generally reduce the volume of imported gravel required, thereby effecting cost savings in gravel purchase and in wear and tear of existing forest roads over which gravel is hauled.
- x. Each road site should have its own specification, and the guidelines set out in this document will assist in the drawing up of a specification and the selection of the method for whatever the site conditions might be.

C.5 FOREST ROAD COMPLETION

This is the stage where a formation is treated with a finishing layer of stone to safely transmit vehicle loads to the road formation. Carriageway width is a minimum of 3.4 m and is widened at bends. On embankment roads this minimum width is increased to 4 m for safety reasons.

C.5.1 MAINTENANCE OF FORMATION BEFORE COMPLETION

Completed formations should be carefully maintained and free from rutting prior to completion of the carriageway. The risk of ruts forming is particularly high on clay soils, especially where compaction has been limited to construction machinery. The cause of rutting is normally as a result of the unpaved formation being used by wheeled vehicles. Uncontrolled water can also cause severe rutting in unpaved formations.

Where necessary rutted formations should be re-graded and compacted by rolling prior to surfacing.

C.5.2 FORMATIONS NOT REQUIRING SURFACING

On a minority of sites, the quality of the sub-grade material is such that grading and rolling alone will produce a road of sufficient bearing capacity without the necessity of importing any surfacing material.

C.5.3 TIMING OF SURFACING

Supplying, spreading and compacting surfacing material is usually one of the most costly elements in road construction, particularly where the material is not available on site or close to hand. Accordingly, it is a work area which merits close attention in planning and execution. To achieve maximum economy in the use of material and the best quality finish, it is essential that the formation should be at or close to its optimum moisture content at the time of surfacing. Therefore, surfacing should ideally only be undertaken in dry weather between May and October.

Formations which have become wet should be kept free of traffic and allowed adequate recovery time before surfacing recommences.

C.5.4 MATERIALS

The carriageway pavement will usually be formed in a single layer. On poor formations, costs will sometimes indicate that the use of a low cost readily available sub-base (e.g. shale) metalled with a thin layer of imported good quality material, will be a more economic solution.

The most suitable material for completion is a durable well graded crushed rock. A well graded gravel, with a small percentage of fines to provide bond, is also suitable. Details of the preferred material gradings are given in the appendices.

Occasionally, due to economic reasons or on account of poor county roads, choice will be limited to the best available local material, e.g. pit-run gravel, river shoals, scree, shales or morainic material. However the breakdown of inferior surfacing material will result in very high maintenance costs.

Material must never be taken from an aquatic zone and can only be taken from a buffer zone with the permission of the Regional Fisheries Authority.

Due to the high cost of materials great care must be exercised in selecting from the range available, so that adequate strength is achieved at the least cost per completed m of carriageway - this criterion will not necessarily entail selection of the cheapest material on offer.

C.5.5 DELIVERY

Multi-axle tipper trucks, will usually be used for long haul from outside sources, while dumpers, tractors and trailers and short-body tipper trucks are commonly used for short haul delivery.

Care must be taken to ensure that delivery traffic does not damage the formation. Delivery vehicles must not travel on unsurfaced formations. Loads must not exceed legal limits and in some instances, limitation of loads below legal limits and smaller truck size may be required. Alternatively, material may be delivered to the road head and re-handled in small quantities (e.g. by dumper or tractor and trailer) - this practice, while very undesirable on cost grounds, may be unavoidable particularly in the case of embankment roads.

C.5.6 SPREADING AND COMPACTION

Delivery vehicles will usually achieve partial spreading during load tipping. Full spreading is best done by motor-grader or small dozer but delivery rate must be high if use of these machines is to be economic. However excavators are commonly used and because of their versatility, they are very suitable for this work. Delivery vehicles and spreading machines will partially compact the pavement and a final grading and rolling (variable number of passes) will complete the operation.

Where possible, it is desirable that the delivery, spreading and compaction is completed as a single contract.



PHOTO 11: Delivery of surfacing material.

C.5.7 DEPTH OF SURFACING MATERIAL

The very minimum material depth of a pavement is that required to bear construction traffic but this pavement depth could be very weak and result in heavy maintenance.

The design pavement depth is a function of bearing strength of the formation. The actual depth of pavement may indeed exceed the design depth and the pavement is considered to be completed only when there is no further, visible deformation from continuous compaction.

C.6 FOREST ROAD CONSTRUCTION PROBLEMS

C.6.1 ERODABLE SOILS

All fine grained soils are erodable and this is particularly a problem in drainage channels that have gradients exceeding 5%. Therefore, forest roadside drains with gradients up to 10% are very prone to erosion.

Frequent culverting ensures that water in drains does not reach sufficient velocity to cause major erosion. The spacing and size of culverts must be very carefully planned to minimise the erosion threat.

C.6.2 LOOSE BOULDER

Sloping sites with loose boulders are unsuitable for solely dozer construction as these machines cannot safely handle boulders. Excavators must always be used for the safe movement of boulders. Level benches must be dug out for the stable placement of boulders below the formation level. Boulders above the formation but within the road reserve should also be removed and placed safely below the formation.

C.6.3 LANDSLIDES/MUDSLIDES

Landslides/mudslides may occur on sloping sites where the soil is saturated (or almost liquid in state). When excavated material is placed on a saturated soil the additional burden from the embankment formed/spoil heap may be sufficient to cause a landslide.

Road construction on steep sites should be stopped if the cutting at the upper side of the formation starts flowing onto the formation, as this is a good indication of a saturated soil.

Where roads have to be constructed in locations prone to landslips, the construction should be delayed until periods of sustained good weather. Also excavated material should be removed from the site.

C.6.4 CLOSURE OF ROADS DURING THE CONSTRUCTION PHASE

Road closure normally arises as a result of periods of prolonged, heavy rainfall.

- ▶ Formation works may have to be suspended if there is a risk of landslides as the road is formed.
- ▶ Dozers on formation work cannot shape or camber formations that are saturated and work must cease until the weather improves.

- ▶ Capping layer construction may have to cease after heavy rainfall as the layer may become saturated and the material can slurry and behave as a liquid.
- ▶ Completion of pavements may have to be suspended in wet weather if the sub grade is saturated. Continuing to complete the road in poor weather conditions results in extra pavement material.
- ▶ Road construction must cease when pavement or formation material is entering watercourses and should only be resumed following mitigation measures to prevent environmental damage.
- ▶ Roads must be closed following an accident on site and the area cordoned off until sanction is given by the Health and Safety Authority (HSA).
- ▶ If any archaeological site is discovered on the roadway then operations should cease until an archaeological investigation is complete.

C.7 CONSTRUCTION MATERIALS/GRAVEL/CRUSHED STONE

The materials used in forest road pavements generally can be classified under the National Roads Authority (NRA) guidelines for sub bases. The materials in the guidelines, with the exception of wet mix macadam which can be used in road repairs, will be suitable as pavements.

The materials set out in these guidelines are for bound roads and it is wise for the designer of unbound forest roads to use materials on the finer side of the grading envelopes to minimise the permeability of the pavement as the formation or sub grade must be kept as dry as possible to ensure maximum strength and to prevent degradation of the formation.

The surface material of an unbound pavement must be durable under traffic and weathering, well graded and mechanically stable.

Variations in pavement design are necessary in sustained periods of wet weather and under very wet conditions uniform single sized 75 mm crushed stone is laid as a pavement and is dressed with quarry maintenance to prevent ingress of water.

It is not advisable to undertake completion works in inclement weather because the road uses more material in the pavement and a macadam road is very difficult to profile without a significant depth of maintenance dressing.

C.7.1 IMPORTED MATERIALS

The most common quarried materials suitable for pavements in Ireland are limestones and certain sandstones. Other commonly quarried materials are quartzite, schist, gneiss and igneous deposits such as reolites and gabbros.

Glacial gravels, in the main from eskers, form the sub bases of the existing road network in Ireland and graded gravels form good pavements. Gravels from eskers must only be taken from Local Authority approved pits.

The cost of importing NRA specification materials is very expensive and the designer should consider raising local material to reduce the pavement costs.

Gravel should not be obtained from river beds as completion material except in cases where permission and a licence have both been obtained from the relevant fisheries authorities.

C.7.2 USE OF A COMBINATION OF LOCAL AND IMPORTED MATERIALS

The deeper the required pavement the more necessary it is to consider a capping layer of local material and a completion layer of NRA specification material.

In practical terms pavement depths exceeding 350 mm should be considered for a capping layer.

C.7.3 COMMONLY USED LOCAL MATERIALS IN FOREST ROAD PAVEMENTS

The most commonly used local materials in forest road pavements are shales, schists, sandstones, gravels and glacial drift material from drumlins and moraines.

While most of those aggregates perform well as a capping layer and are suitable when covered by a sub base of NRA specification material they should not form a pavement alone unless they pass certain Soil Mechanics tests.

Under no circumstances should material contain more than 6% plastic fines (clays/organic material).

Standard specifications are included in the appendices.

C.7.4 SOIL TESTS COMMONLY USED FOR LOCAL PAVEMENT MATERIALS

The following tests are easily undertaken in a soils laboratory and determine the suitability of materials as a sub base.

Atterberg limits

This test determines the state of the soil with changes in moisture content.

Soils that exhibit plasticity are not suitable because of their compressibility and soils with a high liquid limit are also not suitable because of their retention of water and the resultant build up of pore water pressure in the sub base.

Water absorption value (WAV) test

This test determines the percentage of water absorbed by a rock. The higher the WAV the more the rock is subject to weathering.

Particle size distribution and flakiness index test

The particle size distribution determines the grading of the material and its mechanical stability. The flakiness index gives an indication of how the stone particles disintegrate under loading.

Soaked aggregate impact or crushing value test

This test determines the strength of the material when the pavement is saturated.

Procedures and details of the above tests can be found in most soil mechanics text books.

Certain minimum criteria have to be reached in the above tests to determine the suitability of the local materials as a pavement completion material. It is recommended that these tests should be undertaken on all major forest road projects.

If the pavement depth of embankment roads on peat is of the order of 700 to 800 mm, then it is advisable to use local material on a prepared fascine formation as a base layer to reduce the pavement cost. This can then be finished with a thin layer of higher quality imported material.

In most cases in forest road engineering it is neither economically feasible nor practicable to have soil mechanics laboratory tests on all soils and it is important to be able to identify soils by basic field tests.

C.7.5 SOIL IDENTIFICATION AND BASIC FIELD TESTS

Engineers allocate soils into different groups having relatively the same behaviour. This grouping of soils is called soil classification. The most common form of soil classification is the CasaGrande and C.P. 2001 (British Standard code of practice) which concentrate on the Atterberg limit tests and the particle size distribution tests.

Gravels vary in size from 2 mm to 200 mm.

Sands vary from 63 μm to 2 mm and silts and clays that are at the limits of visibility without magnification must be identified in the field by feeling them.

Coarse sands are sharp and gritty when rubbed between the hands.

Finer sands are smoother to rub than coarse sands.

Silts are very fine smooth material.

Clays are greasy and are sticky to feel. Clays that are plastic can be kneaded into a ball rolled between the hands to form a sausage shape without crumbling.

Organic soils and peat are easily distinguished by their odour, by their compressibility and their dark brown, black or grey- black colour.

A dilatancy test is used to distinguish fine sands, silts and clays. A sample of material 25 mm round by 5 - 8 mm thick, wet enough to have a soft consistency, is formed into a pat on an open palm of the hand. The palm is held horizontal and slapped underneath by the other hand several times. If the pat is a silt or fine sand then water will come to the surface, the material will have a livery appearance. The water will recede into the pat again on squeezing with the fingers and the pat dulls, stiffens and crumbles. If the pat is composed of clay then the surface of the pat will not change during the test.

C.7.6 WATER TABLE IN SOILS

The water table in soils is the level to which water rises in a borehole in the soil. The water table indicates the level of saturation of the soil in coarse-grained soils. In fine grained silts and sands the soil may be saturated at a higher level due to capillary action. The crown of the road formation should be at least 300 mm above the winter water table to ensure the pavement and formation are never saturated.

A well-drained road is a good road. The strength of a pavement can be reduced by half, if saturated.

Adequate drainage and a well-cambered formation are vital elements to forming a durable pavement.

C.7.7 THE COST OF RAISING AND SPREADING LOCAL MATERIALS

The cost of raising and spreading local material takes account of the following factors:

- i. The overburden on the quarry.
- ii. The access road cost from the quarry to the forest road site.
- iii. The machine type and cost necessary to dig the parent material.
- iv. The time for loading and unloading the tractor units.
- v. The delays arising from culvert installation.
- vi. The haul distance to the road site and the logistics of increasing the tractor haulage units as the haul distance increases.
- vii. The volume of material required per m of road.
- viii. The ease and the cost of creating loading bays to avoid bottlenecks in the transportation cycle of the material.
- ix. The ability of the excavator or dozer spreading the material to shape and compact the pavement between loads.
- x. Due allowance has to be given to inclement weather which may cause slurring of the quarried material and force a stoppage of the transportation.
- xi. Extra materials may be required to finally shape the capping layer for the completion layer because of rutting.
- xii. The cost per hour of the spreading machine.
- xiii. The cost per hour of tractor unit. The average speed of the tractor units and the volume that can be transported per unit.

Generally the rate of spread and compaction of the material determines how many tractor units can be employed gainfully. It is normally assumed that 20 m³ per hour can be laid satisfactorily.

Where a rock breaker, ripper or blasting is necessary in the quarry then the quarried material should be excavated prior to the road completion.

The construction of forest roads using local materials should be undertaken during dry weather conditions, and preferably during the summer period.

Example:

A capping layer 500 mm deep is required on 1.5 km of proposed road. The embankment road formation 5.5 m wide has been prepared for the capping layer. The pit of glacial gravel is 2 km from the head of the road. Find the cost of constructing the capping layer.

It is decided that an extra 200 m of road will be constructed in the form of passing/turning bays to ensure minimum delays in transportation.

Since there is no problem in quarrying the material the speed of the operation is determined by the placing of the raised material, which cannot exceed 20 m³ per hour.

The total volume of material necessary for the embankment assuming the weather is dry is 5,560 m³. And the time to complete the work is 278 hours.

Using 50hp tractor units and 4 m³ trailers, 5 minutes loading and 5 minutes unloading and an average speed of 15 km per hour then the average haul distance is 2.75 km and the average cycle time is 19 minutes.

The cost of stripping the pit is €1,000.

There is a requirement for 2 Excavators @ €30 per hour and 2 Tractors units @ €20 per hour. The total cost per hour is €100.

The total cost of the work is 278 times 100 plus 1000 = €28,800.

This represents a cost of €16.94 per m road or a cost of € 5.18 per m³.

C.7.8 PAVEMENT DEPTHS

It is important to have knowledge of soils and drainage to determine the required depth of pavement on any formation or sub grade and even experienced practitioners can err when insufficient tests have been undertaken.

Without good knowledge of soils the pavement depth will be estimated as that necessary to carry the construction traffic. This is not a good practice as the road may need further strengthening at a later stage.

The necessity of constructing a pavement is to dissipate the wheel loads onto the formation or foundation and to ensure the foundation does not fail under the reduced stresses transmitted to it. The wheel load spreads on a 2 to 1 slope over the pavement depth and obviously the deeper the pavement is, the less stress is produced on the formation. On very wet peat and organic sites, pavement depths greater than 1 m can cause failure from the dead weight of the pavement because of the very weak nature of the peat.

The California Bearing Ratio (CBR) test is the laboratory test on soils to determine the bearing strength and is widely used on major road designs. This test compares the deformation of the soil under loading to the deformation of a standard road material and the ratio expressed as a percentage can be used to determine the design pavement depth necessary over any sub-grade. There is a relationship between the CBR, the Moisture Condition Value (MCV) test and the shear strength test of any soil and those two tests when operated in the field give a very accurate on site CBR. The great advantage of on-site testing is the material is not too disturbed and the moisture content of the soil is representative of the road formation.

CBR, MCV and shear strength test procedures are available in most soil mechanics text books.

The importance of a well-drained formation cannot be over emphasised and indeed the drainage must remain intact for the total lifespan of the road.

C.7.9 TYPICAL PAVEMENT DEPTHS FOR FOREST ROADS

TABLE 12: Typical pavement depths for forest roads.

FORMATION	WELL DRAINED* CBR	DEPTH OF MATERIAL mm	POORLY DRAINED CBR	DEPTH OF MATERIAL mm
Heavy Clay	2 to 3	550	1 to 2	750
Silty Clay	5	400	3	500
Sandy Clay	6 to 7	330	4 to 5	425
Silt	2	600	1	750
Sand (roughly graded)	20	200	10	250
Sand (well graded)	40	200	15	225
Sandy Gravel	60	200	20	200
Weathered Rock	60	200	60	200

* A well drained site is one where the watertable is more than 600 mm below formation level.

C.7.10 COMPACTION OF SOILS

The pavement must be compacted in layers to achieve maximum densification of the soil. This occurs with the expulsion of air voids. Every material has a moisture content called the optimum moisture content which gives the highest dry density and the designer should aim to compact the soil at this moisture content. This optimum moisture content can vary between 3 to 4.5 % for wet mix macadam material and 10 to 15% for sandy clays.

In forest road construction it is very difficult to ensure the moisture content of the pavement material is at an optimum. In our climate the moisture content is almost always a little higher than optimum. In normal summer conditions the pavement materials will approach optimum values. Only in exceptionally dry weather will material require additional water before compaction. However, in sustained wet periods it may be necessary to postpone pavement construction until the materials dry.

The pavement is compacted in layers not exceeding 3 times the largest size aggregate in the pavement. The compaction effort increases as the number of passes by the roller increases and usually after 5 passes deformation ceases and the pavement exhibits linear elastic properties as the pavement flexes under load.

Normally a 3 to 5 tonne vibratory roller is used for compaction but on pavements over peat it is wise to test the pavement with the roller static before vibrating it.

C.8 QUARRIES, PITS AND SPOIL DISPOSAL AREAS

It is normal practice in forest road construction to use fill material excavated elsewhere on the forest owner's property. Consultation with the Local Authority is necessary in respect of planning obligations before opening a quarry or pit.

Spoil disposal areas are less common in forest road making as surplus spoil is normally levelled off alongside the road. Whenever it is necessary to draw material from a forest road site, it must be ensured that the spoil disposal area will not cause damage to the environment. Run off and sediment loss will most likely be the largest problems encountered.

All quarries, borrow pits, and spoil disposal areas must be planned and designed to minimise:

- ▶ soil erosion;
- ▶ mass soil movement;
- ▶ water quality deterioration; and
- ▶ visual impact.

When no longer required, these areas must be rehabilitated.

C.8.1 GUIDELINES

Location

1. All rock quarries, gravel pits and borrow pits should be located at least 50 m from aquatic zones to minimise the potential damage to stream and riparian values.
2. Spoil disposal areas should be located where the risk of soil erosion, mass soil movement and water quality deterioration is minimal and must also be at least 50 m from aquatic zones.

Drainage

3. During construction and use of rock quarries, gravel pits or borrow pits, run-off water is to be discharged into buffer zones. Where run-off is concentrated it must pass through one or more silt traps sufficient to prevent run-off being directly discharged into streams or drainage lines.

Rehabilitation

4. All gravel pits and borrow pits should be used so as to enable progressive rehabilitation in accordance with the staged depletion of the material.
5. When the gravel source is either exhausted or abandoned, rehabilitation must be completed within two years.
6. Rehabilitation should include:
 - ▶ removal of all rubbish or litter;
 - ▶ ripping of compacted areas;
 - ▶ grading of slopes;
 - ▶ spreading of previously stockpiled topsoil; and

- ▶ revegetating with suitable species.
7. Care shall be taken in restoring a site to minimise danger from overhangs, loose rock and waste material heaps.



PHOTO 12: Roadside quarry.



PHOTO 13: Forest pit.

These activities involve the movement of sizable quantities of material. This results in considerable ground disturbance and as a consequence, large volumes of silt and fine materials can be washed out by rainfall runoff. This washing out effect will be considerably worsened if the work interferes with a drainage channel or watercourse. It is therefore essential that water is carefully controlled during these activities.

Quarries, pits and spoil disposal areas can visually impact on the landscape. To minimise this impact, select locations that are as unobtrusive as possible and rehabilitate the areas as soon as possible. Remember not to depend solely on the shelter of trees as these may ultimately be felled.

C.9 EMBANKMENTS

Embankments, if not properly constructed can cause serious problems and can constitute a safety hazard. Forest produce, being of relatively low value, does not provide sufficient funding for the employment of technologically advanced embankment construction methods. Embankments therefore must be constructed in shallow layers, each compacted by construction machinery before the next layer is commenced. Side slopes must also have gentle, self-containing batter angles.

C.9.1 GUIDELINES

1. Fills and embankments should be consolidated and stabilised using currently accepted engineering practices.
2. The side-slope of embankments should be the natural angle of repose of the material, usually of the order of 1 vertical unit to 1.5 horizontal units.
3. All faces and slopes requiring stabilisation and drainage to be treated prior to the removal of equipment from the site. Stabilisation can be achieved or assisted by:
 - ▶ appropriate sloping, to prevent slippage into roadside drains;
 - ▶ stepping (benching) wherever suitable (essential when vertical height exceeds 6 m);
 - ▶ revegetating/bio engineering where either the embankment exceeds 2 m height or the soil is highly erodable;
 - ▶ forming interceptor drains above embankment slope to minimise erosion as appropriate; and
 - ▶ using retaining walls or other engineering structures, as necessary.

Note: The slopes of cuttings may require similar stabilisation practices.

C.9.2 CONSTRUCTION METHOD

Where the time scale permits, embankment roads on peat should be built up slowly over several years. (On mineral sites an extended time of construction, while beneficial, is not as crucial to success). This approach, allied to periodic attention to lateral drains, will allow for maximum strength gain in both base and formation; ensure a better profile and minimise the risk for failure under eventual heavy loading. Rapid raising of embankments to full height may result in foundation failure. To avoid damage to the site, material should be delivered in small quantities and spread on the formation in shallow layers. Only sufficient material to carry construction

traffic should be used in the first instance. The embankment can be further strengthened, gradually, by the addition of further layers of material. It is important to keep a cambered profile on each successive layer to obviate infiltration of water through hollows or ruts. Initial compaction is confined to that imparted by construction traffic but as an embankment height increases, compaction by rolling is desirable. The risk of failure is considerably reduced by using wide embankments, but economic considerations will dictate formations approximately 5.5 m wide.

Embankment roads will require depths of fill material from 500 to 1000 mm. This results in 3 to 5 m³ of material per linear m of road. In circumstances where large quantities are to be used, lower grade material should be used for the capping layer. This can be surfaced with a good quality finishing material.

C.9.3 SETTling IN PERIOD

As indicated, an extended time of construction is essential to the successful building of embankment roads on sites of low bearing capacity. In addition, the completed road should be allowed to consolidate under its own weight and under management traffic for at least a year before it is subjected to heavy loading. The surface profile should be maintained as settlement proceeds, preferably by the re-distribution of existing formation material rather than by the addition of further material.

C.10 ACCESS TO FOREST ROADS (FROM FOREST)

Good access to the forest from forest roads is essential. However this access must be carefully planned and provided in order to ensure there is no risk to the environment or to the integrity of the road. Provision must be made for extraction vehicles to enter and leave the forest but at the same time the use of forest roads by such vehicles must be kept to a minimum. Well planned access and good control will result in minimal (if any) disruption of the road drainage network and will also minimise sediment deposit on the road.

C.10.1 LEVELLING OF SPOIL BANKS

As far as possible high obstructive spoil banks are to be avoided. They should be levelled over verges where they will provide useful timber stacking/processing ground. Gaps should be pushed through at regular intervals as required to facilitate off-road access (say 30 to 100 m intervals).

C.10.2 DRAIN CROSSINGS

Wherever possible, long continuous road side drains should be avoided. These drains should be outfalled to sediment traps/buffer zones whenever possible. A short distance of roadside (say 5 to 10 m) should then be left unexcavated before commencing the next section of drain. This unexcavated length can be used for machinery access.

In circumstances where it is not possible to outfall the roadside drain, for machinery access, then it will be necessary to construct a culvert on the drain. It is now more normal that this access culvert will be temporary – constructed when access is required and removed when extraction is complete. It is common to use a single length of corrugated steel pipe or strong plastic pipe, surrounded in timber poles, for these culverts.

C.10.3 ACCESS RAMPS ON STEEP SITES

In the course of formation work, ramps should be provided from the formation to higher verges, to facilitate off-road vehicles. The ramps should be at reasonably frequent intervals (say 100 m) and advantage should be taken at local low spots in the excavation. On longitudinal road gradients, access ramps should be located just below run off culverts.

Access ramps should be excavated out of the solid bank and not constructed with fill material. A gradient of approximately 1 in 5 will be adequate on ramps.

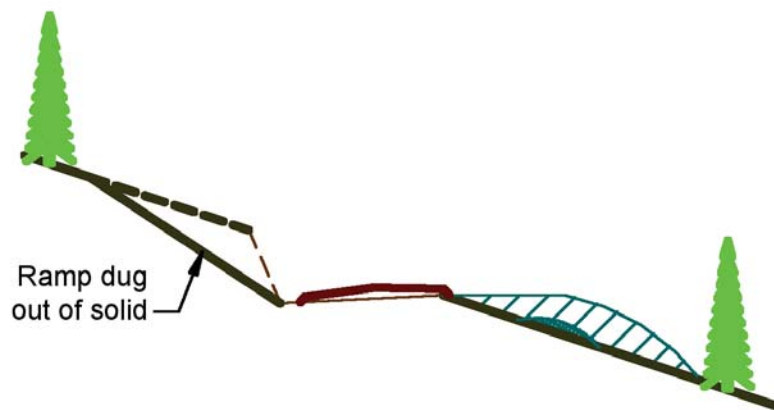


FIGURE 28: Section showing ramp location.

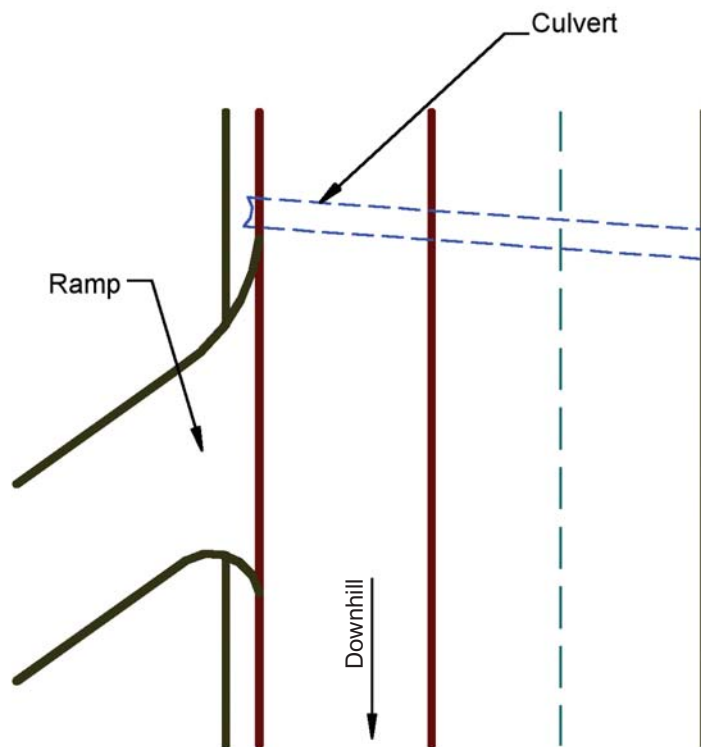


FIGURE 29: Plan showing ramp location.

C.10.4 LOG STEPS

Whenever extraction racks become deeply rutted, there is a need to place log steps across these racks as they approach the road. The purpose of these log steps is to knock mud and muck off the machines before they enter the road reserve. This helps reduce the volume of material that could be washed into the drainage system.

C.10.5 DRAINAGE CONTROL ON SLOPING SITES

It can happen that extraction racks act as channels for surface water flows on sloping sites. For this reason it is very important that water flows are controlled on these routes to prevent drainage flowing onto the forest road system. This control can readily be achieved by providing small cuttings or ramps at right angles to the travel direction, across the racks at regular intervals. The rack run off should never be directly into a watercourse but should avail of a buffer zone.

C.10.6 ROADSIDE DRAINAGE DAMAGE

Damaged or blocked roadside drains can raise the water table resulting in a serious weakening of the road. This leads to severe destruction to the road structure requiring expensive repair. It is therefore necessary to ensure that all harvesting and haulage machinery do not impede roadside drainage.

C.10.7 HARVEST VEHICLES ON ROADS

By their very nature, harvest vehicles are very aggressive on forest roads. This results in surface damage and higher road repair costs. In severe cases the road damage can be excessive enough to hinder timber haulage by trucks.

Harvest vehicles operating on forest roads often bring considerable muck and debris onto the road (whenever control measures are not being properly implemented). This muck and debris can pose a threat to water quality and can also be a hindrance to road vehicles, particularly management vehicles.

Wherever possible, harvest machinery should operate along the verges and roadside banks so as to minimise their impact on the road.

C.11 STREAMS AND WATER CROSSINGS

When constructing forest roads it is not possible to always avoid stream and water crossings. Where crossings are essential, Forest Service guidelines on water must be observed. Regional Fisheries Boards must be consulted before proceeding with work and Local Authorities may also need to be consulted.

Stream and watercourse crossings by bridge, culvert or ford must be designed to meet transport needs and minimise impacts on the site. Relevant approvals must also be obtained.

Health and safety is also a serious concern and for crossing structures exceeding 1.2 m² waterway area, competent designers and contractors must be used.

C.11.1 GUIDELINES

- ▶ The crossing used in any particular situation should be determined by the nature, size and period of flow and characteristics of the bed and banks of the stream and the road classification.
- ▶ All roadside drains, culvert drains and other drainage structures should be installed concurrently with the formation of the road. Sections of partially constructed road to be left over winter or for other extended periods are to be drained by outsloping or cross drains.
- ▶ Competent designers and contractors must be used for larger crossing structures.

Construction operations must ensure that:

1. Disturbance to the stream bed and banks is kept to a minimum.
2. Fill is not pushed into streams, nor into a position from which it can move into a stream.
3. Cement and raw concrete are not spilt into watercourses.
4. Where practicable, stream crossings should be adequately elevated and low approaches maintained such that water drains away from the crossing point.

Culverts

5. Culverts are to be of a size adequate to carry expected peak flows. They should be installed to conform wherever possible to the natural slope and alignment of the stream or drainage line.
6. Culverts greater than 1 m diameter should be buried to a depth of 300 mm or 20% of their height (whichever is greater) below the streambed and the original bed material placed in the bottom of the culvert.
7. Culverts are to be spaced depending on road gradient and susceptibility of sub-grade to erosion.

Bridges

8. Bridges are to be constructed for crossings of streams and watercourses where culverts or fords are not considered adequate. Bridge design should allow for a 1 in 25 year peak flood.
9. Bridges must not constrict clearly defined channels and must be designed and constructed so that the passage of flood water is not restricted.

Fords

10. Fords are not desirable and should only be used when the design has been approved by the Regional Fisheries Board.
11. Fords are to be as wide as the crossing will allow, so that peak flows are well dispersed. The base of the ford should be constructed of erosion-resistant material such as rock or concrete and shall conform to the natural level of the stream bed.

Excavations and embankments

12. Excavations for bridges and placement of abutments or bearings must, as far as practicable, be made above the high water mark.
13. Earth embankments constructed for bridge approaches must be protected from erosion by one or more of the following:
 - ▶ revegetation with naturally-seeded vegetation;
 - ▶ planted or sown grasses or ground cover;
 - ▶ retaining walls, bulkheads or rock surfacing.
14. Topsoil should be stockpiled in a manner suitable for re-distribution during site rehabilitation.

C.11.2 ESTIMATION OF WATERWAY AREAS

In order to ensure that an appropriately sized structure is constructed, the required waterway area must be estimated. This section is intended to give guidance on this procedure but as stated previously, all design and construction work for crossing structures exceeding 1.2 m² waterway area, must be carried out by competent designers and contractors.

The maximum discharge of a given stream will depend on:

- ▶ catchment area (i.e. land area contributing to the stream);
- ▶ rainfall intensity and duration; and
- ▶ the time of concentration for the catchment (which depends on the nature of the area's surface conditions and slope and is a function of what is usually called the Run-off Factor). Flat, heavily vegetated areas will tend to have long times of concentration especially if the soil is permeable and not already saturated. These areas will require rainfall of long duration or high frequency to reach maximum discharge in outfall streams. Steep, bare, impermeable catchments will have very low times of concentration and outfall streams will be subject to flash floods during high rainfall intensity of quite moderate duration.

The methods of estimating probable waterway area required are:

- ▶ where a well-defined channel exists reasonably close to the culvert or bridge location evidence of previous flood flows may be present and the cross-sectional area at that level can be measured.
- ▶ old culverts on the same stream will yield valuable evidence.
- ▶ there are several theoretical methods of varying complexity. The Talbot formula, which is one of the simplest to use, gives a reasonable degree of accuracy when catchment areas (less than 2,000 ha) are carefully measured and the appropriate value is given to the co-efficient.

This formula is: $A = 0.184 C (M)^{0.75}$

where: A = Waterway Area (m^2)
 M = Catchment Area (ha)
 C = A co-efficient varying from 0.125 (flat retentive sites) to 0.5 (steep impermeable areas)

The values $C = 0.125$ or 0.25 suit the majority of sites.

For convenience this formula is given in chart form in Figure 30.

The use of both direct measurement and theoretical methods of computation for the given situation is recommended as a double check. When the waterway is calculated the appropriate size culvert or bridge opening can be selected.

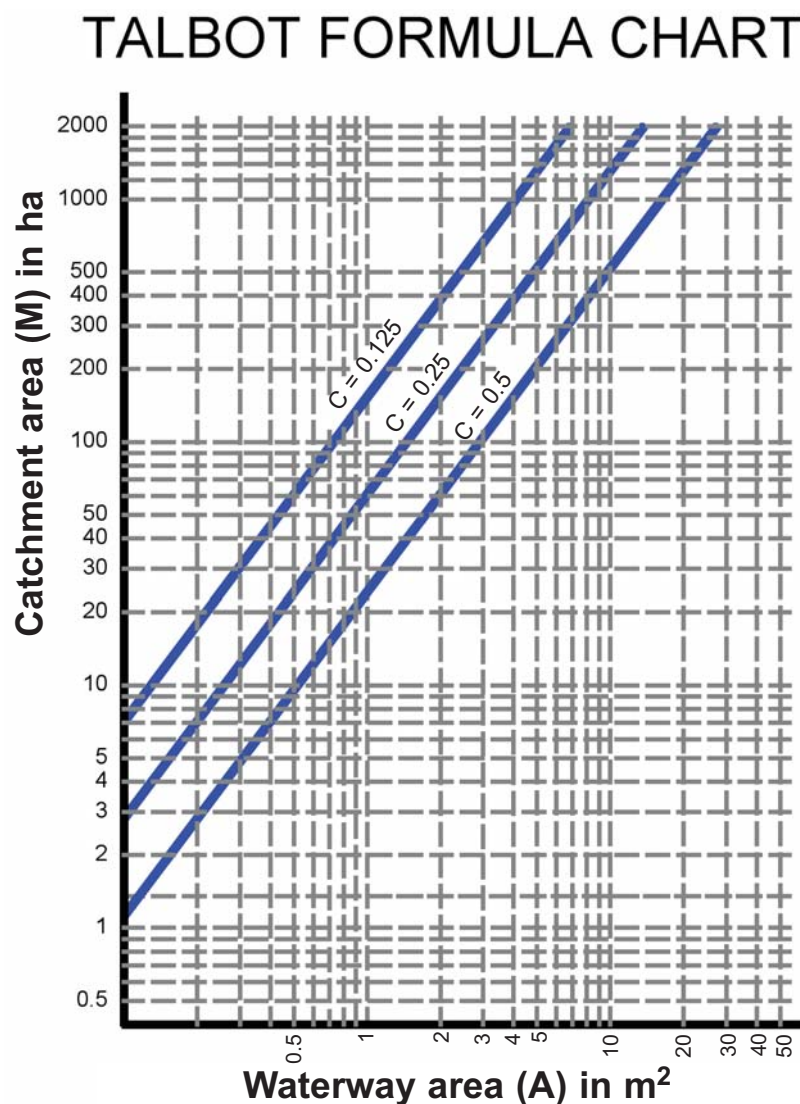


FIGURE 30: Talbot formula chart for waterway area estimation.

Note: A table of values based on the Talbot Formula is included in the appendices.

TABLE 13: Cross sectional areas of pipes.

PIPE DIAMETER mm (inches)	CROSS SECTIONAL AREA	
	(SQUARE METRES)	(SQUARE FEET)
225 (9)	0.04	0.43
300 (12)	0.07	0.76
450 (18)	0.16	1.71
600 (24)	0.28	3.04
750 (30)	0.44	4.75
900 (36)	0.71	7.61
1050 (42)	0.87	9.32
1200 (48)	1.13	12.17

Note: Allow for 20% of pipe height to be buried in stream bed.

C.11.3 CULVERTS TYPES

Culverts are usually constructed using circular pipes. Concrete pipes are most frequently used as they are readily available throughout the country in a range of diameters and are more economic for smaller diameters. Culverts up to 750 mm diameter can be constructed using un-reinforced concrete pipes. Above this diameter, it is necessary to use reinforced concrete pipes which are more expensive. Concrete pipes are heavy and fragile and care must be exercised in their handling and placement.

High density polyethylene plastic pipes (HDPE) are beginning to find favour in forest roadworks as they are much easier to handle due to their lighter weights. The ease of handling is a major safety benefit and can outweigh their additional cost over concrete pipes. There is a range of diameters available. Above 1200 mm diameter, pipes normally have to be ordered from the manufacturers.

Corrugated steel pipes are another type of pipe used in forest roadworks. They are most frequently used for larger diameter culverts as they are available in diameters up to 3.0 m. Like HDPE pipes, larger diameters normally have to be ordered from the manufacturer.

Corrugated steel pipes are intermediate in weight between plastic and concrete pipes and for larger diameters are cheaper than plastic. Another advantage they have over plastic pipes is that they are less susceptible to damage.

Pipe arches (non circular shapes) are sometimes used in place of large diameter culverts. These will normally be in the form of shaped corrugated steel plates assembled and bolted together on site to form the pipe. They will normally have an almost flat base and circular crown.

C.11.4 CULVERT CONSTRUCTION IN MINERAL SOIL SITES

Trenches for culverts are to be cut true to line and to an even grade -generally parallel to the natural grade where there is an existing stream. Where formation work is being done by an excavator, this can be employed.

Trench width should be a minimum of 400 mm wider than the external pipe diameter but they should still be confined in width to minimise the impact of backfill on the structure. Trench depth, where pipes are not to be surrounded with concrete, should be such as to give minimum cover of 300 mm plus the diameter of pipe being used.

Trench beds should be of uniform fine-grained material and the presence of rock, large stones or anything which would give a point bearing is not permitted.

Pipes should be carefully placed onto the trench bed. Short length concrete pipes will be butted together and no jointing material used. Other types of pipe will be jointed to the supplier's specifications.

Appropriate backfill material is to be carefully rammed around and over the pipes, care being taken to exclude large stones in the fill immediately near the pipes. Corrugated steel and plastic pipes require graded granular material which must be very well compacted to manufacturer's specifications. Good quality excavated material can normally be used for backfilling concrete pipes.

Concrete seal walls and aprons should be provided at inlets and outlets of culverts where there is a danger of erosion. Boulders may be an acceptable alternative if water volumes and associated culvert sizes are small.

C.11.5 CULVERTS LARGER THAN 750 MM DIAMETER

Structures such as these require the attention of competent practitioners.

Where culvert size is 750 mm diameter or greater, consideration should be given to use of alternatives, such as reinforced concrete pipes, steel pipes or HDPE pipes. In case of **unreinforced concrete pipes** of 750 mm diameter or greater, the pipes shall be bedded on a concrete bed, 150 mm thick, and a further 150 mm of concrete placed as haunching and surround to the pipe.

Culverts in peat sites

Where possible peat should be fully excavated and mineral back-fill carefully compacted to bring the trench bed up to bed level prior to laying of the culvert. Construction otherwise is as for Mineral Soil Sites. Difficult situations where full excavation is not feasible may require the use of a raft of timber poles under the pipes.

C.11.6 CULVERT LENGTHS

Length = 1 m for each m width of formation
+ 1 m for each 250 mm of cover at centre of formation.

Note: Minimum length for any culvert should be 6 m.

C.11.7 EFFECTIVE CULVERT SPACING

The effectiveness of culverts depends very much on their correct spacing. In order to keep them functioning effectively, proper maintenance is also important, especially for 'open top' culverts.

The spacing of culverts depends mainly on the gradient of the road, the amount of rainfall, the steepness of the terrain and the soil conditions. In a watershed forest in steep terrain with high

rainfall, the proposed spacing (in m) of culverts is derived from

$$800 \div \text{Percentage Gradient}$$

However, in areas with heavy rainfall and large catchment areas, a shorter spacing may be required, especially on roads with a 9% (1 in 11) gradient or steeper. The correct spacing of culverts may however be worked out through experience.

Table 14 should serve as a guideline.

TABLE 14: *Culvert spacing guideline.*

ROAD GRADIENT IN PERCENT	800/GRADIENT	SUGGESTED SPACING IN STEEP TERRAIN WITH HEAVY RAINFALL
	m	m
5	160	80
6	130	65
7	114	55
8	100	45
9	88	40
10	80	35
11	72	30
12	66	20 - 30

Note: Culverts should be placed above and below superelevated sections of road.

C.11.8 BRIDGES

Bridges must always be designed by competent practitioners and constructed by expert contractors. International standards and codes (e.g. BS 5400) must be observed and as an example, design live loadings for forest bridges are shown in Table 15.

Traditionally, forestry bridges were normally constructed using timber beams and timber decking supported on mass concrete walls. Timber bridges require high maintenance and usually have a relatively short life span. It is now more normal to use precast concrete beams supported on reinforced concrete abutments, finished with a deck of *in situ* concrete. Other common bridge types in forestry are reinforced concrete slabs or steel universal beams with timber decks. For safety reasons, handrails are now a necessity on all bridges.



PHOTO 14: Concrete beam forest bridge.

TABLE 15: Design live loads for bridges.

SPAN m	HIGHWAY AUTHORITY UNIFORM DISTRIBUTED LOAD kN/m
3.0	160.9
3.5	145.1
4.0	132.7
4.5	122.6
5.0	114.3
5.5	107.2
6.0	101.2
6.5	95.9
7.0	91.2
7.5	87.1
8.0	83.4

Note: The above table gives HA loading per m length of lane. These loads would be spread over a number of beams.

C.11.9 FORDS

Fords are flattened sections of river bed which permit water flow over them and allow vehicles to travel safely through the normal flow. They can be used for shallow flat crossings but only where approval has been obtained from the local Regional Fisheries Board Inspector.

- ▶ They are only safe up to a water flow depth of 150 mm.

- ▶ Ford sites should be located at wide river sections where evidence of erosion of the river bed is minimal.
- ▶ The ford site should be capable of containing flood waters from a 25 year peak flood.
- ▶ The surface level of the ford should not change from the original river bed level as a raised ford level causes serious scouring downstream.
- ▶ Ford aprons should be at least 5 m wide and the ramps from the forest road down to the apron should not exceed 8%.
- ▶ The ford designer must protect the structure against wear back from the change in the flow pattern of the stream.
- ▶ The most common fords constructed are concrete, reinforced concrete and masonry.
- ▶ Fords should be designed by competent practitioners.

It is advisable to provide depth markers, guides, kerbs, signs, etc, to reduce the risk of accidents and by not permitting their use when the water is too deep.

Fords should not be used except where crossings are infrequent, say less than five in any day. They have many disadvantages:

- ▶ They can easily introduce pollution to the watercourse.
- ▶ Vehicle wheels will carry mud into the water.
- ▶ It is difficult to minimise the road drainage flowing into the water course because the approach roads must descend into the crossing.
- ▶ Occasional high water flows will make fords dangerous.
- ▶ Regular inspection of fords after storms is essential because of the structural damage risk.

It is therefore inadvisable to construct fords unless the timber volumes are small and the cost of a more expensive structure is not feasible.

C.11.10 IRISH BRIDGES

Irish bridges are suitable for crossings in ravine locations where they are located on bedrock with little likelihood of erosion. Until the 1950s, Irish bridges were constructed as a set of stone culverts with a stone paved overlay. Modern Irish bridges are a set of parallel culverts (300 to 900 mm diameter) laid across a stream. They are normally bedded and surrounded in concrete and then overlaid with a dished concrete slab.

The culverts of an Irish bridge will carry normal dry weather flows but in heavy flows, the river will flow over the dished slab.

Disadvantages with Irish bridges

- ▶ Because of small pipes they can become blocked. This can cause erosion and the changing of a river course because of the damming effect.
- ▶ If used, care must be taken to prevent scour and erosion on the downstream side. This requires a professional engineering design.

- ▶ When water flows over the slab and exceeds 150 mm depth, the Irish bridge should not be used by traffic.

Irish bridges are rarely used nowadays as their disadvantages usually outweigh their benefits.

C.12 ROAD CURVES, JUNCTIONS, PASSING AND TURNING PLACES

Road curves, junctions, passing and turning places are forest road features that require special attention. Each will have minimum geometric properties which must be achieved if the road is to perform its intended function.

C.12.1 GUIDELINES

1. Road curves, junctions, passing and turning places are to be designed and constructed to facilitate safe and efficient use of the roading network.

Curves

2. The minimum standard radius of curvature is 20 m (measured from the road centre line) except for the edges of bellmouths.
3. A radius greater than 20 m should be utilised whenever possible, subject to physical and economic constraints.
4. Formation and carriageway widths are to be widened at curves to allow for vehicle 'track-in'.

Passing places

5. Passing places should be provided by widening of the carriageway at intervals of approximately 300 m.

Turning places

6. Turning places are to be provided at or near the end of cul-de-sac roads. These should take the form of:
 - A circle, of 12 m radius; or
 - A T-junction, similar to a standard bell-mouth, the leg of the T being at least 30 m long.
7. Additional turning areas should be provided on very long stretches of junctionless road.

Road junctions

8. All road junctions both within the forest and from the forest to the county road should wherever possible be of right-angled, bell-mouth design.

9. Skew junctions should only be used where it is not practical to construct a right-angled, bell-mouth junction.
10. Local Authorities should be contacted at the road planning stage whenever a junction from the forest to the county road is planned.

C.12.2 ROAD CURVES

The minimum standard radius of curvature is 20 m and a larger radius should be employed where physical and economic constraints so permit. In difficult situations it may not always be feasible to make a standard curve but in large forest blocks and where cross slope is not a problem, it should usually be possible to avoid the use of hairpin bends.

C.12.3 EXTRA WIDENING AT CURVES

Formations and carriageways need to be widened at curves so as to allow for vehicle 'track in'. Tables showing extra widening requirements are included in the appendices.

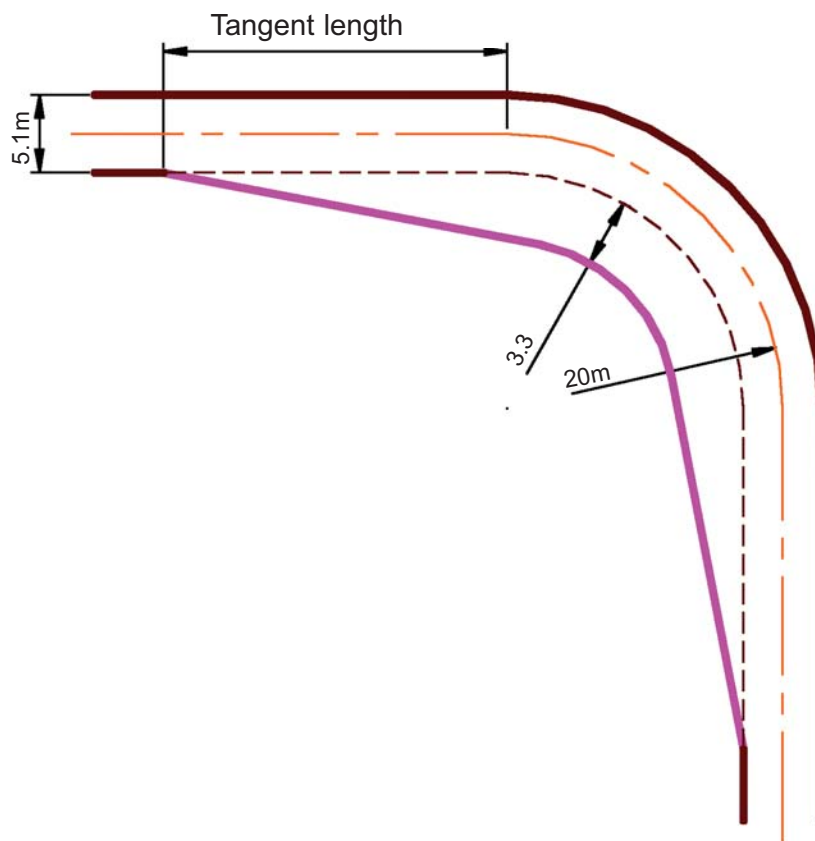


FIGURE 31: Plan view of curve widening.

C.12.4 ROAD JUNCTION

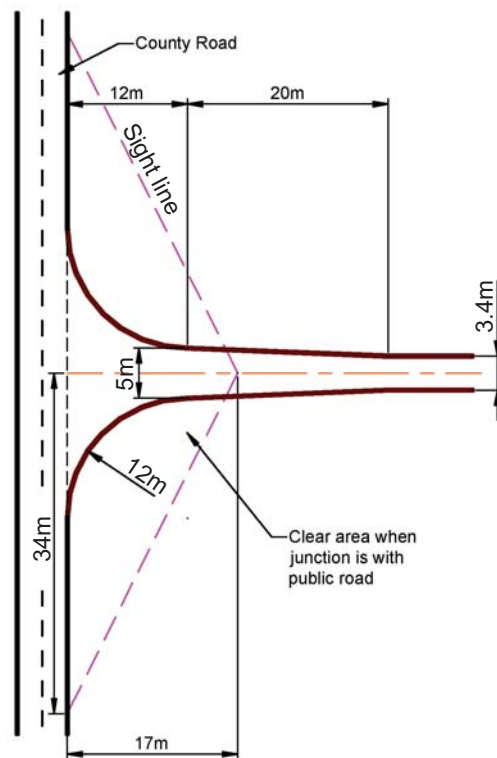


FIGURE 32: Plan view of typical road junction.

Where conditions permit all road junctions should be right-angled, bell-mouth type as shown in Figure 32. Skew junctions of type shown on Figure 33 may be used otherwise. Junctions with public roads may require planning permission.



PHOTO 15: Forest road/public road junction.

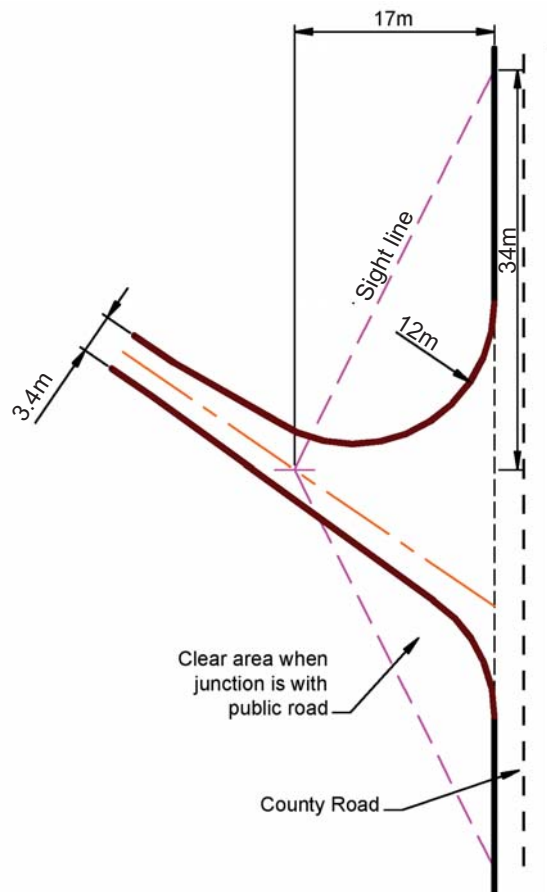


FIGURE 33: Plan view of typical road skew junction.

C.12.5 PASSING PLACES

Passing places are similar to longitudinal loading bays and are obtained by widening the road an additional 4 m for approximately 20 m length at intervals of about 300 m.

It will not usually be necessary to provide special passing places on excavated roadways where formation widths will be such that widening of the carriageway at intervals will be sufficient. Fortuitous extra widening, such as at borrow pits and junctions, will also serve as passing places.

On embankment roads passing places should be provided where turning places for construction traffic have to be constructed.

C.12.6 TURNING PLACES

Turning places must be provided at or near the end of cul-de-sac roads. Turning places can take the form of a circle, approximately 12 m radius, or a T-junction similar to a standard bell-mouth, the leg of the T being at least 30 m long. It is desirable to place the leg of the T to the right hand side of the road from the direction of access so that when a lorry is reversing the driver can have a clear sight of the leg being turned into.

Careful attention to selection of turning places at layout stage will usually give a satisfactory result but ad-hoc solutions may be required on difficult sites.

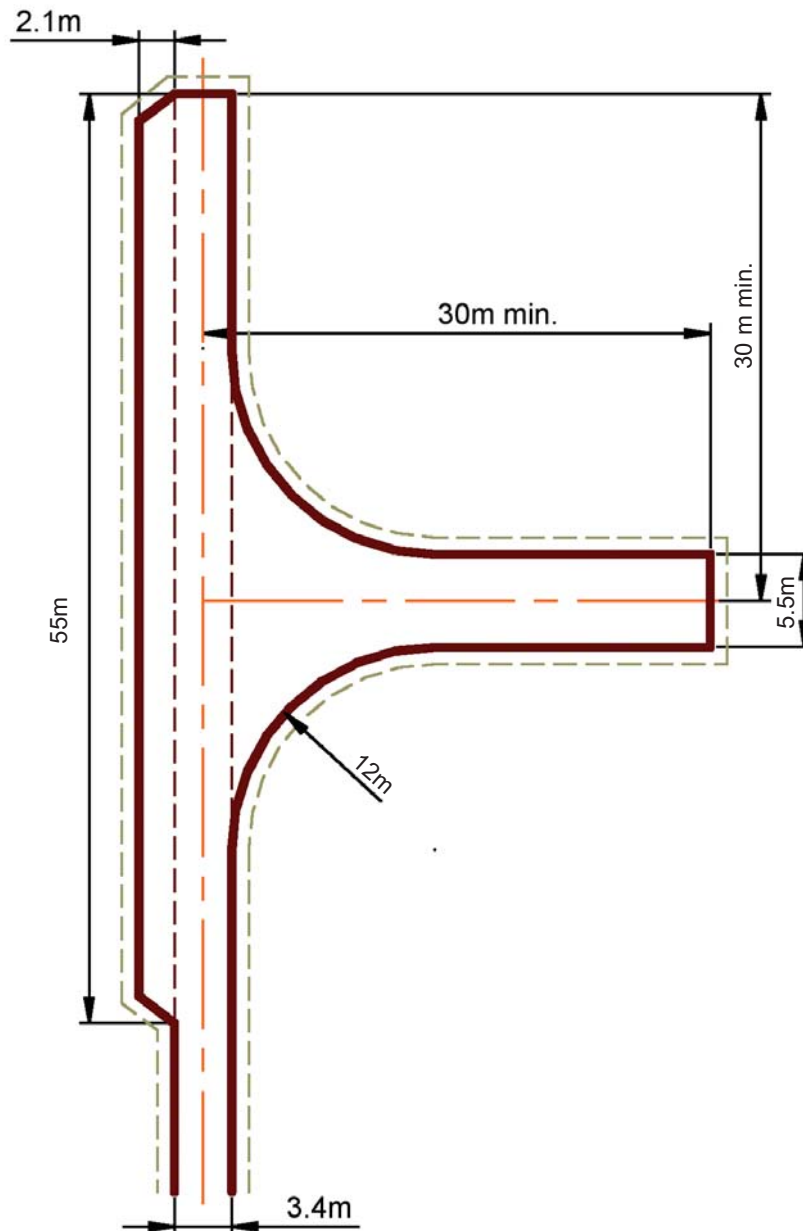


FIGURE 34: Plan view of T type turning area.

C.13 INTERACTION WITH PUBLIC ROADS

Forest road networks must eventually join the public (county) road network. These intersections most frequently occur along minor, and often substandard, public roads.

The public roads are the responsibility of the Local Authorities and the National Roads Authority. It is important for forest managers to ensure that adequate consultation takes place between themselves and the Local Authorities Engineers.

Great care must be exercised to ensure that the forest business makes the least impact possible on the public road network. Junctions must be of the highest standard possible and all forest activities, other than timber and materials transport, kept off the public road.

C.13.1 GUIDELINES

1. Forest road facilities should be located so that minimal lengths of substandard public roads are used in so far as practically possible.
2. The number of forest entrances should be kept to a minimum.
3. Forest road entrances must be provided with adequate drains and culverts.
4. Forest road drainage must be kept within the confines of the site.
5. Pull-in lay bays (longitudinal loading bays) on public roads should not be provided, except where unavoidable.
6. Forest owners/managers/agents must liaise with Local Authority staff about principal activities and main developments.
7. Harvest operations and timber loading must never take place on a public road.

C.13.2 PUBLIC ROAD DAMAGE

Under the Roads Act 1993 it is an offence in specific circumstances to damage a public road. Those held liable for damage to public road could be liable to both the cost of reinstatement and a fine. The best course of action is to avoid situations where conflict will arise. When assessing the suitability of a county road for the haulage of timber the following points may be of benefit:

- ▶ if there is any sign of pavement deflection or deformation then it is likely that there will be problems;
- ▶ any sign of transverse (across the road) cracking on the road surface may indicate a weak sub-grade. This again may lead to problems;
- ▶ any sign of longitudinal cracking (along) the road may indicate very serious potential problems. This is particularly so if there are deep roadside drains present. In this situation the road should not be used until examined and passed fit by an engineer;
- ▶ a public road that has no obvious drainage and is prone to flooding is likely to cause serious problems.

In all of these circumstances it is advisable to consult with the Local Authority in advance of any timber movement.

C.13.3 PUBLIC ROADSIDE DRAINAGE

It is essential that all public roadside drainage is kept clear during construction (and use) of forest roads. Section 73 of the Roads Act 1993 makes it an offence to obstruct public roadside drainage.

C.13.4 JUNCTIONS

Junctions between forest roads and public roads require the highest of standards and clear sight lines are very important. Sight distances can be in the order of 90 m for national routes and 70 m for regional roads.

Unfortunately, due to site constraints, not every forest property can be provided with a top quality exit onto a public road and so special care must be taken to minimise the hazards caused in these cases.

It is advisable to discuss the location and layout of forest road/public road junctions with the Local Authority Area Engineer before proceeding with the work.

C.13.5 FOREST ACTIVITY

It is necessary to adopt the best standards of practice in respect to the use of public roads. The key points of this practice are:

- ▶ public roads must not be used by extraction equipment;
- ▶ public roads must not be used for the handling, stacking or loading of timber; and
- ▶ public roads are to be used solely for the transport of timber.

A good motto to adopt is 'Keep Forestry in the Forest'.

Note: The entire area between the road fences (including carriageway, hard shoulders, grass verges and road drains) is considered as the public road.

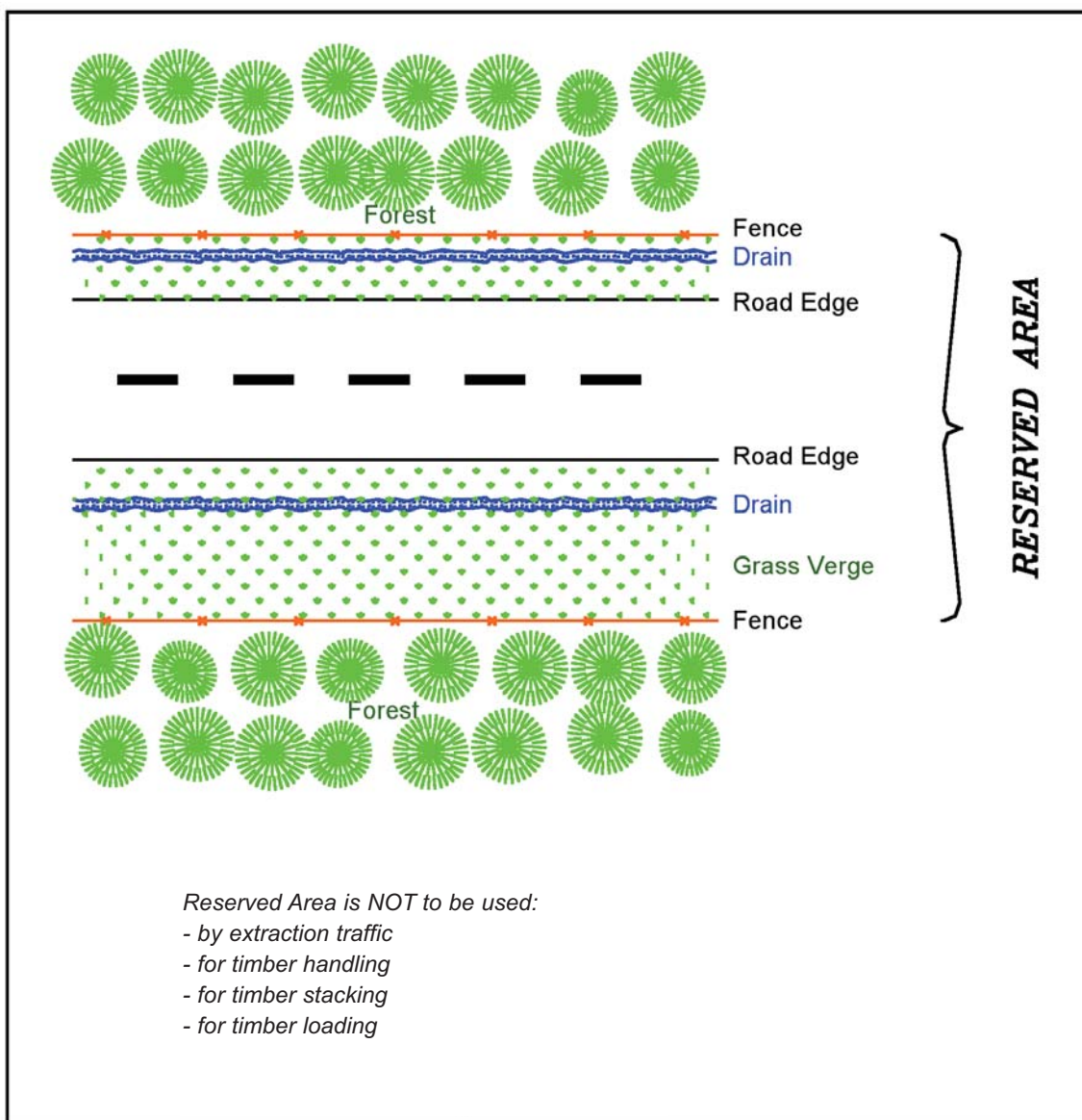


FIGURE 35: Care of public roads.

C.14 LOADING BAYS ALONG PUBLIC ROADS

Loading bays along public roads should only be constructed whenever it would otherwise be uneconomical to construct a forest road within the property. This usually occurs on account of difficult ground conditions or for small pockets of otherwise inaccessible timber. However, if at all possible, loading bays on public roads should be avoided.

C.14.1 GUIDELINES

1. Loading bays must be constructed to promote safe and efficient loading practices and minimise interference with public roads and users of same. The precise layout of the loading bay will depend on the site characteristics.
2. Local Authorities should be contacted at the road planning stage whenever a loading bay adjoining or exiting onto the public road is planned.
3. Where site conditions and construction considerations permit, loading bays should be of either:
 - widened loading bay with turning area; or
 - back in type loading bay.
4. Longitudinal loading bays immediately adjoining the public road are the least favoured and should only be constructed having explored other types.
5. Care should be taken to screen loading bays from public view in as far as is practical.
6. Particular attention should be given to avoiding damage to and fouling of roads and ancillary drains, culverts etc. either in the construction or subsequent use of loading bays.

C.14.2 LOADING BAYS

There are three types of recognised loading bays:

- ▶ a drive in loading bay (loading bay with internal turning area);
- ▶ a back in loading bay;
- ▶ a longitudinal loading bay.

The preferred choice is a drive in loading bay followed then by a back in loading bay. Longitudinal loading bays are the least favoured type and due to safety concerns, should never be used on public roads unless there is absolutely no other reasonable alternative.

Longitudinal loading bays should consist of a hard-standing for trucks with adjoining cleared stacking ground. The metalled area must not be less than 20 m long by 5 m deep with additional allowance for the truck to sweep in and out.

Particular attention should be directed to the elimination of damage to and fouling of the roads and ancillary drains, culverts etc. either in the construction or subsequent use of loading bays.

Typical loading bays are illustrated in Figure 36.

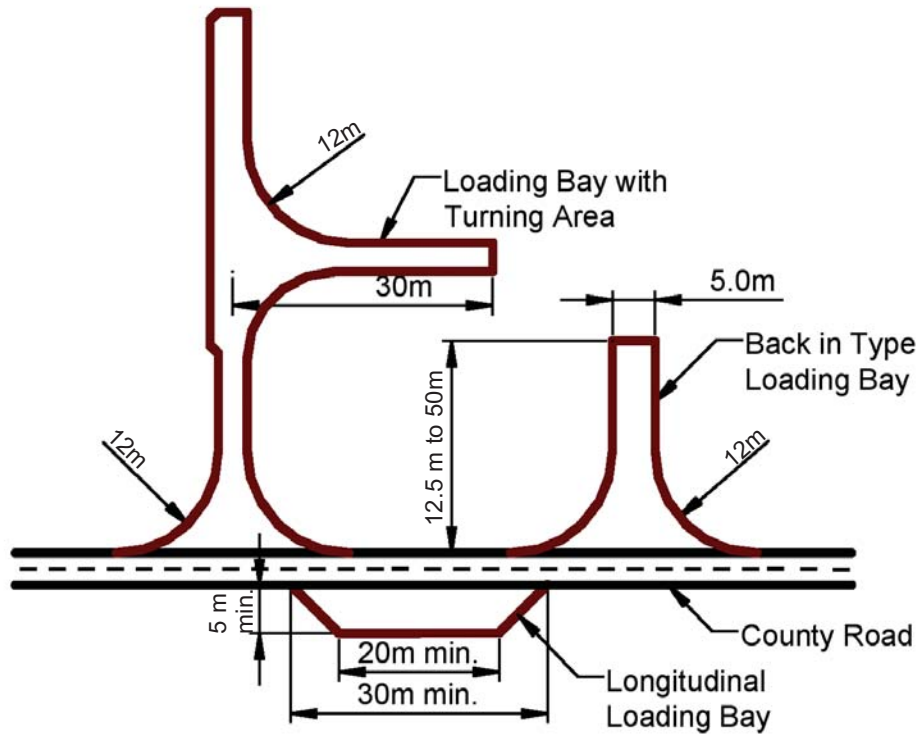


FIGURE 36: Typical loading bays.



PHOTO 16: Drive in loading bay with internal turning area.



PHOTO 17: *Back in type loading bay.*

Section D: Management of Forest Roads

D.1 ROAD UPGRADING

Road upgrading is a major operation on an existing road to ensure it is capable of timber haulage. The purpose of this operation is to bring a currently substandard road up to full standard.



PHOTO 18: Resurfaced road upgrade.

Work may be considered as road upgrade when:

- ▶ the formation or carriageway has to be widened; or
- ▶ the entire carriageway has to be substantially sheeted with material (as distinct from patched); or
- ▶ a new drainage system and/or a significant number of new culverts has to be installed.

The cost of upgrading roads is substantial and is generally 30 to 70% that of constructing a new road on the same site.

D.1.1 GUIDELINES

The guidelines and standards for new road formation and completion work apply equally to road upgrade work.

D.1.2 RECOGNISING THE NEED FOR ROAD UPGRADE

The following tables serve as guidance in recognising the need for road upgrade.

The most common deficiencies occurring in forest roads can be grouped under three main headings: **Structural**, **Geometric** and **Harvesting**.

TABLE 16: Structural road deficiencies.

Structural

	DEFICIENCY	RESULTS	INDICATIVE SIGNS
1.	Lack of or inadequate camber. Standard camber: 100 mm (minimum)	No surface water run-off. Water ponding on road surface.	Severe rutting when subjected to extraction traffic during wet weather. Erosion of road surface along sloping roads after heavy rainfall.
2.	Lack of or inadequate roadside drains.	High water table during wet weather. Lowering of bearing and shear strength of sub-grade.	Severe rutting when subjected to extraction traffic during wet weather.
3.	Inadequate culverting.	Erosion of road edges and possibly erosion of road surface.	Scouring of road sides and/or road surface.
4.	Insufficient thickness of surfacing material.	Failure of sub-grade when subjected to heavy loads.	Severe rutting when subjected to extraction traffic.
5.	Poor quality road surfacing material.	Breakdown of surfacing material from the action of traffic, frost and rain.	Severe rutting of road surface.
6.	Spoil windrow on downhill side of formation.	Surface water run-off obstructed.	Erosion of road surface.

TABLE 17: Geometric road deficiencies.**Geometric**

	DEFICIENCY	RESULTS	INDICATIVE SIGNS
1.	Inadequate tree clearance. Standard: 15 m (minimum).	Road shielded from sunlight and sheltered from drying winds, formation unable to dry out resulting in a reduction in the bearing capacity and shear strength of the sub-grade.	Severe rutting in clay soils and severe rutting and pot-holing in mineral soils when subjected to extraction traffic.
2.	Inadequate road width. Standard formation width -5.5 m (minimum). Standard carriageway width -3.4 m (minimum).	Inadequate surfaced width and possible lack of roadside drains.	Severe rutting on either side of surfaced carriageway especially at bends and corners.
3.	Steep gradients Standards:- Straights - 1 in 10 (maximum) Curves - 1 in 12 (maximum)	Excessive road surface wear. Greater likelihood of damage from surface water.	Trucks encountering difficulties. Wheel spin. Rutting.
4.	Poor alignment/tight bends. Standard radius - 20 m (minimum).	Ravelling of road surface and rutting at road edges.	Truck rear wheels leave road surface and rut limits of formation and banks.

TABLE 18: Harvesting road deficiencies.**Harvesting**

	DEFICIENCY	RESULTS	INDICATIVE SIGNS
1.	Spoil embankments along roadsides.	Difficulty in gaining access to forest and inability of keeping extraction plant off road.	Damage to drains, road formation and road surface with spoil from embankment and damage to road surface from extraction plant.
2.	Lack of turning areas.	Traffic required to travel great distances to turn causing unnecessary travel and putting unnecessary pressure on road.	
3.	Inadequate stacking areas.	Timber stacked on roadside.	Severe rutting on opposite side of formation.

D.2 ROAD MAINTENANCE AND REPAIR

Good practice in forest road maintenance and repair is essential to:

- ▶ protect the road foundation;
- ▶ disperse water;
- ▶ minimise environmental impact; and
- ▶ optimise return from the expenditure invested in the road network.

D.2.1 GUIDELINES

1. Roads are to be inspected on a regular basis.
2. Roads are to be maintained as necessary to minimise erosion of the road surface. The

surface of roads should be cambered, and any windrows of soil on the outside of the road be regularly breached, except where they have been intentionally constructed for the protection of fills.

3. Road drainage systems are to be maintained to protect the road from erosion and to minimise discharge of turbid waters into streams.
4. Vegetation beside roads should, where necessary, be controlled to improve visibility for drivers and prevent vegetation invading the road surface or blocking roadside drains.
5. All trees which fall onto or across roads are to be removed as soon as possible.
6. Roads should be assigned a regular maintenance schedule prioritising, according to risk, the need for maintenance and reduction of potential adverse environmental impact.
7. All forest drains must be cleared of lop and top during harvesting operations to ensure that watercourses are not redirected as this can result in serious damage to roads.

D.2.2 DISTINCTION BETWEEN REPAIR, MAINTENANCE AND UPGRADE

It is important to distinguish between repairs and maintenance, which are very separate operations. Road upgrade is a separate issue discussed in section D.1.

Road Repair is concerned with the reinstatement of road facilities to a former condition. This work is usually associated with harvesting, as harvesting and timber haulage operations are the principal cause of road damage. For this reason most repairs are carried out during and immediately after harvesting.

Road Maintenance is concerned with keeping roads, not currently in use, in a usable condition. It should be carried out on an ongoing basis and particular attention should be given to the maintenance of drains and culverts. It is best carried out during summer months.

D.2.3 WHY MAINTAIN AND REPAIR ROADS?

Maintenance and repair is necessary for:

- i. the preservation of the capital asset;
- ii. the continued safety of the users;
- iii. access for emergency services (i.e. fire brigade/ambulances); and
- iv. to reduce vehicle operating costs.

Satisfactory maintenance/repair is usually achieved by retaining the standards of the road as built.

Capital asset

Forest roads represent a significant investment by forest owners and as such it is vital that this investment is preserved.

User safety

Safety of access to forest properties is also of major concern and the forest road network must be maintained to an acceptable standard to ensure continued safe access.

Access for emergency services

Access for the fire brigade in the event of a fire or the ambulance service in the event of a personal injury is vital and roads must be maintained in a usable condition for such contingencies.

Reducing vehicle operation costs

Reducing vehicle operation costs is important to road users and a well maintained road will reduce the wear and tear on tyres and suspensions and can therefore reduce the overall cost of timber haulage.

D.2.4 MAIN ELEMENTS TO REPAIR AND MAINTENANCE

The main elements to repair and maintenance are:

- i. drainage;
- ii. surface; and
- iii. pavement thickness.

Drainage

This is the most important aspect of road repair and maintenance. It is imperative that the sub-grade (soil) strength is retained by having a clear drainage ditch to ensure a water table that is as low as is possible. Otherwise the pavement strength may be dramatically reduced and expensive failure and loss of asset may follow.

The purpose of the ditch is not only to transport water, but also to intercept springs and depress the water table. It is extremely important to maintain a good drain profile to ensure good sub-grade drainage. Figure 37 shows the effects of good and bad drainage on sub-grade strength. It should be noted that a saturated sub-soil has less than half the strength of a dry sub-soil (i.e. can only carry less than half the load).

The reshaping or cleaning of ditches must be carried out during dry weather to minimise erosion and sedimentation resulting from soil disturbance. **It must be remembered that there may be domestic water supply points or fishery interests downstream and local advice should be sought.** It should not be necessary to carry out this reshaping very often, perhaps every 10 years or so. When necessary, this work is best done by using excavators, which can also reshape the road profile to ensure good run-off of water.

A well-profiled ditch should require little maintenance and if it has established grass cover, it will suffer less deterioration.

In order to ensure that there is no obstruction of the flow of water from the road to the ditch, channels should be opened and maintained at regular intervals along a road. These can be established/maintained when re-grading the road (using a power grader) or by excavator when cleaning the ditch. Alternatively the road edge can be graded to allow the water to run-off easily.

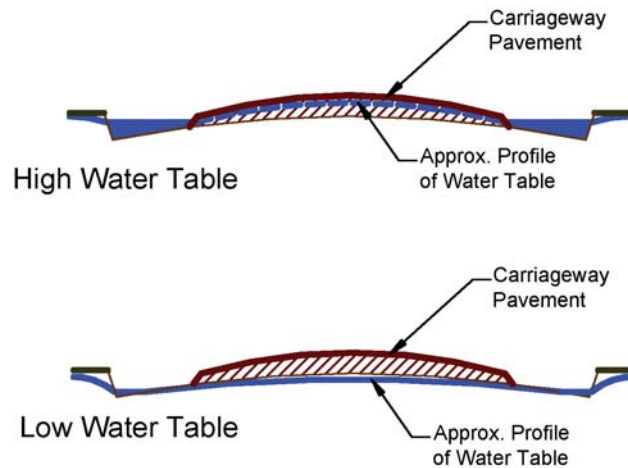


FIGURE 37: Effects of water table level.

Roadside trees can also impede the proper establishment and maintenance of road drainage. This may result in a loss of pavement strength due to saturation of the sub-soil. Trees should not be planted within 7.5 m of the road centreline. When reforestation operations are being carried out on a site, it is important to ensure that the mounding and drainage operations do not interfere with the existing roadside drainage. A roadside drain should be located at least 1.5 times its depth from the edge of the formation.

On existing roads where tree clearance is inadequate (i.e. less than 15 m), consideration should be given to removing the trees along the road edge. This should be done to allow sunlight and wind to get at the road surface in order to allow the surface to dry out. This will also facilitate the safe excavation of roadside drains. Overhanging branches should also be removed for the same reasons.

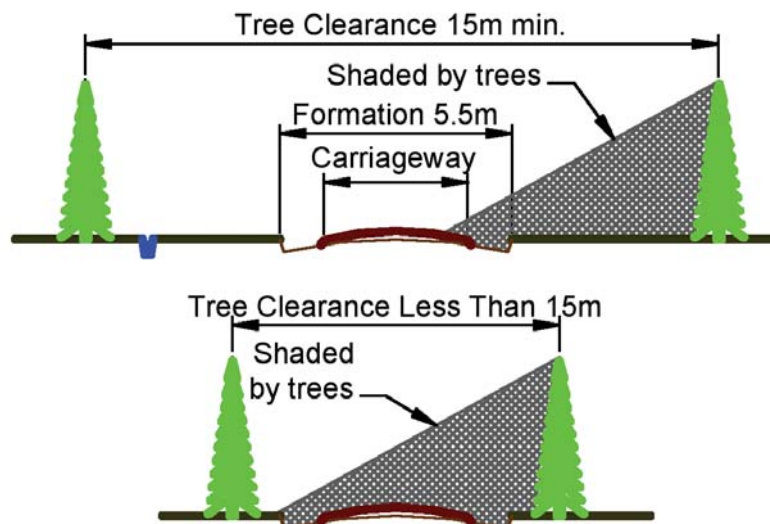


FIGURE 38: Effects of tree clearance width.

In mountainous areas, the proper maintenance of drainage is especially important. In high rainfall areas culverts are located more frequently to allow water to discharge on the downhill side with minimum erosion. It is vitally important to ensure that these culverts are regularly inspected and are kept free flowing in order to ensure the efficient disposal of floodwaters. Sediment traps where provided should be cleared regularly.

Poor water control, from blocked drains and/or wheel ruts acting as new drainage channels, will result in road damage if unchecked.

Grass cutting and cutting of woody growths before they become too substantial is necessary to ensure an unobstructed flow of water into drainage ditches. These need to be carried out every 2 to 5 years depending upon site conditions and soil type. The best method of carrying out this cleaning is by tractor mounted flail mower. (Note: Tractor-mounted flail mowers should not be used to clean drains as there is a danger from flying debris such as stones). An alternative, where environmental constraints allow, is the use of herbicides or a combination of both.

Major culverts and bridges should be inspected on a regular basis to ensure that they are not blocked or damaged. They should also be assessed occasionally, or whenever considered necessary, by a competent person.

Inspections are particularly important after periods of heavy rain. A blocked culvert or bridge can cause serious erosion of a road and can cause very costly damage to an area. The advice of an engineer should be sought immediately whenever a structure shows sign of deterioration. The inspection of bridges and culverts is especially important in time of heavy rainfall particularly in mountainous areas. If rainfall exceeds say 14 mm in a 24 hour period, then it is necessary to inspect these structures both from a road maintenance and safety viewpoint.

Surface

The material cost involved in the construction of a road carriageway is usually the most expensive part of a road. Therefore good maintenance of the surface is extremely important. Some common problems encountered in the repair and maintenance of the road carriageways are:

- ▶ potholes;
- ▶ camber;
- ▶ vegetation.

1. Potholes

Potholes are very common on flat sections of unbound roads. The potholes are caused by the increase in pore water pressure in pavement fines especially on impermeable formations resulting in the ejection of the fine material from the pavement. The need for a good longitudinal fall is essential in impermeable sites and indeed potholes are very rarely seen on roads with slopes greater than 3%.

The presence of potholes is not a particularly damaging condition in terms of the preservation of the road other than the actual loss of surfacing material. Heavy potholing does however lead to a substantial increase in user complaints, more so if the length of journey extends beyond a few kilometres. Eventually the presence of extensive and severe pot-holing becomes, not just-an annoyance, but an increased and unacceptable risk to the safety of the user and gives rise to claims for increased vehicle operating costs.

Re-grading should therefore be scheduled according to the condition of the surface and for guidance it is suggested that 80 to 100 potholes per km represents a reasonable level at which to re-grade. In very exceptional circumstances, where high volumes of traffic are carried, it may be necessary to re-grade more than once per year, but this would be usually associated with recreational usage where 'user satisfaction' is very important.

2. Camber

It is extremely important to ensure a road that is only used occasionally has a good camber or cross slope. This ensures that rainfall will quickly drain from the road surface into roadside drain and will not erode the road surface.

On roads where camber is poor (see sketch below), there is often severe erosion of road surface when rainwater travels along the road for long distances. This is a particular problem in mountain regions and on roads that have a steep gradient. Good camber (100 mm fall from the centre of the carriageway to its edge is advisable) can be achieved at the same time as re-grading for potholes and vegetation.

Re-grading of road surface is best carried out by a power grader. A tractor with blade or an excavator could also be used. Care must be taken to ensure that the graded material does not enter side drains or block roadside edges. It is necessary to compact the road surface after re-grading to prevent the ingress of water and to provide strength. This is best done by a towed or self-propelled roller. If drainage works are also required on a particular site then using an excavator for both operations is probably the best method.

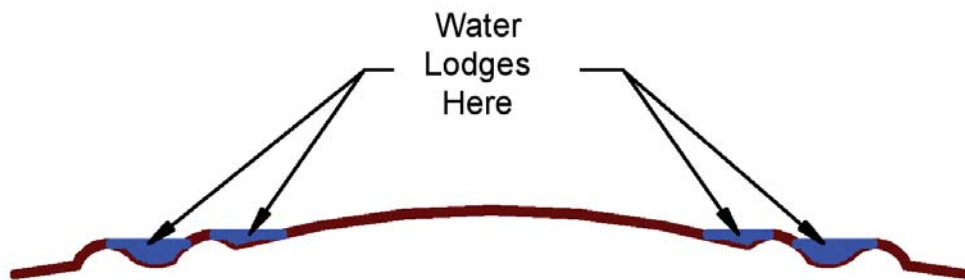


FIGURE 39: Effects of deformed pavement.

3. Vegetation

Without any traffic, an unsurfaced road is likely to become overgrown and the surfacing material becomes contaminated with organic debris from grass, moss and roots. If after some years it is brought back into use, the contaminated surface layer is often lost because it is either deliberately removed to improve traction and for the safety of users, or it simply erodes quickly because it is loose and of low strength. It is possible to avoid the road becoming overgrown by re-grading and compaction on a return period of 3 to 5 years depending on site condition. The costs of this fallback re-grading must be balanced by the value of the lost asset from the surface contamination. Major forest blocks where there are a number of main routes should definitely be maintained in this manner. Alternatively chemical spraying may be used to prevent the roads becoming overgrown. Only when a long period of non-use is expected and high financial interest rates apply is it considered to be appropriate to temporarily abandon a road.

Pavement thickness

The constructed pavement thickness must be preserved or excessive rutting will occur due to higher than intended stresses in the sub-grade. This in turn may lead to deep-seated failure requiring a total and expensive reconstruction.



PHOTO 19: Overgrown forest road.

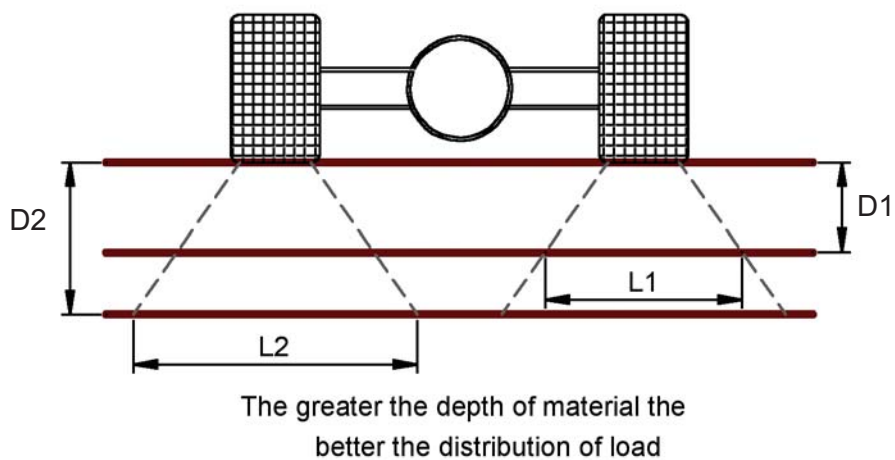


FIGURE 40: Effects of pavement thickness.

Loss of pavement thickness is due to the attrition of surface stone and is caused by:

- ▶ **Heavy rains** washing away small sized particles and the subsequent release and rolling away of coarser material.
- ▶ **Dislodgement and dispersal by vehicle tyres.** This effect can be from all vehicle types and it is worsened by extra traffic, increased speed and by the aggressive tyres of off road vehicles.

Note: Ideally harvesting traffic i.e. processors and forwarders, should not travel on a forest road. Consideration should be given to creating roadside racks on thinning sites to avoid extraction directly onto roads. If it is not possible to avoid this then placing brash on the road surface should help to reduce the damage to the road. This brash must be removed from the road and roadside drains as soon as possible after completion of the extraction operations.

- ▶ **Re-grading** can itself lead to some loss of material from the surface. A skilled operator can reduce the loss during the actual re-grading operation. Re-grading should therefore only be done when necessary. In order to preserve an adequate pavement throughout the life of the road additional material will need to be provided occasionally.
- ▶ **Bad practices**, which can also lead to severe road damage, include skidding timber along and processing timber on the roadway. These are very destructive of both the carriageway and the formation. Road verges, off road stacking spaces and levelled spoil banks should be used for this work.

Re-metalling costs vary widely with local availability of stone, but usually a crushed stone is required in order that it can be placed in a thin layer. Materials used for re-metalling should be well graded, i.e. range in size from coarse stone (50 mm) down to fine particles. Crushed stone is preferable but may not always be available in an area. Only approved aggregates should be used in the re-metalling of roads. It is important to compact the material being spread as it is being placed, otherwise it will be dispersed by vehicular traffic.

Re-shaping is usually done by either an excavator or a motor-grader and compacted by a towed or self-propelled roller. Addition of some surfacing material may be necessary occasionally. In the case of embankment roads, re-shaping is best done by the re-distribution of material (e.g. by pushing the summit of a switchback to fill a depression) rather than by adding further material, which may only result in sub-grade over-loading, with further accelerated settlement and possible failure.

D.2.5 OTHER FACTORS

Other factors, which affect the state of a road, are:

- ▶ winter conditions; and
- ▶ overloading.

Winter conditions

During periods of frost, the moisture content within the body of the pavement increases from water drawn in by capillary action and as vapour, in extreme cases ice lenses may form. Whilst frozen this has minimal impact.

However, severe problems arise when the thaw begins. Pavements are then both unconsolidated and saturated. Use in that condition by heavy vehicles is likely to cause severe damage.

When snow falls on a forest road similar unconsolidated and saturated conditions may occur. Roads should not be used when covered with snow or immediately after the thaw. Fortunately weather conditions such as snow and severe frosts are not common in Ireland and generally when they do occur they do not last for long.

In addition it should be remembered that a saturated road has less than half of the strength of a dry road. Therefore using roads that are very wet should be avoided if at all possible.

Overloading

The various Road Traffic Acts prescribe the dimensions and legal loads with which all vehicles must comply. The legal constraints on use require that a vehicle does not exceed the maximum

permitted weight and the individual axles do not exceed their maximum permitted weight.

Forest roads are designed to carry the same loads as public roads but the effect of overloading and abuse are probably more immediately evident on forest roads. Damage caused by abuse of the road and the costs of subsequent repairs and maintenance can be substantial.

Like all other civil engineering works, a road is a structure and as such is designed to carry specific loading. This is primarily vehicle loading applied through the wheels and axles. In terms of local damage the wheel load is significant, while the axle load weight has a cumulative effect on the life span of the road.

The normal method of designing a road is to express the design capacity as millions of standard axles. For instance, a motorway could be designed to carry 50 million standard axles. Forest roads are designed to carry construction traffic and could be expected to carry up to 50,000 standard axles, depending on site conditions. The road will suffer a small deterioration every time a vehicle travels over it. However overloading of a vehicle will accelerate this process. The following tables show the increased damaging effect of vehicle overloading on bound (tarred) roads. The damaging effect on unbound (gravel) roads will be greater.

TABLE 19: Damaging effects of overloading.

GROSS VEHICLE WEIGHT OVERLOAD (tonnes)	INCREASED DAMAGING EFFECT (%)
2	23
4	49
10	155
20	443

Note: Table courtesy of Forestry Contracting Association Ltd, Aberdeenshire.

The practice of raising the non-drive axles so as to increase traction could, on loaded vehicles, lead to overloading of other axles on the tractor unit. This can, in turn, lead to increased level of damage to the road. Situations where this would be necessary should be avoided as much as possible, for example, by providing suitable level sites for stacks to be loaded to vehicles.

Recent research funded by COFORD and carried out jointly by Coillte and University College Dublin has given some insight into the effects of overloading on roads in this country. On some roads where experiments were carried out, the results showed just how serious the damage caused by overloading can be. The results are summarised in Table 20.

Use of Super Single tyres on timber haulage trucks can cause up to 50% more damage than the conventional double wheel axles.

TABLE 20: Capacity effects of overloading.

AVERAGE GROSS VEHICLE WEIGHT	(INCREASE)/REDUCTION IN ROAD LIFE CARRYING CAPACITY
35 tonnes	(50% increase possibly)
43 tonnes	16% reduction
48 tonnes	44% reduction

D.2.6 SUMMARY

- i. Road maintenance and road repairs are classified as separate operations.
- ii. Road maintenance is concerned with keeping roads, not currently in use, in usable condition.
- iii. Road repairs are concerned with the reinstatement of road facilities to a former condition.
- iv. Road repairs should be carried out to an acceptable standard as soon as possible following damage. Restoration is needed after harvesting to prevent or minimise serious deterioration if left in a damaged condition.
- v. The minimum standard of road repairs/road maintenance should be such that a road can be used by emergency services if so required.
- vi. Because of the nature of the individual operations the cost of repairs will nearly always be far greater than that of maintenance.
- vii. The frequency and degree of maintenance and repair work necessary will depend principally on traffic intensity and the quality of original construction. Embankment roads will usually have high maintenance costs due of settlements and deformation, particularly so on deep peat sites.
- viii. Regular inspection of roads during harvesting is necessary to spot trouble. Particular attention should be directed to maintaining a good cambered road profile and to the clearing of drains and culverts.
- ix. Periodic inspection of roads at other times is very important to spot incipient trouble which, if not checked, may ultimately require expensive reconstruction. This inspection should be a routine procedure with emphasis on periods following bad storms. Particular attention should be directed to clearing of drains and culverts, which may be fouled by lop-and-top or washed down debris.
- x. Addition of some surfacing material may be necessary occasionally. In the case of embankment roads, re-shaping of the formation is best done by the re-distribution of material rather than by adding further material.
- xi. It is pointless spreading expensive materials on a flat narrow sunken road with no side drains or culverts.
- xii. Overhanging branches should be removed as should roadside trees less than 7.5 m from the centreline of the road. This will facilitate drying out of the road, which will increase the overall strength of the road.
- xiii. Forest roads are not usually designed to cope with fast-moving traffic so the temptation to maintain road surfaces to too high a standard must be resisted. As long as the longitudinal and cross-sectional profiles are reasonably maintained, the roadway is free from vegetation and it is secure against infiltration of ground water and rainfall, no additional expenditure should be incurred.

D.3 ROAD CLOSURE

Forest roads are not all weather roads. Under certain weather conditions (severe storms, heavy snowfalls) roads should be closed to traffic to ensure the safety of the road users and to minimise the damage caused to the road structure.

D.3.1 GUIDELINES

1. Roads should be closed to timber transport in wet conditions when disturbance of surface material poses a threat to stream water quality.
2. Timber transport should be suspended in dry weather on roads where the surface materials have unravelled to a degree that poses a threat to stream or wetland water quality in subsequent wet weather.
3. Existing roads should be closed after heavy snowfalls in the interests of safety.
4. Roads and road structures, e.g. bridges and culverts that have been damaged by rain must be closed until the damage is rectified.

D.3.2 SURFACE EROSION

In very wet weather, the surface of an unbound road may either erode due to uncontrolled water running along the surface or may loosen under loading due to increases in pore water pressure. In either event, finer material in the road surface is dislodged resulting in two particular problems. Firstly, the surface binding is greatly reduced with a consequent loss of strength and possibly stability in the road. Secondly, the fine material can be washed away into watercourses causing pollution.

D.3.3 WATERLOGGING/FREEZING

The road surface can become saturated in very wet weather. As pressure is applied to the surface in the form of passing lorries, the water in the road (contained in the minute material voids) is compressed. Since water is an incompressible material, it will force itself elsewhere. It does this by dislodging finer surface particles causing the problems covered in the previous paragraph.

In freezing weather, this problem is accelerated during thaw periods. Water expands as it freezes and in doing so loosens the road surface. As it thaws, the material bonding has been weakened so particle expulsion will more readily occur. It is therefore essential that forest roads are not used during a thaw.

Section E: Appendices

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E.2 PRINCIPAL LEGISLATION

EC (Natural Habitats) (Amendment) Regulations 1998

EU Council Directive 79/409/EEC on the conservation of wild birds

EU (Conservation of Wild Birds) (Amendment) Regulations 1999

European Communities (Natural Habitats) Regulations 1997

European Communities (Environmental Impact Assessment) (Amendment) Regulations, 2001.
S.I. No. 538 of 2001

Forestry Act 1946

Forestry Act 1956

Forestry Act 1988

National Monuments Acts 1930-1994

National Monuments Acts 1930-1994 (Approval of Consent (I) Order 1995)

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Planning and Development Act, 2000

Planning and Development Act, 2000 (Commencement) (No. 3) Order, 2001 S.I. No. 599 of
2001

Planning and Development Regulations, 2001 S.I. No. 600 of 2001.

Road Traffic Acts 1933-1993

Road Act, 1993

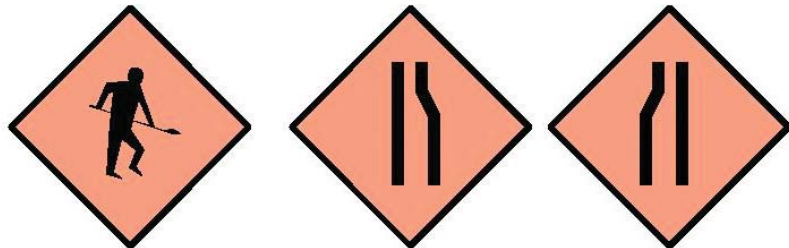
Road Traffic (Construction and Use of Vehicles) Regulations 2003. S.I. No. 5 of 2003

Safety Health and Welfare at Work Act 1989

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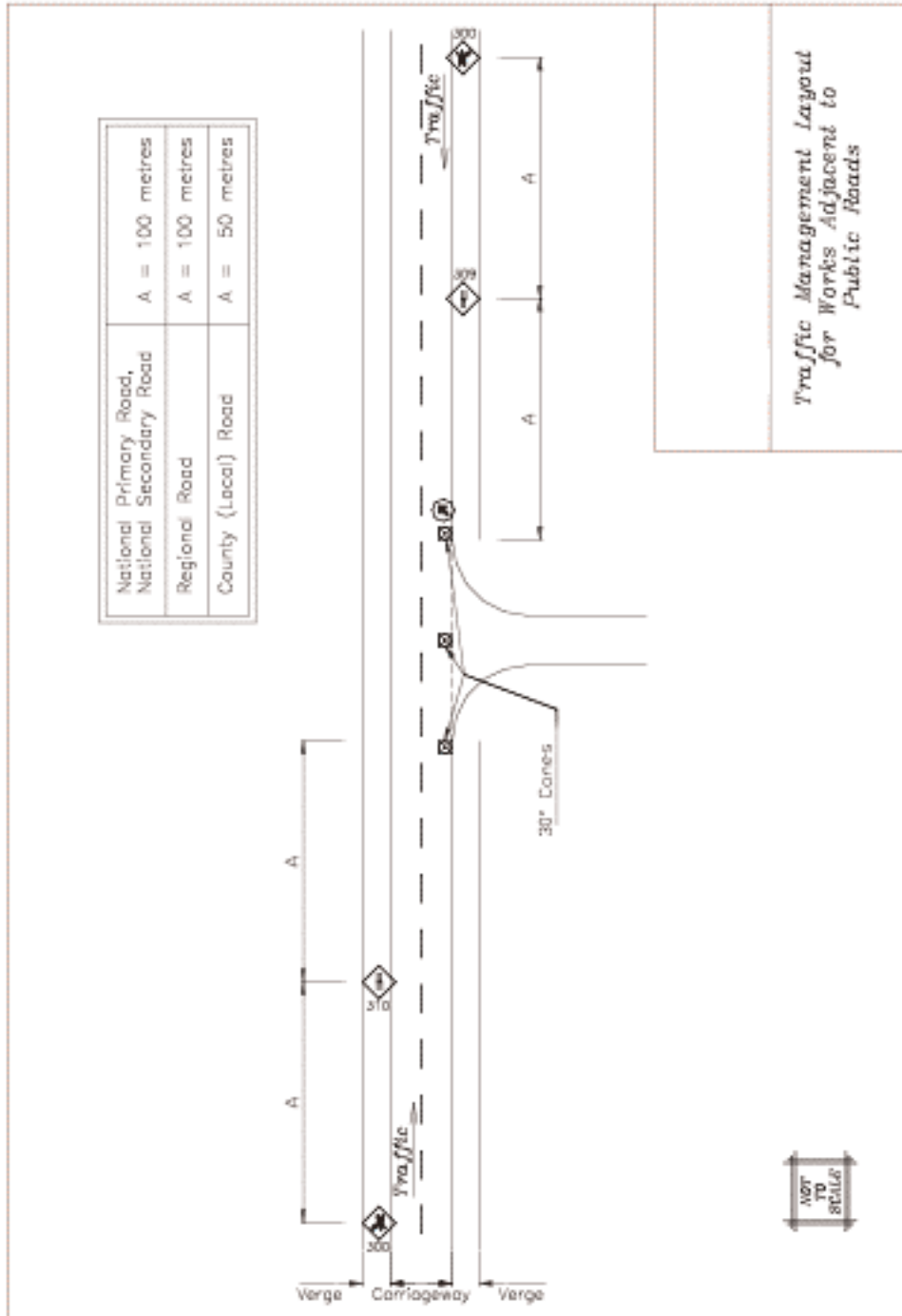
E.3 APPROPRIATE SIGNS FOR USE ON FOREST ROADWORKS



	 CAUTION Beware of open excavations	 Construction site ahead
	 CAUTION Beware of overhead electric cables	 KEEP CLEAR
 Wear High Visibility Jackets	 Construction site KEEP OUT	 Construction site NO UNAUTHORISED ENTRY
 Wear Safety Boots	 Wear High Visibility Jackets Wear Safety Boots	 DANGER Road Closed DO NOT PASS THIS POINT
 Wear Hard Hats	 Wear High Visibility Jackets Wear Safety Boots Wear Hard Hats	

Guidelines for Safety Signs to be use for Forest Roadworks

E.3.1 LAYOUT OF SIGNS



E.4 TABLE OF GRADIENT AND EQUIVALENT GRADES

GRADIENT	GRADE	ANGLE
1:300	0.3%	0.19°
1:200	0.5%	0.29°
1:100	1.0%	0.57°
1:95	1.1%	0.60°
1:90	1.1%	0.64°
1:85	1.2%	0.67°
1:80	1.3%	0.72°
1:75	1.3%	0.76°
1:70	1.4%	0.82°
1:65	1.5%	0.88°
1:60	1.7%	0.95°
1:55	1.8%	1.04°
1:50	2.0%	1.15°
1:45	2.2%	1.27°
1:40	2.5%	1.43°
1:35	2.9%	1.64°
1:30	3.3%	1.91°
1:25	4.0%	2.29°
1:20	5.0%	2.86°

GRADIENT	GRADE	ANGLE
1:19	5.3%	3.01°
1:18	5.6%	3.18°
1:17	5.9%	3.37°
1:16	6.3%	3.58°
1:15	6.7%	3.81°
1:14	7.1%	4.09°
1:13	7.7%	4.40°
1:12	8.3%	4.76°
1:11	9.1%	5.19°
1:10	10.0%	5.71°
1:9	11.1%	6.34°
1:8	12.5%	7.13°
1:7	14.3%	8.13°
1:6	16.7%	9.46°
1:5	20.0%	11.31°
1:4	25.0%	14.04°
1:3	33.3%	18.43°
1:2	50.0%	26.57°
1:1	100.0%	45.00°

E.5 FORM 4 - SITE INVESTIGATION REPORT

SITE INVESTIGATION REPORT	SHEET No. _____
---------------------------	-----------------

Forest Owner: _____ Production Year _____

Property/Townland: _____

OS No. _____ Date of Survey _____

Road Type: New Upgrade T/A Row

Programme Requirements:

Survey _____(m) Form. _____(m) Comp. _____(m)

Upgrade Form. _____(m) Upgrade Comp. _____(m)

Engineered track _____(m)

Engineering Specification Compliance? Yes No

Hazards Identified? Yes No

Environmental Guidelines observed? Yes No

County Development Plan Checked? Yes No

If any 'No' above, attach a report explaining reasons for deviation

Distance (m)	Peat (mm)	Mineral (type)	Rock (type)	Culvert Ø (mm)	Slope +/- 0°	Comments

Will planning permission be required? Yes No

Signed _____

Date: _____

E.6 SPECIFICATION FOR ROAD MATERIAL

No. 1 Specification, as per Clause 803 of the National Roads Authority's 'Specification for Road Works' for Granular Material Type A.

Type A granular material shall be gravel or crushed rock. The material shall be well graded and lie within the following grading envelope.

B.S. Sieve Size	Percentage by Mass Passing
75 mm	100
37.5 mm	85 - 100
10 mm	40 - 70
5 mm	25 - 65
600 µm	8 - 30
75 µm	0 - 10

No. 2 Specification, as per Clause 804 of the National Roads Authority's 'Specification for Road Works' for Granular Material Type B.

Type B granular material shall be crushed rock. The material shall be well graded and lie within the following grading envelope.

B.S. Sieve Size	Percentage by Mass Passing
75 mm	100
37.5 mm	85 - 100
10 mm	40 - 70
5 mm	25 - 45
600 µm	10 - 22
75 µm	0 - 8

No. 3 Specification, as per Clause 805 of the National Roads Authority's 'Specification for Road Works' for Granular Material Type C.

Type C granular material shall be screened or crushed gravel. The material shall be well graded and lie within the following grading envelope.

B.S. Sieve Size	Percentage by Mass Passing
75 mm	100
37.5 mm	80 - 100
20 mm	60 - 80
10 mm	40 - 65
5 mm	25 - 50
600 µm	8 - 20
75 µm	0 - 8

No. 4 Specification, as per Table 8/5 of the National Roads Authority's 'Specification for Road Works' for Wet Mix Macadam.

The granular material should consist of crushed rock and shall have the following grading.

B.S. Sieve Size	Percentage by Mass Passing
50 mm	100
37.5 mm	95 - 100
20 mm	60 - 80
10 mm	40 - 60
5 mm	25 - 40
2.36 mm	15 - 30
600 µm	10 - 22
75 µm	0 - 8

Notes: The quality of the rock or gravel in these materials should be to the approval of the Engineer and he should be at liberty to request further testing of the material he thinks necessary.

The use of wet mix macadam for forest roads is usually confined to repair works.

No. 5 Specification, for Crush-run Stone or Pit-run Gravel.

The quality of the stone must be to the satisfaction of the Engineer and must be well graded within the following limits.

B.S. Sieve Size	Percentage by Mass Passing
75 mm	100
10 mm	40 - 65
75 mm	0 - 10

Samples must be supplied for testing if requested by the Engineer.

No. 6 Specification, for alternative Graded Material.

Alternative graded materials to the four National Roads Authority blends specified will be considered, provided the quality of the stone and the grading is to the approval of the Engineer. The proposed range of grading should be supplied with tenders but the maximum size should not exceed 75 mm.

Note: No's 5 & 6 specifications are used when only when there is difficulty in getting material conforming to the standard NRA specifications.

E.7 ESTIMATION OF WATERWAY AREAS USING THE TALBOT FORMULA

$$A = 0.184 C (M)^{0.75}$$

where: A = waterway area (m²)

M = Catchment area (ha)

C = A co-efficient varying from $\frac{1}{8}$ (flat retentive sites) to $\frac{1}{2}$ (steep impermeable areas)

Catchment (ha)	Waterway Area (sq. meters)		
	c = 0.125	C = 0.25	c = 0.5
5	0.077	0.154	0.308
10	0.129	0.259	0.517
20	0.218	0.435	0.870
50	0.432	0.865	1.730
100	0.727	1.455	2.909
150	0.986	1.972	3.943
200	1.223	2.446	4.893
250	1.446	2.892	5.784
300	1.658	3.316	6.632
400	2.057	4.114	8.229
500	2.432	4.864	9.728
600	2.788	5.577	11.153
700	3.130	6.260	12.520
800	3.460	6.920	13.839
900	3.779	7.559	15.117
1000	4.090	8.180	16.360
1200	4.689	9.379	18.757
1400	5.264	10.528	21.056
1600	5.819	11.637	23.274
1800	6.356	12.712	25.424
2000	6.879	13.757	27.514

E.8 EXTRA WIDENING AT CURVES

Semi Circle (180° Curve)

Curve Radius (m)	Max. Extra Widening (m)	Degree Necessary for Max. Widening	Max. Tangent Widening (m)	Tangent Length (m)
10.7	5.1	40° to 140°	4.3	36.6
12.2	4.6	30° to 150°	3.8	33.5
13.7	3.8	25° to 155°	2.9	30.5
15.2	3.2	25° to 155°	2.4	27.4
18.3	2.6	20° to 170°	2.0	24.4
22.9	1.9	15° to 165°	1.6	21.3
30.5	1.4	10° to 170°	1.1	18.3

3/8 Circle (135° Curve)

Curve Radius (m)	Max. Extra Widening (m)	Degree Necessary for Max. Widening	Max. Tangent Widening (m)	Tangent Length (m)
10.7	4.4	35° to 100°	3.7	33.5
12.2	4.1	25° to 110°	3.4	33.5
13.7	3.6	25° to 110°	2.9	30.5
15.2	3.0	25° to 110°	2.4	27.4
18.3	2.6	20° to 110°	2.0	24.4
22.9	1.9	15° to 120°	1.6	21.3
30.5	1.1	10° to 125°	1.1	18.3

1/4 Circle (90° Curve)

Curve Radius (m)	Max. Extra Widening (m)	Degree Necessary for Max. Widening	Max. Tangent Widening (m)	Tangent Length (m)
10.7	3.7	25° to 65°	3.1	33.5
12.2	3.3	20° to 70°	2.9	30.5
13.7	3.1	20° to 70°	2.5	27.4
15.2	2.7	15° to 75°	2.3	27.4
18.3	2.4	15° to 75°	2.0	24.4
22.9	1.9	15° to 75°	1.6	21.3
30.5	1.4	10° to 80°	1.1	18.3

$\frac{1}{8}$ Circle (45° Curve)

Curve Radius (m)	Max. Extra Widening (m)	Degree Necessary for Max. Widening	Max. Tangent Widening (m)	Tangent Length (m)
10.7	2.3	5° to 40°	2.0	27.4
12.2	2.2	5° to 40°	2.0	24.4
13.7	2.1	5° to 40°	1.9	24.4
15.2	2.0	5° to 40°	1.8	24.4
18.3	1.9	5° to 40°	1.6	21.3
22.9	1.6	10° to 35°	1.3	21.3
30.5	1.4	10° to 35°	1.1	18.3

- NOTES -



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