Guidelines for Forest Engineering Practices in South Africa

2014
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Acknowledgements

The first edition of this document was known as the *Harvesting Code of Practice* and resulted from a project initiated by Forest Engineering Southern Africa (FESA) in 1992. In the second edition of the document, it was renamed the *Guidelines for Forest Engineering Practices in South Africa*, and was published in 1999.

Since the 1999 publication, the industry has progressed in areas such as mechanisation of forest operations, forest certification, safety standards, biofuels and other advancements. This has therefore resulted in the need for a handbook revision in order to stay abreast of and provide updated guidelines for current practices. Revisions have been made and new information added to make this document a current useful hands-on tool for the South African forest engineer and forester.

The following individuals contributed to the updating of the second edition of the handbook, resulting in this, the third edition of the *Guidelines for Forest Engineering Practices in South Africa*:

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Foreword

As South African commercial forestry continues to develop and compete within the global market, production processes are assessed and benchmarked against both local and international forestry values, norms and standards. Part of this broad-scale assessment procedure is the certification of our plantations and mills, without which many markets are closed to our products. Certification of forests and their associated management and operations provide an internationally accepted framework whereby the social, environmental and economic values of good forest practice are adhered to. Although several certification bodies exist, most of South Africa’s certified forests subscribe to the Forest Stewardship Council (FSC).

Values for activities practised in forestry (i.e. harvesting, road construction and maintenance, transport and silviculture) should be documented for the Forestry Industry and written within the framework of the environment in which the industry operates (i.e. natural, economic and human resources). A set of guidelines, of which this document is an element, comprising the previously mentioned activities, is therefore necessary to address the needs of the industry.

Factors that influence the environments are:

- The “external environment”, which refers to the forces which are not under direct control of the industry. These include natural disasters, political changes, labour trends, the role of the environmental pressure groups, international market trends, the economy of the country and world affairs.

- The “internal environment”, which refers to the environment that can be controlled by the industry. This is best achieved through effective management, research and development, planning, training, and education.

“Forest Engineering” is the application of the scientific, mathematical and sound forestry principals in the implementation of machinery with the purpose of improving the efficiency of all operational processes. This includes activities associated with timber harvesting for both industrial purposes and energy generation from related biomass and encompasses harvesting, extraction, transport logistics and the associated construction and maintenance of forest roads. All forms of biomass have a potential value when in the form of standing trees. Forest engineering therefore encompasses all operations required to turn this potential value into a realised return at rotation age in a safe, sustainable, environmentally responsible, cost effective manner.
The *Guidelines for Forestry Engineering Practices in South Africa* is a management tool which provides guidelines for all those involved with forestry, and assists organisations and timber growers in managing internal environments effectively.

FESA took the initiative in 1992 to develop the first version of this document, namely the Harvesting Code of Practice. This edition was updated in 1999 to produce the *Guidelines for Forest Engineering Practices in South Africa*. This document is the product of another revision process, with the addition of new chapters and updating of others. Some of the changes which have been made include the addition of a planning chapter; guidelines for shovel logger operation; guidelines for biomass harvesting, extraction and transport operations; significant additions to the transport sector of the handbook and general updates throughout. The guidelines in this document are still based on Southern African conditions and are intended to be a guide for forest engineering practices in South Africa.

### PURPOSE OF THIS DOCUMENT

To supply guidelines which will promote sustainable forest engineering practices in South Africa by enhancing product quality, productivity, cost effectiveness, safety and environmental responsibility.

One should note that this document does not cover all aspects of forest engineering exhaustively and is not a stand-alone document. It should be used in conjunction with other more detailed FESA handbooks and publications as and when required. For more information visit www.icfr.ukzn.ac.za
CHAPTER 1: Introduction

This document is comprised of the following chapters:

- Values (Chapter 2);
- Planning (Chapter 3);
- Access Development (Forest Roads) (Chapter 4);
- Harvesting, Extraction and Extended Primary Transport (Chapter 5);
- Secondary Intermediate and Secondary Terminal Transport (Chapter 6);
- Post Harvesting Operations (Chapter 7).

Elements which must be considered and guidelines which should be followed in terms of the effect of operations on economics, ergonomics, the natural environment, productivity and safety are highlighted throughout the document. These guidelines should be followed in conjunction with the values when contemplating the conversion of a standing tree into a useable product (e.g. sawlogs, poles, pulpwood or biomass) and its delivery to a conversion site (e.g. mill, preservation plant or siding/depot).

This document should be used for:

- Planning of forest roads, transportation, extraction routes and timber harvesting;
- Execution of the plans drawn up and adjustments to such plans;
- Monitoring of operations in progress;
- Feedback necessary during and after completion of the operation (auditing).
CHAPTER 2: Values

Values can be defined as important and enduring beliefs or ideals shared by members of a culture or group about what is good or desirable and what is not. Environmental, commercial and socio-political values of natural renewable resources must be balanced to conform to ethical requirements as well as ensure optimum utilisation and a sustained yield of the renewable timber resource. This chapter provides an overview of the various values attached to forest and forest operations and gives a framework for the development of appropriate management guidelines in harvesting operations aimed at protecting these values. Recommended strategies and tactics concerning each of these values are presented. Best management and operational practices aim to balance the commercial interests of forest operations with the values attached to forest land by:

- Avoiding and minimising negative impacts of forest operations;
- Optimising timber/biomass utilisation;
- Maximising the growth rate in plantation forests;
- Protecting the health and well-being of the forest work force and the public;
- Matching harvesting systems and equipment to the specific site conditions.

A systematic approach to establishing special management zones and determining the required protection methods is outlined in Figure 1. A special management zone (SMZ) is an area that requires adherence to special management practices to protect certain values. These may include streams and vleis with their associated vegetation, archaeological sites, arboreta, indigenous forests, and sensitive soils, steep slopes, viewing spots, recreational areas, research plots and areas of social importance.

Figure 1: A systematic approach to establishing special management zones (SMZ’s) and determining the required protection methods.
2.1 Soil

To ensure a sustainable timber supply from afforested land, it is essential to protect the soil and water and their relationships with other land components. Soil and water values are discussed in separate parts within this chapter but cannot be treated in isolation from one another.

Soil is the primary natural resource required for the cultivation of a forest. This chapter refers to soil with regards to its characteristics and complex interaction with the environment. Soil values are concerned with soil disturbance, soil compaction, soil erosion and nutrient loss, and these all have an influence on the productive capacity of the site.

**Strategy**

- Minimise site degradation through appropriate forestry practices to ensure a sustainable timber yield.

**Tactics**

Methods of protecting soil values include:

- Define soil sensitivity under specific soil moisture conditions to determine possible machine impact (i.e. terrain and sensitivity classification);
- Classify vehicles and choose systems to suit the terrain, soil sensitivity, growing stock and weather conditions.

**Soil Erosion**

This can be defined as the loss or movement of soil from the growing site by water or wind.

Methods of reducing erosion include:

- Identify highly erodible soils and prevent disturbance in these areas;
- Prevent concentrated runoff and reduce water velocity;
- Maintain maximum ground cover;
- If slash must be stacked, ensure that it is stacked along the contour;
- Use designated extraction routes to minimise the extent of the area disturbed;
- Use brush or synthetic products such as geo-fabric mats when sensitive areas need to be traversed;
- Plan roads accurately, construct them properly and keep them well maintained;
- Ensure that roads have efficient drainage systems that match the rainfall, soil type and terrain;
- Rehabilitate eroded areas.

**Soil Compaction**

This can be defined as the increase in bulk density of a soil, usually as a result of vehicular movement.

Methods of reducing soil compaction include:

- Avoid areas with a wetness hazard;
- Use designated extraction routes to avoid uncontrolled vehicle movement within the stand;
- Use slash to “pave” extraction routes;
- Use vehicles with low ground pressure;
- Rehabilitate compacted areas.

**Nutrient Loss/Transfer**

This can be defined as the removal of soil nutrients from a site through erosion, leaching, biomass removal, carbon removal (through fires) and/or volatilisation. Figure 2 shows a typical nutrient cycle in the forest.

Methods of reducing nutrient loss include:

- Map the soils of the site to help identify the nutrient status;
- Leave nutrient rich biomass at the site;
- If bark is removed from the stem, allow it to remain in the stand;
- Break up and broadcast slash and debris where possible;
- Mulching of residue speeds up the nutrient breakdown process and ensures fewer nutrients are lost;
• Roadside processing operations should promote the return of the forest residue (e.g. branches) into the stand; and
• Avoid burning where possible. However if burning is essential, ensure that the fire is of a low intensity.

Figure 2: Typical forest nutrient cycle.

2.2 Water

Water is essential for all life support. Water values refer to wetland areas which include riparian zones, streams, springs, catchment areas, swamps, marshes, bodies of standing water and all the associated riparian vegetation. Any work done in a stand will almost invariably have some effect on water quality, water yield, stream sedimentation and watercourse stability.

Strategy
• Apply special management consideration to all wetland management zones;
• Conserve water quality;
• Consider seasonal changes in wetlands.

Tactics

Methods of protecting water values include:
• Identify hydrologically sensitive areas and indicate these on the harvesting plan, with special precautions suggested on how they should be protected;
• Prevent down-slope soil disturbance by ensuring adequate drainage control;
• Minimise the extent of the area disturbed;
• Avoid contamination of wetland areas, especially with reference to fuels and oils;
• Situate extraction routes, landings and depots outside of wetland areas. Construct these in such a way that they will not affect the water quality or the riparian vegetation;
• Ensure that roads and drainage systems are well planned, properly constructed and well maintained;
• Minimise river/stream crossings;
• Minimise felling and/or dragging of trees in wetland areas;
• No debris should be deposited in riparian zones or waterways;
• If debris has accumulated in the riparian zone or waterway, remove it with minimum damage;
• Protect wetland areas with detailed harvest planning and well controlled operations.
2.3 Forest Health and Hygiene

**Forest Health**
This relates to factors which affect the well-being of trees and are mainly external influences which cause retarded growth or physical damage. Neglecting forest health could encourage disease, insect attack or susceptibility to fire, leading to the loss of timber and/or poorer wood quality.

**Forest Hygiene**
This refers to the general appearance and condition of the forest before, during and after timber harvesting, extraction and transport, as well as corresponding road construction.

**Strategy**
- Minimise the opportunity for insect and disease infestation;
- Maintain forest hygiene;
- Reduce fire risk.

**Tactics**
Methods to maintain forest health and hygiene include:
- Avoid damage to residual trees through careful planning, training and supervision;
- Remove all marketable timber as soon as possible;
- Adhere to fire prevention regulations;
- Manage slash to reduce the fire risk;
- Ensure all roads are cleared for accessibility after the operation ends for the day;
- When not in operation, cable yarder anchors should not block access roads;
- Take the necessary precautions to prevent oil or spillage;
- Do not service machines infiel;
- Remove all repair and maintenance material and litter after completion of the operation.

2.4 Scientific and Ecological Values

Studying the interactions between the various components of the environment is referred to as the scientific value of forest land. Habitats should be managed to sustain interaction between the various components. Plantations and associated habitats (including wetlands, corridors, fire belts, grasslands, savannas, fynbos and indigenous forests) provide a more specialised value than merely commercial worth to the human community, such as their intrinsic scientific and ecological qualities. These areas also have important educational and recreational properties. Some exotic plantation sites or species also have significant scientific research value.

**Strategy**
- Planning should take the influences of road construction and harvesting on scientific and ecological values into consideration;
- Scientific and ecological values need to include the protection of:
  - Endangered and scarce flora and fauna;
  - Unusual plantation stands or trees (e.g. Arboreta, seed orchards, stands of noteworthy species and unusually old/large trees);
  - Research sites;
  - Areas of landscape diversity.
Tactics
Methods to protect scientific and ecological values include:

- Identify scientific and ecologically important areas in the field. Inspect and map these areas and generate plans for special management and harvesting operations;
- If a new site is identified before or during the harvesting/road construction process:
  - Alert the relevant authorities;
  - Document the values;
  - Protect the site.

2.5 Paleontological, Archaeological and Historical Values

People have inhabited the southern African sub-continent for thousands of years. Traces of their presence can be found almost everywhere, including the major forestry regions. All paleontological, archaeological and historical sites are unique, and once destroyed or damaged, cannot be recreated. The National Heritage Resources Act provides for the identification, registration, assessment, protection and management of southern Africa’s heritage resources through the South African Heritage Resources Agency (SAHRA). Sites of special significance (i.e. aesthetic, architectural, historical, scientific, social, spiritual, linguistic and technological) are graded according to their importance. Grade I sites are national heritage sites whilst Grade II and III sites are provincial heritage sites.

Strategy
All paleontological, archaeological and historical sites are protected under provisions of the Act and may not be destroyed, damaged, disfigured, excavated or altered in any way. No part of a site may be removed or exported without first obtaining a permit to do so from SAHRA.

Tactics
Methods of protecting paleontological, archaeological and historical sites include:

- Consult all known records to ascertain whether any sites are known to occur within the boundaries of the plantation;
- Keep an up-to-date record of each site and its characteristics and mark its position on a map;
- Stop work immediately if fossils or evidence of human occupation are found during the course of forestry activities. Seek expert advice before continuing;
- Draw up short and long-term special management plans once the future of the site has been decided upon;
- Brief all employees and contractors on the significance of the sites.

2.6 Aesthetic and Recreational Values

Many of the plantation forestry areas in South Africa are situated in areas where tourism and recreation are important sources of income. Picnic sites, camping grounds, scenic drives, hiking and biking trails, walks and waterfalls are frequently visited because of their influence on the human psyche.

Strategy

- Take special care to ensure that harvesting practices and roads blend in with the natural visual character or land use character of the area;
- Consider influences of road construction and harvesting operations on recreational activities during planning.

Tactics
Methods of conserving aesthetic and recreational values include:

- Shape the felling area according to the natural landscape patterns and features, if compartment boundaries allow it;
- Provide screening of harvesting operations by using a felling sequence from background to foreground, if practical;
• Retain a buffer of either indigenous trees and shrubs or mature plantation trees in the foreground areas to “soften” the landscape change during felling, if practical;
• When creating a harvesting schedule, areas above the skyline should, if practical, be felled well ahead of the areas below it. This will allow a “greening” period for the upper area to recover before being exposed;
• In areas of high aesthetic and recreational value, it is more visibly pleasing to create a mosaic of forest age classes where possible;
• Identify the most visible areas as seen from popular observation points such as main roads, lookout points, hiking trails and camping areas. Special planning in terms of timing and sequence is required in areas where tourism occurs;
• Waste creates negative impressions, therefore cut stumps low and remove all utilisable timber;
• Remove litter generated by harvesting operations from the stand;
• Minimise noise and dust during operations close to recreational and residential areas.

2.7 Human Resources

Human resources are an important asset in the production process. The health and safety of workers is enforced by law.

Strategy

• Provide a safe and healthy working environment;
• Ensure a competent and motivated workforce by developing the individuals through education and training;
• Develop and implement a safety programme with appropriate safety standards;
• Improve machines and design equipment according to satisfactory ergonomic standards.

Tactics

Methods to enhance human resource values include:
• Encourage self-improvement;
• Provide training and retraining;
• Adhere to safe working procedures;
• Conduct regular inspections with the aid of checklists to ensure that all machinery and tools are mechanically sound and equipped with the appropriate safety devices;
• Evaluate the ergonomics status of equipment;
• Enforce the use of prescribed personal protective clothing and equipment;
• Ensure that all operators have been trained or are in training before operating any equipment;
• Use warning signs where required and adhere to them at all times;
• Report all accidents according to legislative requirements;
• Promote occupational health and hygiene.

2.8 Commercial Values

Commercial values refer to the efficient utilisation of capital, equipment and human resource to profitably convert the standing tree into a marketable product. Forestry products are typically low value, high volume products which require extremely efficient supply chain planning, execution and management. Forest engineering costs in South Africa typically constitute between 60 and 70% of the entire forestry value chain costs.

Strategy

• Forest engineering must be seen as a link in the holistic production chain from the nursery to the processing plant;
• Maximise profits by optimising value recovery through the application of sound harvesting practices, whilst considering the management prescriptions for other important values (such as site sustainability);
• Minimise transport costs by concentrating on a well-planned, constructed and maintained road network.
Tactics

Methods to enhance commercial values include:

• Each operation should strive towards satisfying the needs of the customer in terms of the “In Full, On Time and All Specifications Met” principle;
• Specify grading for the various states of conversion in the harvesting plan and control this during the operations;
• Knowledge of the work object, final product, available harvesting systems, safety standards and harvest planning are all essential.
Planning is vital for the optimisation of parts of the forest engineering value chain as well as the forest engineering value chain as a whole. A balance of the optimal forest road networks, harvesting systems and transport systems which are aligned with the most profitable market’s requirements and future sustainability must be found and implemented. The objective is to select and implement systems which minimise costs and maximise revenue, but which are balanced with other objectives such as social, environmental and quality considerations.

Planning success will depend on:

- Reliable maps;
- Well defined operating objectives;
- Group reconnaissance trips;
- Careful system choices;
- Thorough paper planning and field verification;
- Thorough review of implications (impact appraisal);
- Readiness to change the plan if required by having alternative choices;
- Effective communication between planners and operators;
- Market conditions and expected market volumes;
- Product specifications;
- Accurate yield information.

Planning is carried out at four distinct levels; namely strategic, tactical, annual and operational. All four levels apply to all spheres of forest engineering operations; namely roads, harvesting and transport. They vary significantly in the time frame they span as listed below.

<table>
<thead>
<tr>
<th>Type of planning</th>
<th>Time frame</th>
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<tr>
<td>Strategic</td>
<td>Full rotation length of timber (several years)</td>
</tr>
<tr>
<td>Tactical</td>
<td>3 – 5 years (generally the life span of equipment)</td>
</tr>
<tr>
<td>Annual</td>
<td>Yearly</td>
</tr>
<tr>
<td>Operational</td>
<td>Per operation – continuous</td>
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One should note that the different types of planning vary significantly in their focus, but all are necessary for a well-planned, productive, sustainable forest engineering system to be achieved. The types of planning have been discussed briefly in the paragraphs which follow.

The Strategic Plan (also known as the long term fibre resource plan or LTFRP) generally covers a period of time equal to the rotation age of the commodity being procured (i.e. around 8 years for hardwood pulpwood, or around 25 to 30 years for softwood sawtimber). It identifies the annual allowable cut to sustain a normal forest, as well as considering harvesting and transport trends and the external environment. It provides a schedule of predicted volumes to be harvested, and forms a high-level approach to which the business should align itself.

The Tactical Plan covers a forecasted period of 3 to 5 years. It lays the foundation for all short to medium term road, harvesting and transport decisions and is a three to five year working plan to ensure a continuous, sustainable timber supply, considering available timber volumes and market requirements. It is done to ensure appropriate selection, allocation and utilisation of resources and equipment, ultimately leading to a cost effective, sustained timber supply. The plan considers the entire forest engineering chain (i.e. roads, harvesting and transport systems) as well as its implications on the external environment, and aims to find a solution which most efficiently meets the targets required of it. It is therefore imperative that a forest engineering tactical plan be comprised of access development, harvesting and transport plans, the interdependencies of which have been considered and interwoven.
The **Annual Plan of Operations (APO)** covers a forecasted period of one year. It details the roadworks, areas to be harvested and corresponding transport plans and routes for the harvested timber/biomass to be moved along. It forms the basis for the annual budget and comprises the following:

- Scheduling of roadworks to be carried out within the course of the year;
- Scheduling of compartments to be harvested and corresponding equipment/systems to carry out the harvesting;
- Scheduling of the extraction, extended primary transport, secondary intermediate transport and/or secondary transport operations associated with the timber/biomass to be removed from each compartment.

The **Operational Plan** covers a single forecasted operation (e.g. the construction of a single road or the harvesting of a single compartment). In this planning, one operation from the APO is planned in detail in terms of the activities required to carry it out. An operational plan can detail how and when a compartment will be felled, how and when the timber/biomass will be removed and transported to the mill or how and when roadworks will be carried out on a specific road.

Field work (including terrain classification and impact assessment) is fundamental to tactical, annual and operational planning. It is imperative that competent people do the planning and that the machine operators and supervisors are involved in the process. The planning of forest roads (access development), harvesting and transport are discussed in the chapters which follow.
CHAPTER 4: Access Development (Forest Roads)

In forestry operations, the planning, construction and maintenance of the forest road network, depots, landings and extraction routes is referred to as access development. This is necessary to provide passage for equipment and personnel to the standing tree, and to facilitate the removal of products from the forest. Access development is generally a costly exercise which can have a major influence on transport and harvesting costs. Poor access development is a threat in terms of erosion, soil displacement and sedimentation of streams. Once road construction has commenced, the impact becomes difficult to reverse.

A well planned, constructed and maintained forest road, extraction route and associated drainage network is essential to ensure low transport and extraction costs, safe driving and a road that blends in with the environment. Although this chapter provides guidelines for forest road construction, the same influencing factors, potential impacts and methods of reducing negative impacts also apply to the upgrading and reconstruction of existing roads. For more detailed information on forest roads, refer to the South African Forest Road Handbook (www.icfr.ukzn.ac.za).

4.1 Road Classes

In South African forestry, roads are classified into one of three categories, namely:

- **Class A** – Roads suitable for all vehicles in all-weather conditions, with full signage;
- **Class B** – Roads suitable for all vehicles and can be all-weather roads. Constructed to a higher standard than Class C roads;
- **Class C** – Roads suitable for all vehicles, but will most likely not be all-weather roads and will most likely not cater for two way traffic.

Regarding the purpose of the road, it should be built and maintained to the specification as required for the type of traffic, quantity of traffic, and season in which the traffic will use the road. Construction, management prescriptions and maintenance requirements vary significantly depending on the road class in question.

4.2 Access Development Tactical Plan

An optimal balance between forest roads, extraction routes, landings and depots is required to maximise the long-term profitability of land owner’s assets. Road spacing (the average distance between roads for a certain area), road density (the total length of road/s within a specific area) and extraction route density (the total length of extraction route/s within a specific area) should be consistent with forest management requirements. The forest road design, method of harvesting and transport systems should all be considered together.

**Factors influencing the planning of access development:**

- Size of area to be opened up;
- Topography;
- Terrain (e.g. proportion of steep and flat areas);
- Soil properties;
- Competence of planners;
- Availability and type of road construction equipment;
- Types of harvesting and extraction systems to be used;
- Types of loading and transport systems to be used;
- Volume of timber to be removed;
- One-way versus two-way traffic requirements.
Potential negative impacts of inefficient planning may include:

- High transport costs due to inaccessibility, incorrect road standards, incorrect vehicle choice, and poor placing of landings and depots;
- Loss of productivity due to the inability to balance harvesting and transport systems;
- Unnecessary costs to upgrade, restore and maintain roads;
- Over-capitalising on road construction due to incorrect standards or unsuitable road and extraction route density;
- Loss of productive forest areas;
- Damage to the natural environment and other sensitive areas;
- Purchasing of harvesting equipment or employing extraction methods that do not fit in with the overall harvesting systems;
- Delays in timber supply caused by poor road standards or unfinished roads.

Methods of reducing the likelihood of negative impacts:

- Determine the road density needed to achieve the optimal balance between the terrain, harvesting methods and transport systems;
- Plan the road network to minimise the total cost from stump to mill (extraction, extended primary transport, secondary intermediate transport, secondary transport and road construction costs);
- Decide on a practical and consistent road identification system;
- Design and construct roads using sound engineering guidelines and standards that will minimise maintenance and road user costs, as well as meet the functional requirements keeping in consideration the planned life-span of the road;
- Design and construct roads as straight and flat as far as is practical to minimise the amount of gear changes and reduce fuel consumption for transport vehicles;
- Plan roads and extraction routes well in advance of the felling operations;
- Consider transport directions and the use of both one- and two-way traffic options;
- Generate a long-term road maintenance programme to ensure timely maintenance, restoration or upgrading to maximise cost savings;
- Conduct continuous maintenance on roads being used for timber haulage;
- Include haulage roads, extraction routes, landings and depots in the road network;
- Fit the access network to the topography to limit interference with the natural surroundings;
- Avoid duplication of opening up (i.e. do not construct roads in areas that can be reached from an existing road);
- Identify borrow pits (gravel pits) containing suitable material for road construction;
- Compare alternative routes to determine the most appropriate route (balancing management requirements, environmental issues, construction costs and long-term transport costs).

4.3 Roads and Depots

4.3.1 Road Design

The design of a forest road must be consistent with the objective of the strategic, tactical, annual and operational plans. Road standards depend on the terrain and the proposed means and objectives of the corresponding harvesting and transport operations.

Factors influencing the design of the road:

- Purpose/s for which the road will be used;
- Amount of timber to be hauled over the road;
- Longitudinal and horizontal terrain profiles;
- Soil types and in situ materials available for construction;
- Volume and dimensions of timber products to be transported;
- Types and dimensions of vehicles to be used for timber transport;
- Load sizes;
• Travel speeds;
• Season of road usage (wet or dry);
• Proximity of road construction materials;
• Length of season suitable for road construction and time required for road aggregate to consolidate before heavy use;
• Road use patterns (i.e. permanent or periodic);
• Rainfall pattern, peak flow times and flood events to determine minimum drainage standards;
• Future harvesting and/or planting considerations.

The operational plan should include:
• The site map, indicating the centre line, road width, positions of cuts and fills, bends, position of cross sections, engineering structures and drainage network;
• The longitudinal profile indicating the profile of the terrain, the planned grade line, the centre line, elevation of the road and cut fill areas;
• Horizontal profile indicating terrain as well as cut and fill slope dimensions;
• Balancing of earth movements (i.e. cutting as much as is required to be filled);
• Drainage and other engineering structures;
• Scheduling of construction operations, people and machines;
• Capital and life cycle cost estimates.

Positive results of a well-designed and planned road:
• Unnecessary road length and width minimised due to good planning and road specifications consistent with management requirements;
• Roads constructed under suitable weather conditions;
• Time provided for roads to consolidate after construction to decrease the rate of sedimentation and runoff from the road surface, and decreased side cast material and spills;
• Impact on the natural environment and sensitive areas is minimised;
• Side cuts and fills are stable;
• Transport costs are reduced;
• Repair and maintenance costs are reduced;
• Improved driver and vehicle safety and comfort.

Methods of reducing the likelihood of negative impacts:
1. Road Planning
• Use qualified and competent people to design roads;
• Match the total area (length and width) of roads to meet operational requirements;
• Comply with the minimum safety and construction requirements for the anticipated traffic load;
• Match road design to the functional requirements of the transport vehicles in order to minimise user costs (i.e. minimise gear change and maximise average vehicle speeds);
• Do not exceed maximum allowable gradients as prescribed in respective original equipment manufacturer (OEM) specifications;
• Use planning resources, such as topographic maps and aerial photographs to identify areas where roads should, and should not be located;
• Avoid steep and unstable sites, large rocks and cliffs, sites prone to landslides and environmentally sensitive areas such as swamps, sandy soil, natural drainage channels and riparian zones;
• Make use of natural topographical feature such as saddles, ridge tops, natural benches (Figure 3) and flatter slope, to keep earth works to a minimum.
Figure 3: Natural bench.

- Ensure the survey of the proposed road is thorough, accurate and documented;
- Pre-determine potential stream crossing points, but attempt to minimise the number of stream crossings;
- Ensure crossings are at right angles to the stream;
- Ensure that both the approach and departure areas to and from the stream are level;
- Minimise interference with natural drainage (e.g. use bridges or culverts rather than fords);
- Construct roads running parallel to a stream as straight as possible and not following the stream flow path (Figure 4);

Figure 4: Road construction next to streams.

- Avoid designated scientific, ecological, paleontological, archaeological and historical sites;
- Locate total road width and side cast material outside designated Special Management Zone's (SMZ's) such as riparian zones (Figure 5).

Figure 5: Roads near special management zones.
2. **Road Geometry**

Road surface shapes and characteristics depend on management objectives and terrain:

- **Crowned roads** (roads whose centre lines are elevated to a roof type profile in order to allow excess water to flow off the road to both the cut and fill slopes, *Figure 6*):
  - Water is quickly drained off the road surface;
  - Slope of crown: 3% to 6%;
  - A suitable drainage system and drainage structures are required;
  - Suitable maintenance of the road surface, side drains, cross drains and culverts is essential.

![Figure 6: Crown roads.](image)

- **In-sloping roads** (roads whose entire running width slopes towards the cut slope, *Figure 7*):
  - Recommended in mountainous terrain to control surface drainage and for ease of construction;
  - Keep the road width as narrow as is practical to minimise disturbance;
  - Suitable drainage systems and corresponding construction and structures are required;
  - Suitable maintenance of the road surface, side drains and culverts is essential;
  - The slope across the road must be 4% to 6% higher than the longitudinal (travel) grade.

![Figure 7: In slope roads.](image)

- **Out-sloping roads** (roads that drain water to the outside (fill slope), across the entire road running surface, *Figure 8*):
  - Only recommended in areas with gentle topography;
  - Hard-wearing material must be used on the road surface;
  - Regular maintenance of the road surface is required;
  - The slope across the road must be 4% to 6% higher than the longitudinal (travel) grade.

![Figure 8: Out-sloping roads.](image)
3. **Cut and Fill**

- Combine horizontal and longitudinal profiles to balance cuts and fills, so that excavated material from cut sections can be used for filling the other sections thus minimising the amount of earth excavation and material handling (*Figure 9*);

![Figure 9: Longitudinal cut and fill.](image)

- Avoid large cuts;
- Balance the cross sections to utilise *in situ* material (*Figure 10*);
- Use excavators as much as possible for earth-moving operations;

![Figure 10: Cross sections cut and fill.](image)

- **Benching** of embankments may be required (*Figure 11*):
  - In areas with highly erodible soils;
  - To stop and redirect water runoff before it reaches the road, thus helping to prevent erosion;
  - To limit the amount of debris potentially falling on the road during construction and normal use;
  - To improve a driver’s line-of-sight;
  - To allow passage for tree ends with tree-length transport;
- Do not use material that can decompose (branches, organic material and topsoil) in the fill;
- Design embankments (cut or fill side slopes) to match the soils ability to maintain the slope’s angle of repose so to reduce cut slope collapse and hence soil erosion (See following table).
• **Full bench** construction is recommended in the following situations (*Figure 12*):
  - On slopes with a horizontal profile in excess of 60%;
  - In deep, soft soils;
  - Where excavated material on potential fill slopes poses a landslide threat;
  - Where the road is situated above streams, indigenous forest or other sensitive areas;
  - Where the material is required for fill elsewhere.

---

**Recommended maximum angles of repose of cut slopes for different in situ material**

<table>
<thead>
<tr>
<th>Material</th>
<th>Angle</th>
<th>Percent</th>
<th>Degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut – Stable Soils</td>
<td>1:1</td>
<td>100%</td>
<td>45°</td>
</tr>
<tr>
<td>Non-cohesive soils</td>
<td>1:2</td>
<td>50%</td>
<td>27°</td>
</tr>
<tr>
<td>Parent Rock</td>
<td>10:1</td>
<td>–</td>
<td>85°</td>
</tr>
<tr>
<td>Fill</td>
<td>4:5</td>
<td>80%</td>
<td>39°</td>
</tr>
</tbody>
</table>

---

*Figure 11: Benching of a road.*

*Figure 12: Benching of a road.*
4.3.2 Depot Design

Depots are areas for potentially large volumes of timber to be stored and/or handled prior to transportation to processing sites or other intermediate and final locations. They are usually used by extended primary or secondary intermediate timber transport operations, and should be planned, constructed, maintained and rehabilitated (if no longer required) as part of a strategic primary and secondary transport network. Landings do not fall into the same category as depots, and are covered in section 4.6.2 of this manual.

Factors influencing depot design:

- Terrain (e.g. slope, aspect and soil type);
- Maximum volume of timber to be stored at any one time;
- Timber size, log assortments and stack dimensions;
- Potential volume of build-up of bark and off-cuts and other logging debris;
- Types and numbers of machines to be employed for processing, sorting, stacking, loading and transport;
- Length of the season suitable for potential construction and time required for depot to consolidate before heavy use;
- Rainfall pattern to determine the minimum allowable drainage standards (use severe rainfall events rather than the annual average rainfall to calculate this);
- Life-span of depot.

Positive results of a well-designed depot:

- Confined area of concentrated timber volumes to facilitate loading operations with limited spill over of operations and potential logging debris;
- Limited potential for soil erosion and runoff to pollute streams and sensitive zones;
- Improved safety;
- Improved inventory and stock control;
- Improved vehicle movement control.

Potential negative impacts of a poorly designed depot:

- Soil erosion and sedimentation;
- Visual impact;
- Damage to logs and equipment;
- Poor inventory and stock control;
- Impaired water quality due to water run-off and streamside pollution.

Methods of reducing the likelihood of negative impacts:

- Situate depots away from streams and plan them in such a way that the eroded material does not enter any watercourses;
- Locate depots away from sensitive areas;
- Do not harden depot if it is not necessary;
- Mark (cordon off) depot boundaries so they do not encroach on surrounding area, nor do they become encroached upon by the surrounding vegetation;
- Where possible, avoid building a depot on the edge of a steep slope, however, a gentle slope (not exceeding 6%) will facilitate drainage;
- Manage water runoff to prevent excess sedimentation and poor water quality, especially where logs may need to be irrigated by diverting water leaving the depot into surrounding vegetation and silt traps;
- Avoid using fire breaks a depots;
- Depots must be well drained and kept as dry as possible at all times;
- Divert water leaving the depot into surrounding vegetation and silt traps, not directly into water courses;
- Special attention should be given to drainage and surfacing of depots to be used in the wet season;
- Stockpile cover material (clear of bark, branches and other debris) for eventual use in depot rehabilitation;
- Plan fuel sites and machine maintenance areas well and keep them as far as possible away from water courses;
• Do not place depots or loading equipment below power lines or electrical utility lines;
• Make provision for the temporary stock piling of bark and off-cuts.

4.4 Forest Road Construction

Forest roads refer to all the paved and unpaved roads required to transport forest products, equipment, and personnel to and from the forests as well as within the forests. Construction of forest roads generally requires earth movement and, depending on the type of road being constructed, some form of surfacing. They should therefore be well thought out and planned to achieve exactly what is required of them in a sustainable, economically efficient, productive manner. Roads should be pegged out before corridor preparation commences to ensure that the road plans are well copied into reality.

4.4.1 Corridor Preparation

The corridor is the area of a new road that must be cleared before earth moving operations can start. The width of the corridor is equivalent to the road width plus an additional cleared verge area. The corridor includes the cut slope area and the fill slope area. All vegetation is cleared from the corridor and potential marketable timber (if the corridor runs through standing trees which must be felled for the corridor to be opened) is prepared for removal. Topsoil removed from the road path can be used for the rehabilitation of cut and fill surfaces or stockpiled for other uses.

Factors influencing corridor preparation:
• Type and density of the vegetation;
• Size and total volume of marketable timber within the corridor;
• Length and width of the road;
• Slope of the terrain and ground roughness;
• Season and rainfall pattern when corridor preparation is to commence;
• Possible environmental hazards and negative impacts.

Positive results of well-prepared corridors
• Extended line-of-sight distances;
• Road markings are clearly visible and easy to follow;
• All marketable timber felled to open the corridor can be removed efficiently before construction commences;
• Topsoil is not lost and can be reused for slope stabilisation or other uses.

Potential negative impacts of poor corridor preparation:
• Soil erosion and sedimentation;
• Marketable timber damaged and/or destroyed;
• Marketable timber, topsoil and slash can be covered by the fill;
• Corridor clearing operations become unsafe.

Methods of reducing the likelihood of negative impacts (Figure 13):
• Clear the area of trees and brush well in advance of construction to allow the soil to dry out;
• Stack marketable timber in the cleared area and remove it before construction begins;
• Stack unmarketable timber, branches and underbrush at the downhill edge of the road below the extent of the fill material, to reduce side cast spilling or moving further downhill;
• Install culverts and bridges in advance of actual construction to keep the activities as dry as practical;
• Remove topsoil (including litter and raw humus) and store it above the cut for later use;
• Remove stumps, logs and debris to prevent them being buried in the load-bearing portion of the road;
• Use the correct construction equipment to limit impacts.

4.4.2 Earth Moving

Construction of the road itself (in the initial form of earth moving) can commence after road planning and corridor clearing.

Factors influencing earth moving operations:
• Length, width and sub grade depth of the road or depot;
• Slope of the terrain, ground cover (grassland or dense bush) and ground roughness;
• Soil type (sensitivity to erosion);
• Total volume and distance that earth/gravel is moved to fill cuts and for road surfacing;
• Correct ratio between cut and fill;
• Types and limitations of construction and transport equipment (e.g. haulers);
• Season and rainfall pattern when construction is to commence;
• Suitability and availability of in situ materials to avoid bringing in additional material.

Positive results of good earth moving operations:
• Timely opening up of the terrain (corridor preparation) allows routes to be prepared and drained before grade preparation commences;
• A well-constructed sub grade lays a sound foundation for the construction of the base and surface course;
• Limited impact on the environment.

Potential negative impacts of poor earth moving operations:
• Negative visual impact;
• Water quality may degrade as a result of increased sedimentation in runoff from roads and side cast spill;
• Loss of fill material due excessive side cast spills;
• Damage to the natural environment (e.g. riparian zones and indigenous forests) and sensitive areas due to side cast spills;
• Soil slides caused by inadequate angles of repose of cuts and fills;
• Inadequate supply of in situ material resulting in high transport costs during grade preparation and surfacing;
• Increased fire hazard due to rolling rocks, blades of earth moving machines and faulty exhaust systems;
• Fuel and oil spillages;
• Damage to standing trees and the natural environment caused by aggressive opening up methods (e.g. blasting and side casting, oversized machines); and;
• Injuries to workers.

Methods of reducing the likelihood of negative impacts:

1. Excavation

   • Balance cut and fill soil volumes correctly;
   • Avoid working in excessively wet conditions;
   • Utilise available material from the cut for the fill or transport it to an area where material for fill is not available if it is of suitable quality (strength);
   • Use excavators rather than bulldozers in sensitive areas and steep slopes (Figure 14):
     ○ Excavators can be used to construct full bench road profiles;
     ○ Excavators allow more efficient use of material (not lost on fill slopes) resulting in lower visual impact;
     ○ Cut material can be loaded by the excavator for transport to another location;

   ![Figure 14: Use of excavators on sensitive or steep slopes.]

• Side casting (Figure 15) can be used in more stable and easier terrain, but:
  ○ The cut and fill techniques require compaction of the fill and greater planning intensity;
  ○ Side casting can produce greater visual impact;

   ![Figure 15: Side casting.]

• Warning and information signs should be posted around the construction zone;
• Do not allow people or activities on the lower slopes during excavation;
• Install fords, culverts and drainage devices as soon as possible after corridor preparation and maintain them;
• Do not push fills into streams or a position where they can be washed into streams.
2. **Blasting**
   - Only certified experts may work with explosives and should be consulted during road planning;
   - Keep blasting to a minimum to lessen costs and avoid damage;
   - Control blasting so that blasted material can be utilised;
   - Adhere to safety regulations.

4.4.3 **Drainage and River Crossings**

Water is the greatest causer of road degradation. Excess water on the road weakens the foundation, erodes surfaces and embankments, and causes landslides. Water must be diverted away from the road or removed from the road surface and then redirected into the surrounding vegetation or drainage channels.

**Factors influencing the drainage system:**
- Slope of the road (longitudinal and horizontal terrain profiles);
- Road surface compaction;
- Rainfall pattern;
- Suitability and availability of in situ material for construction;
- Size, slope, vegetation and soil type of the catchment area;
- Regularity and effectiveness of maintenance.

**Positive results of an adequate drainage system:**
- Reduced maintenance and reconstruction costs;
- Increased life-span of the system;
- Reduced transport costs;
- Less erosion and sedimentation caused by uncontrolled water runoff;
- Enhanced safety and driver comfort.

**Potential negative impacts of an inadequate drainage system**
- Degradation of road surface, resulting in higher transport costs;
- Roadway erosion and washaways;
- Erosion and weakening of cut slopes and fills;
- Erosion of side drains when there is inadequate diversion and high velocities of runoff;
- Reduction of water quality due to increased sedimentation during construction and high traffic movement;
- Damming of streams and diversion of water courses;
- Impedance of aquatic life due to potential streambed scouring;
- Visual impacts;
- Localised disturbance to stream beds and river banks.

**Methods of reducing the likelihood of negative impacts:**

1. **Road surface**
   - Ensure a minimum longitudinal gradient of 2-3% to facilitate water runoff, depending on terrain restrictions;
   - Ensure the requirements for the slope of crowned, in-slope and out-slope roads are met;
   - Install side drains, catch drains, mitre drains and/or culverts to remove water. Water bars and reverse dips can also be used;
   - Do not build out-sloping roads in steep terrain or on high clay content soils (vehicle travel becomes hazardous in wet conditions);
   - Construct scour checks to slow water velocity in side drains;
   - Ensure that run-off from the road is not discharged directly into the streams; divert water into surrounding vegetation or sediment traps.
2. **Side drains, mitre drains and catch drains** *(Figure 16)*

- Construct drains on the side of a road to catch the surface runoff from the road, and divert run-off to an area suitable for dispersing the water;
- Construct catch drains above the cut slope to intercept surface runoff which would otherwise cause erosion on the face of the cut slope;

  ![Figure 16: Side and catch drains.](image)

- Reduce erosion in drains where high water flow velocities are expected (e.g. by lining with stones, concrete, grass and gabions);
- Ensure drains have a minimum gradient of 3% so as to facilitate drainage;
- Use mitre drains, water bars and/or reverse dips for the dispersal of water where required;
- Inspect, maintain and clean drains regularly.

3. **Culverts**

- Space culverts according to road grade, soil and rainfall intensity;
- Install culverts at all points where a road crosses a seasonal or permanent watercourse unless an alternate form of crossing is required (e.g. a bridge);
- Minimum diameter of culverts will depend on the rate of stream flow, surrounding topography and maximum rainfall events;
- Install culverts on well prepared and compacted beds, with a fall of at least 2% (too little fall will result in sedimentation and blocking, whereas too much will result in scouring);
- When installing culverts do not push fills into streams or into a position where they can be washed into streams;
- Protect crossing embankments by using gabions, concrete structures or hyson cells;
- Protect the inlet and outlet of culverts from entering and discharging flow;
- Use sediment traps made of logs, rocks, tree tops, branches or concrete;
- Inspect, maintain and clean culverts regularly;
- Design culverts to allow for fish movement;
- Use headwalls to minimise erosion around the culvert inlet and outlet;
- Ensure culverts are joined in a watertight manner (e.g. using rubber collars and grouting) to prevent water exiting at join points;
- Select culvert strength based on type and intensity of traffic to be going over it;
- When installing a culvert, ensure a fill of soil at least 50% of the diameter of the culvert on top of it.

4. **River Crossings**

River crossings *(Figure 17)* are constructions at which seasonal or permanently flowing stream or river waterways are traversed by traffic. The selection of which type of crossing to install is largely determined by peak water flow volumes. Culverts can be used for waterways with low peak flow volumes (see previous sub-section for these prescriptions), or fords and bridges can be used. Considerations to bear in mind when considering river crossings are as follows:
• Do not alter the natural flow of the stream (slope and alignment);
• Avoid steep approaches to stream crossings;
• Stream crossings should be at right angles to the stream, where possible;

Figure 17: Construction of river crossings.

• Select natural crossings with easy approaches;
• Construct stream crossings on firm, stable soil, concrete base or rock substrate;
• Consider the viability of alternative routes to minimise the number of crossings;
• Plan construction to coincide with low water flows to prevent environmental impacts;
• Prevent damage to river beds and side walls by protecting the inlet and outlet;
• Construct stream crossings in such a manner so as to minimise disturbances to the existing stream;
• Design the crossing to ensure accessibility during peak flood flow;
• Keep machines out of streams as much as practical during construction;
• Restore remaining stream in situ structure, river beds and stream banks (as close as possible) to their original state following crossing construction.

5. Drifts (Fords)
• Only suitable for seasonal access of low use roads (Figure 18);
• Consolidate stream entry and exit points to reduce scouring;
• Use a firm stable stream bed (preferably rock) and approach to minimise stream bed disturbance and limit water quality degradation during use;
• Use gabions, hyson cells and/or concrete structures to protect the crossing;
• Use an excavator for construction to reduce the impact of stream disturbance and consequential sedimentation.

Figure 18: Construction of drifts.
6. **Bridges** *(Figure 19)*

- Consult a specialist in terms of construction and maintenance;
- Consider alternative road locations before deciding that a bridge is necessary;
- Design permanent stream crossings to withstand specified flood levels (e.g. 50 years);
- Use only rot resistant and/or treated timber when constructing a permanent crossing from wood;
- Use kerbs on the side of the bridge, where required, to stop fill material (gravel) from sliding down the sides;
- Design bridges so as not to disrupt fish passage;
- Protect bridge embankments by using concrete structures, timber barriers, gabions or vegetation;
- Inspect and maintain bridges regularly.

![Figure 19: Construction of a forest road bridge.](image)

### 4.4.4 Bends and Intersections

Bends and intersections in the road network can have a major impact on vehicle speed and therefore influence transport productivity and costs. Bends and intersections should be well planned and constructed.

**Factors influencing bends and intersections:**

- Minimum vehicle turning circle;
- Slope of the terrain, ground cover (grassland or dense bush) and ground cover roughness;
- Soil type (sensitivity to erosion);
- Rocky outcrops;
- Ratio between cut and fill.

**Positive results of well-designed bends and intersections:**

- Extended line-of-sight distances and enhanced driver safety;
- Higher average speed;
- Reduced transport costs;
- Reduced road maintenance costs.

**Potential negative impacts of poorly designed bends and intersections:**

- Limited line-of-sight distances;
- Potentially high visual impact;
- Erosion and sedimentation problems;
- Dangerous bends and intersections;
- Reduced transport options.
Methods of reducing the likelihood of negative impacts:

1. Bends
   • Use a minimum radius that is compatible with the proposed transport system;
   • Consider the average transport speed required when designing the bend;
   • Design the road so that there is an intermediate straight line (calculated by 1.5 x vehicle length) between bends (Figure 20);

   ![Figure 20: Determining straight line distance between bends.](image)

   • Increase the width of the road in a bend to improve maneuverability and safety around corners. Widening starts and ends approximately 10 to 30 m before and after the bend;
   • Ensure adequate driver visibility, which depends on travel speed and condition of the road surface (minimum stopping distance);
   • Keep the radius constant throughout the bend (Figure 21);
   • Use one bend with a larger radius rather than two sharp bends in the same direction;
   • Use one sided camber (in-sloping) on bends with radii of less than 100 m. Banking of the outside of the curve improves safety and driving comfort and reduces maintenance costs.

   ![Figure 21: Maintaining constant radius through the bend.](image)

2. Intersections
   • Obtain approval from the relevant authorities for intersections with public roads where appropriate;
   • Do not make the longitudinal grade of the approach road more than 6% where practical;
   • Design road intersections as close to right angles as possible (even if it is necessary to introduce a curve before the intersection, Figure 22);

   ![Figure 22: 90° road intersections.](image)
• Intersecting road angles, for two-way traffic, should not be less than 60˚ (Figure 23);

![Figure 23: Intersecting road angles for two-way traffic.](image)

• Intersecting road angles can be less than 60˚ when the direction of haul is one way only (Figure 24);

![Figure 24: Intersecting road angles for two-way traffic.](image)

4.4.5 Road Surfacing

The structure of a forest road generally consists of the following (Figure 25):

• Sub grade – This is the road surfacing foundation (*in situ* material);
• Base course – This is the layer of materials that support the weight of the traffic. On roads with only one layer on top of the sub grade this layer has a dual function; it provides for vehicle support and is the vehicle running surface;
• Surface course – This is the top layer that provides a running surface for vehicles.

![Figure 25: Typical forest road structure.](image)

Surfacing refers to the addition of layers of materials on or above the sub grade surface. All roads have some form of surfacing, which could consist of one or more layers. The surfacing may be concrete, asphalt, crushed aggregate, stabilised, native or earth surfaces. The last four types of surfaces are common to forest roads.

• Crushed aggregate – Sized material that has been crushed (manufactured) and blended to meet the specifications of required particle size;
• Stabilised surface – Road surfaces whose existing materials are modified by the addition of chemical stabilisers for added layer strength, dust abatement and to prevent surface moisture penetration;
• Native surface (gravelling) – Surfaced with naturally occurring imported materials that may or may not be modified;
• Earth Surface – Surfaced with soils from within the roadway \textit{(in situ)}, without the use of imported or manufactured materials.

The number, quality and thickness of the selected layers will depend on the proposed traffic loading and sub grade characteristics.

**Factors influencing road surfacing:**

• Traffic intensity, season and load volume;
• Standard and life expectancy of the road;
• Curvature, longitudinal slope and horizontal slope profile;
• Season and rainfall pattern when surfacing is to commence;
• Transport distance of imported materials;
• Types and limitations of transport and construction equipment;
• Sub-grade characteristics (e.g. swelling clays or poor drainage);
• Time required for the sub-grade to consolidate;
• Total volume and types of material required for the base and surface course.

**Positive results of good surfacing operations:**

• A sound surface source (laid on a good quality base course and a well prepared sub grade) will support traffic in a safe and cost effective manner;
• Correct compaction of the sub grade base- and surface course will reduce maintenance costs and extend the life of the road;
• Improved load bearing capacity of the road;
• Improved ride quality;
• Increased travel speed;
• Less erosion and sediment flow.

**Potential negative impacts of poor surfacing operations:**

• A road may not reach its design life if the sub grade and surface layers are inadequately designed, constructed, maintained or used;
• Rapid degradation of the road surface may occur due to the poor preparation of the foundation or poor choice of surfacing material;
• Visual impact increased;
• Water quality can deteriorate due to increased sedimentation during construction and road use;
• Dangerous and/or impossible vehicle movement;
• Increased transport costs;
• Difficult and expensive maintenance.

**Methods of reducing the likelihood of negative impacts:**

1. **Sub grade preparation**

• Excavate poor quality sub grades (clayey soils and/or low load bearing soils) and replace with better quality material;
• Install sub-surface drainage in wet areas and where water-sensitive soils occur;
• Rip and mix the road bed, apply water to achieve optimum moisture content and then compact to the recommended bulk density;
• Test the sub grade for sufficient compaction before commencing with surfacing;
• Shape the surface of the sub grade to ensure drainage.

2. **Base course**

• Ensure adequate strength to support traffic loading by increasing thickness of the layers, using better quality material or using modified material (e.g., chemical stabilisers);
• Take cognisance of the environmental conditions and the micro-climate when selecting material.
3. Surface course

- Ensure the material is suited for the envisaged road standard;
- Use good quality material for construction and routine maintenance;
- Use material that is suited to rainfall patterns and micro-climate conditions;
- Ensure the surface is smooth and with adequate camber to encourage water runoff;
- Camber according to road standard and material characteristics;
- Perform soil tests to determine suitable road paving mixtures;
- Adjust the thickness of the pavement depending on the expected axle mass loads, traffic density, design of the road and properties of the material used;
- Determine if in situ materials can be utilised to reduce transport costs;
- Ensure adequate compaction (at optimum moisture content);
- Build roads above the natural ground level where possible to ensure adequate drainage.

4.4.6 Rock Quarries and Borrow Pits

Factors influencing the choice and size of rock quarries and borrow pits:

- Terrain (slope and soils type, sensitivity to erosion);
- Available material and material quality;
- Total volume of rock or gravel required and/or available;
- Transport distance from source to project;
- Type of loading and transport equipment available;
- Over burden or topsoil materials available for maintenance and rehabilitation;
- Visibility from public roads and public areas;
- Possible environmental impacts;
- Legal constraints. Refer to Minerals Act (Act 50 of 1991) where all quarries and borrow pits are classified as mines and are required by law to obtain a mining permit. A permit is not required where the material will be used on one's own property (i.e. not sold). Further information can be obtained from the Department of Mineral and Energy Affairs.

Positive results of good rock quarries and borrow pits selection:

- Decreased road construction costs;
- Improved material used for hardening of roads;
- Decreased road maintenance cost;
- Decreased erosion of road;
- Decreased sedimentation into sensitive areas.

Potential negative impacts of poor rock quarries and borrow pits selection:

- Long term visual impact;
- Soil erosion, mass soil movement and water quality deterioration;
- Illegal positioning of quarries and borrow pits;
- Safety hazard.

Methods of reducing the likelihood of negative impacts:

- Draw up a management plan which will address mining approach, extent of opening up, boundaries, amount of material required, overburden management strategy, environmental and social considerations and mitigations as well as a maintenance and rehabilitation strategy;
- Locate borrow pits and quarries so that they are visually unobtrusive, by leaving a tree barriers and/or brush screens to shield them from view or by locating them behind a hill, ridge or other natural barrier, if possible;
- Locate borrow pits and quarries to avoid potential damage to or interference with streams and riparian zones;
- Store topsoil and organic matter from borrow pits or quarries for subsequent borrow pit or quarry rehabilitation;
• Consider the drainage of borrow pits during the planning phase and maintain drainage in regularly used quarries;
• Direct drainage through a filter strip or silt traps and not directly into a watercourse;
• Ensure adequate signage;
• Mark (corden off) the boundaries to ensure the borrow pit/quarry is managed within the parameters and boundaries set for it;
• Do not mine quarry to a vertical slope, rather terrace or slope it to reduce rock fall and ensure safety;
• Where possible, mine horizontally into a slope rather than vertically downwards into a hole.

Rehabilitation of rock quarries and borrow pits:
• Consult the Mineral Act (Act 50 of 1991) to ensure that legal requirements are met;
• Rehabilitate all rock quarries and borrow pits within two years after they are no longer in use, or progressively, as sections are no longer used;
• Ensure that the area is properly drained;
• Remove all litter and other waste material;
• Smooth slopes and rip compacted areas, and cover with over burden or topsoil materials;
• Stabilise and re-vegetate slopes, preferably using the same species as are found in the natural surroundings.

4.4.7  Slope Stabilisation

Cuts, fills and other exposed faces and slopes should be well drained, protected from erosion and stabilised by natural vegetation regeneration. Re-vegetate either by planting or seeding with grass or other suitable flora.

Factors influencing slope stabilisation:
• Length, width and angle of the slope requiring stabilisation;
• Types of cover material used and method of application;
• Rainfall pattern and intensities;
• In situ materials available for covering the slopes;
• Total volume and type of stabilising material required;
• Time required for slopes to consolidate;
• Season of rehabilitation;
• Degree of slope stabilisation maintenance.

Positive results of good slope stabilisation:
• Reduced risk of erosion;
• Vegetated slopes are more aesthetically pleasing than bare ground;
• Reduced long-term maintenance costs;
• Reduced risk of embankment slip.

Potential negative impacts of poor slope stabilisation:
• Aesthetically displeasing;
• Increased rate of runoff and sediment from exposed slopes may affect water quality;
• Erosion may undercut slopes;
• Dangerous driving conditions due to side slope material being washed onto the road surface;
• Potential landslides and rock falls;
• Drainage systems could silt up or block.

Methods of reducing the likelihood of negative impacts:
• Mulch and seed exposed areas to improve stability and aesthetics and increase;
• Seed as soon as possible depending on season and rainfall pattern;
• Utilise topsoil stockpiled during corridor preparation to encourage re-vegetation of exposed slopes;
• Prevent water from running over slopes and reduce runoff velocity through drainage;
• Compact slopes before seeding, if required;
• Scarify the slope before replacing the topsoil to provide the required bond or use a mechanical pegging or battering device to retain the topsoil;
• Avoid locating roads where they could result in the blocking of stream channels;
• Mix grass seed with an emulsion to assist in keeping the seed in place until it sprouts, especially on slopes. The emulsion also helps preserve ground moisture;
• An initial covering of bio-degradable mats, wire mesh or concrete blocks can also be used to facilitate the vegetation in gaining roothold;
• Apply a thin layer of concrete or wire mesh on rock prone to erosion or rock falls.

4.5 Road Maintenance

Roads must be maintained regularly to ensure a safe, stable running surface and to minimise road deterioration.

Factors influencing the frequency and intensity of maintenance:
• The quality of road surfacing material, road design and construction techniques used;
• Effectiveness of the drainage system and its maintenance;
• Rainfall patterns and season of use;
• Intensity and type of traffic;
• Stability of cuts and fills;
• Standard of the road;
• Longitudinal and side slopes of the road;
• Material used, thickness and treatment of the sub grade and road surface;
• Type and limitations of maintenance equipment;
• In situ and potential import materials available for maintenance.

Positive results of adequate road maintenance:
• Reduced wear and tear on vehicles due to good running surfaces;
• Lower transport costs due to lower vehicle running costs and higher travel speeds;
• Improved safety and driver comfort;
• Reduced dust generation;
• Improved tractability;
• Reduced environmental impacts.

Potential negative impacts of inadequate road maintenance:
• Rapid deterioration of the road surface due to traffic and natural forces (wind and rain);
• Uncontrolled water runoff due to blocked drainage systems (causing erosion, sedimentation and scouring of the road);
• Increased damage and maintenance cost of vehicles;
• Roads having to be prematurely upgraded to their former specifications.

Methods of reducing the likelihood of negative impacts:
• Drain water from the road as soon as possible;
• Apply a planned road maintenance programme to ensure that regular checkups are conducted and maintenance is done when and as required;
• Keep drainage systems open and clear of debris at all times;
• Inspect roads regularly during wet weather as it will help identifying major problem areas;
• Use suitable road construction material, road and drainage standards and construction techniques;
• Fix the source of erosion problems, and not only the problems themselves.
1. **Road Surface**

   - Mow, or blade, reshape and compact the road surface of permanent roads regularly;
   - Temporarily close roads which are prone to wet weather traffic damage after excessive rain;
   - Plant or allow grass to re-vegetate roads that will not be in use for some time. This stabilises road surface thereby resulting in less erosion;
   - Remove trees and other debris that fall onto the road during the harvesting operation as soon as possible;
   - Re-use recoverable material from the sides of the road, then spread and re-level and finally compact the surface layer. However be sure that this material is suitable for re-use (*Figure 26*).

![Figure 26: Recovering material to spread over road surface.](image)

2. **Roadside**

   - Maintain cuts and fills to ensure their stability. Replant or stabilise these as soon as exposed areas appear;
   - Control the roadside vegetation only to the extent necessary to keep the fire control purposes (e.g. by slashing or mowing, *Figure 27*).

![Figure 27: Maintaining roadside vegetation.](image)
3. Drainage

- Clear drains and culverts regularly to avoid blockages;
- Regularly maintain culverts and bridges and silt traps;
- Keep openings to culverts and bridges clear and always ensure that water can flow through them without hindrance;
- Open side drains and mitre-drains with a grader, blade tractor or excavator;
- Inspect and repair stream crossings, drifts, bridges and culverts;
- Maintain scour checks inside drains.

4. Extraction Routes and Landings

4.6 Extraction Route Design

Extraction routes provide access into, within and out of the stand for extraction equipment. Extraction routes generally require no earth moving but should be planned and marked infield before extraction commences.

Factors influencing the extraction route design:

- Slope;
- Ground roughness and obstacles;
- Soil type and susceptibility to erosion and compaction;
- Total volume of timber to be removed;
- Felling and bunching/stacking pattern;
- Timber size and number of passes;
- Positioning and spacing of landings and depots;
- Type and capabilities of machines to be used for extraction;
- Season suitable for harvesting;
- Rainfall pattern;
- Competence of planners;
- Location of SMZ’s.

Positive results of good extraction route design:

- Reduced impact (e.g. soil erosion and compaction) caused by harvesting equipment;
- Controlled vehicle movement in the stand, thus keeping the affected area to a minimum;
- Improved productivity;
- Improved safety and driver comfort;
- Less damage to equipment and tyres.

Potential negative impacts of poor extraction route design:

- Visual impact;
- Loss of productive growth.

Methods of reducing the likelihood of negative impacts:

- Plan extraction routes to minimise the area covered by equipment movement, restrict extraction gradients and reduce extraction distance;
- Avoid the layout of extraction routes in stream beds, riparian zones and other SMZ’s;
- Plan and mark extraction routes infield according to acceptable standards before felling commences;
- Limit and mark stream crossings clearly;
- Cross streams at right angles (Figure 28);
• Plan extraction routes to travel in straight lines as much as possible;
• Do not branch intersections off the main extraction routes directly opposite each other;
• Lay out intersections at 45° angles or less, where practical, with reference to movement towards the landing;
• Plan for downhill extraction rather than uphill when using ground-based extraction systems;
• Avoid extraction straight up and down steep slopes with soils of high erosion potential;
• Do not exceed machine capabilities in term of slope limitations when planning extraction routes (refer to Chapter 5 for information on slope limitations of machines);
• Avoid earth moving as far as practical;
• Limited excavation may be required on side slopes greater than 20% to achieve narrow (machine width) machine roads;
• Consider out sloping of 2% to 6% for skidding and forwarding routes on side slopes (2% for drainage, debarked hardwood logs generally slide off slopes greater than 6%);
• Restore extraction routes after use to minimise erosion, siltation and excessive runoff of water;
• Re-use old extraction routes where possible;
• Install water bars at regular intervals if required, on steeper extraction routes (Figure 29);
• Minimise compaction, erosion and moisture loss by covering extraction routes with slash.

4.6.2 Landing Design

A landing is an open area created for the temporary storage of extracted timber prior to further transport, be it secondary intermediate or secondary transport.

Factors influencing the landing choice and design:
• Slope;
• Ground roughness;
• Soil type;
• Total volume of timber to be handled;
• Maximum volume of timber to be stored at any time;
• Position of the landing (e.g. in stand, at roadside, centralised or decentralised);
• Harvesting method employed (e.g. hot deck or cold deck);
• Types of machines to be used for extraction, sorting, stacking, loading and transport;
• Amount of handling and corresponding amount of equipment necessary at the landing;
• Transport vehicles used to remove the timber from the landing and corresponding road dimensions;
• Rainfall pattern to determine minimum drainage standards (maximum rainfall recorded in one to three days is more important than the annual average rainfall);
• In situ material available for construction;
• Proximity of riparian or wetland areas.

Positive results of good landing choice and design:
• Concentrated timber reserves to facilitate loading and transport operations;
• Products are separated and stored;
• Improved safety through less interference with transport during extraction operations;
• Improved log preparation;
• Reduced extraction cost due to potentially shorter lead distance.

Potential negative impacts of poor landing choice and design:
• Soil erosion and sedimentation;
• Visual impact;
• Compaction.

Methods of reducing the likelihood of negative impacts:

1. Location and Size
• Limit landing size to be no larger than required in order to accommodate all work procedures;
• Situate landings away from wetlands (e.g. streams and riparian areas);
• Do not use power line reserves for landings;
• Avoid using fire breaks as landings during periods of high fire danger.

2. Drainage
• Locate landings on gentle slopes to facilitate drainage (3 to 6 %) if practical;
• Divert water approaching the landing into the surrounding into surrounding vegetation or silt traps, and not directly into water-course;
• Give special attention to the drainage of landings in sensitive areas or during the wet season.

3. Construction
• Stockpile cover material for rehabilitation during construction;
• Keep the stockpile clear of bark, branches and other debris.

4. Log Stacking
• Build log stacks on firm, level ground;
• Apply adequate measures to prevent stacks from collapsing or logs from falling off;
• Ensure sufficient space between stacks to allow for safe and unobstructed movement;
• Do not stack logs within wetland areas (Figure 30).
4.6.3 Rehabilitation

Rehabilitate the affected area after harvesting operations have been completed so as to prevent long-term deterioration of the area.

Factors influencing rehabilitation:

- Slope and ground roughness;
- Soil type and susceptibility to erosion and sedimentation;
- Condition of the site after harvesting and road construction have been completed;
- Method and type of machines used for harvesting and transport;
- In situ materials available for rehabilitation.

Positive results of adequate rehabilitation:

- Sustained timber production;
- Improved aesthetics;
- Improved re-establishment.

Potential negative impacts of inadequate rehabilitation:

- Soil erosion and sedimentation.

Methods of reducing the likelihood of negative impacts:

- Remove all litter and waste material from the site;
- Make water bars at an angle of between 30˚ and 60˚ to the extraction route (Figure 29);
- Reduce water velocity by discharging the water into the surrounding vegetation and slash or by placing slash across extraction routes;
- Take advantage of natural drainage points;
- Remove temporary crossings;
- Restore stream and riparian crossings to their original state, as far as practical;
- Drain excessive rutting in steeper areas to prevent channelling of water and subsequent erosion;
- Rehabilitate excessive rutting;
- Drain extraction routes in areas with soils susceptible to erosion if harvesting is stopped for one week or more;
- Drain, clear and rip depots and landings on completion of harvesting where required;
- Spread stockpiled cover material on landings if it is not to be used again;
- Re-vegetate unused landings, depots, roads and extraction routes to blend in with the surrounding area.
In forestry, harvesting involves the felling and processing of timber and resulting biomass into a required product. Extraction (primary transport) and extended primary transport dovetail with the harvesting operations and generally form part of them (e.g. a full tree harvesting system may begin with the harvesting processes of felling and debranching, then undergoes an extraction process of skidding or forwarding to roadside, then continues with the harvesting process of crosscutting). Extraction and extended primary transport are concerned with moving the timber and other biomass from infield to a point accessible for some form of secondary intermediate or secondary transport.

Harvesting, extraction and extended primary transport operations generally involve the choreography of several activities and processes. This usually requires a team of people, equipment and machinery as well as support crew and management. In order to manage modern harvesting operations professionally, the following is needed:

- Management and staff who are competent in their jobs;
- An understanding of machine availability and utilisation;
- An understanding of system balancing;
- The ability to determine productivity;
- An understanding of machine costs and system cost components;
- Good communication skills;
- An understanding of possible environmental impacts;
- An understanding of the safety risks associated with the machines used, as well as the environment the machines are operating in;
- An understanding and application of machine and equipment limitations;
- The ability to adapt to changing circumstances;
- An understanding of timber and/or other biomass supply chains.

5.1 Harvesting, Extraction and Extended Primary Transport Plans

During tactical harvest planning, the balancing of compartments and harvesting systems over a period of time (normally three to five years) is done to ensure a sustained timber and other biomass supply and the optimal utilisation and allocation of equipment. This is carried out in conjunction with road and transport planning, as well as considering silvicultural requirements. It facilitates amongst other things the determination of human resource and equipment requirements. Costs and environmental considerations are also weighed up.

The most important aspects to be considered in a tactical harvesting plan are:

- Strategic plan;
- Descriptive terrain classification;
- Balancing timber and other biomass volumes over the set time frame;
- Markets for timber and other biomass and products;
- Balancing of equipment (harvesting and transport);
- Harvesting systems and site machine matching;
- Influence of silviculture operations and environmental factors in general;
- General future sustainability.
Tactical harvest planning includes the following steps:

- Determining broad customer needs;
- Obtaining compartment information;
- Choosing equipment to match the site;
- Identifying wet or dry periods and associated compartments;
- Consolidation of compartments.

Planning success will depend on:

- Knowledgeable and experienced foresters and contractors;
- Reliable maps;
- Well defined operating objectives;
- Group reconnaissance trips which include relevant stakeholders;
- Careful system choices;
- Thorough paper planning and field verification;
- Thorough review of implications (impact appraisal);
- Readiness to change the plan if required by having alternative choices;
- Effective communication between planners and operators;
- Market fluctuations;
- Accurate information.

Operational planning:

Before operational harvesting commences each compartment is individually planned in detail.

Such an operational plan should include the following:

- A large scale contour map showing the following:
  - Compartment boundaries;
  - Special management zones (SMZ’s) such as indigenous forests, historic and archaeological sites, buffer strips and riparian zones;
  - Functional terrain classification;
  - Felling direction;
  - Extraction routes;
  - Landing locations;
  - Haulage roads;
  - Streams and stream crossing locations;
  - Contours;
  - Map scale;
- Harvest and transport scheduling;
- Harvesting, extraction and transport systems (i.e. method of felling, conversion, extraction and transport) matched to the terrain and balanced;
- Equipment and human resource requirements;
- Direction of timber and other biomass flow and haulage;
- Special protection measures to be taken when opening up the compartment;
- Management prescriptions to protect specific values and designated SMZ’s;
- Compartment details (e.g. total volume, average stem volume, spha, dbh, length, species, age);
- Detailed production and cost calculations.
Operational harvest planning includes the following steps:

- Preliminary office work;
- Field work;
- Production and cost information (office work);
- Harvesting ownership of the felling compartment (signing on the compartment);
- Daily management and production control;
- Return of ownership of compartment to silviculture management (signing off of the compartment).

5.2 Timber Harvesting, Extraction and Extended Primary Transport

For the purpose of this handbook, timber harvesting, extraction and extended primary transport refers to all the activities required to convert standing trees into saleable products at a location accessible to some form of secondary (on-road) transport.

5.2.1 Felling and Conversion

Felling and conversion can be done either manually, motor-manually or with mechanised systems. Each of the following sub-sections (felling, debranching, crosscutting, debarking and infield stacking) deals with the different methods used in felling and conversion.

These guidelines are not aimed at providing a full range of equipment and operational solutions, but rather an overview of the most common options, and only provides guidelines for standard equipment. One should note that equipment may for example be specialised or modified to make it better suited to specific conditions. Due to the diversity of the options available and ever-changing technology, such equipment has not been covered in this document. Please refer to other related sources of information, such as the Ground-based Harvesting Handbook or the Cable Yarding Handbook for further information.

5.2.1.1 Felling

Factors that influence productivity and product quality during felling operations include:

- Tree diameter, length and volume;
- Tree species;
- Crown shape and size;
- Tree spacing (walking or travelling distance between the trees);
- Lean of the tree;
- Felling direction (uphill, downhill or parallel to the contour);
- Soil type and condition;
- Terrain (slope, roughness and condition);
- Density of regeneration and weeds;
- Weather conditions;
- Mechanical availability;
- Machine utilisation;
- Serviceability and suitability of equipment;
- Operator skills;
- Safety.
General principles:

- Felling should be planned and controlled to:
  - Ensure the safety of operators and all other workers;
  - Facilitate extraction;
  - Reduce damage to felled as well as remaining trees;
  - Keep harvesting activities away from stream, riparian zones and other designated SMZ’s;
  - Avoid loss of useful products (maximum value recovery).
- Chainsaw and machine operators must be well trained and must adhere to strict safety standards;
- Felling aids (e.g. winches, felling levers and wedges) should be used when felling trees:
  - With a profound lean;
  - In prevailing windy conditions;
  - In steep areas;
  - Next to public roads, streams, indigenous forests, riparian zones and other designated SMZ’s.
- Trees close to power lines, telephone lines, fences and pipelines need special attention;
- Be aware of the environmental, safety and social impacts of where the trees will land, or where the extraction machines have to go to access them;
- Conservation areas, cultural sites and the nests of protected bird species must all be considered;
- Debris in water ways and riparian zones;
- Aesthetics;
- Avoid of breeding sites of birds;
- Fell according to the planned felling direction to facilitate the next activity (e.g. crosscutting, debarking, stacking or extraction);
- Fell away from streams, riparian zones and other surrounding vegetation;
- Remove trees and debris from streams, riparian zones and other designated SMZ’s;
- Cut trees as close to the ground as possible.

Motor-Manual Felling

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%) – up</td>
</tr>
<tr>
<td>Slope (%) – down</td>
</tr>
<tr>
<td>Ground condition</td>
</tr>
<tr>
<td>Ground roughness</td>
</tr>
<tr>
<td>Piece size (m³)</td>
</tr>
</tbody>
</table>

NOTE: The information in the matrix above regarding slope, ground conditions and ground roughness is classified according to the National Terrain Classification System for Forestry (ICFR Bulletin 11/94). Throughout this chapter, reference will be made to these terrain conditions. A summary of the classification system has been included in Appendix 1. A slope conversion table has also been included in Appendix 2 to facilitate the user converting degree slopes to percentage slopes (and vice-versa) if required.

Machinery:

- Chainsaw;
- Felling aids; felling lever, felling wedges, tree jack, winch and pulling lever.
Positive results of motor-manual felling:

- Minimum impact on soil (compaction and erosion) in sensitive areas;
- Can be carried out on a wide variety of terrain conditions;
- Low capital cost;
- Wide application scope.

Potential negative impacts of motor-manual felling:

- Physical injuries to operator, assistant, other workers and visitors (high risk operation);
- Long-term health effects on operator;
- Loss of valuable timber due to breakages and high stumps;
- Damage to remaining trees in thinning operations;
- Impedance of extraction and silvicultural practices by high stumps;
- Manual debranching and debarking cannot commence until felling is complete due to safety requirements (lost production);
- Low production.

Methods of reducing the likelihood of negative impacts:

- Train operators and assistants adequately;
- Wear and use personal protective equipment and clothing at all times;
- Make adequate allowance for rest breaks;
- Ensure adequate food and water intake;
- Follow safe work procedures;
- Ensure no other operation or person is closer than two tree lengths from the tree being felled;
- Take special precautionary measures regarding the potential downhill slide of trees, especially Eucalyptus, when felling on slopes;
- Use a winch or other felling aids when felling trees close to SMZ’s, power lines, telephone lines, pipe lines, fences and public roads.

Mechanised Felling

A choice can be made between a machine which only fells trees (feller buncher) or a machine which fells and processes trees (harvester). The machine choice is made based on the many factors investigated during tactical harvest planning. Many different types and brands of felling machines and harvesters are available. The owner, or potential owner, must ensure that he/she is familiar with the application of the different machines in accordance to their operating environment. All operators should receive training relevant to the specific machine used.

Recommended terrain conditions for felling machines (feller bunchers and harvesters)

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
<th>Wheeled</th>
<th>Track-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Wheeled machines with tyre chains or bogey tracks if necessary)</td>
<td>Non levelling</td>
<td>Cab levelling</td>
</tr>
<tr>
<td>Slope (%) – up</td>
<td>≤35</td>
<td>≤40</td>
</tr>
<tr>
<td>Slope (%) – down</td>
<td>≤20</td>
<td>≤30</td>
</tr>
<tr>
<td>Ground condition</td>
<td>1 – 2</td>
<td>1 – 3 (1 – 4 high flotation tracks)</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 3</td>
<td></td>
</tr>
<tr>
<td>Piece size (m³) – (max depending on head and carrier choice)</td>
<td>FB: Up to 1.0 m³</td>
<td>Harvester: Up to 0.6 m³</td>
</tr>
</tbody>
</table>

NOTE: These criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.
Machinery:

- Wheeled or tracked feller-buncher;
- Wheeled or tracked harvester.

Positive results of mechanised felling:

- The cab provides a safer and more favourable working environment for the operator compared to manual felling;
- Correct machine selection can result in reduced environmental impacts such as compaction and soil disturbance;
- High production machines;
- Reduced felling damage;
- Better directional felling protecting SMZ’s, improving safety and extraction productivity.

Potential negative impacts of mechanised felling:

Most of the impacts of mechanised felling are similar to that of motor-manual felling, however the severity of impact is less due to the increased control that the operator has over the tree that is being felled.

- High capital costs;
- Physical injuries to other workers possible;
- Soil erosion and compaction damages due to machine tracks and wheels;
- Impedance of extraction and silvicultural practices by high stumps.

Methods of reducing the likelihood of negative impacts:

- Train operators adequately;
- Proper machine selection;
- Ensure no other operation or person is allowed within two tree lengths of the felling operation or as specified by the manufacturer;
- Follow safe work procedures;
- Keep machines away from stream beds and river banks;
- Keep machine movements on the extraction routes as far as practical;
- Fell timber, or place logs where the extraction machine or next activity can easily reach it and cause minimal environmental damage;
- Avoid sensitive soils or take special precautions;
- Where necessary, make use of slash beds to reduce compaction;
- Ensure sound daily maintenance;
- Ensure prompt machine servicing as specified by the manufacturer;
- Operate the machine within its capabilities as specified by the manufacturer.

5.2.1.2 Debranching

Factors that influence productivity and product quality during debranching operations include:

- Tree species;
- Branchiness (size and number of branches);
- Tree spacing (walking or travelling distance between the felled trees);
- Felling layout;
- Felling direction (uphill, downhill or parallel to the contour);
- Terrain (slope, roughness and condition);
• Serviceability and suitability of equipment;
• Slash management requirements;
• Operator skills;
• Debranching equipment;
• Mechanical availability;
• Machine utilisation;
• Piece size;
• General health and fitness levels of labour force (in a manual operation).

**Manual Debranching**

### Recommended terrain conditions for manual debranching

| Limitation/Application Matrix |  
|-----------------------------|----------------|
| Slope (%)                   | ≤60            |
| Ground condition            | 1 – 5          |
| Ground roughness            | 1 – 5          |

**Equipment:**

• Axe, hatchet or spud.

**Positive results of manual debranching:**

• Low environmental impact (e.g. noise, fuel spillage and soil damage);
• Low capital cost;
• Job creation opportunity.

**Potential negative impacts of manual debranching:**

• Low productivity;
• Personal injuries;
• Ergonomically undesirable;
• Slash discarded into water ways and riparian zones;
• Low production.

**Methods of reducing the likelihood of negative impacts:**

• Train workers adequately;
• Avoid debranching on steep slopes in wet and slippery conditions;
• Use the appropriate tools for the task;
• Wear and use prescribed personal protective equipment and clothing (the use of leg protectors which adhere to the FESA standard, FESA 001:1998 as set out in the document “Protective device for users of sharp-bladed tools: Requirements for leg protectors” is recommended);
• Follow safe work procedures;
• Make adequate allowance for rest breaks;
• Ensure adequate food and water intake;
• Work according to the harvest plan to facilitate the next activity (e.g. debarking, crosscutting, stacking and extraction);
• Do not deposit slash in streams, riparian zones, fire breaks, roads or other designated SMZ’s.
Motor-Manual Debranching

### Recommended terrain conditions for motor-manual debranching

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%)</td>
</tr>
<tr>
<td>Ground condition</td>
</tr>
<tr>
<td>Ground roughness</td>
</tr>
</tbody>
</table>

### Machinery:
- Chainsaw.

### Positive results of motor-manual debranching:
- Low capital cost;
- Simple maintenance;
- Minimum impact on soil in sensitive areas;
- Mobile machine can be used on a wide variety of terrain conditions.

### Potential negative impacts of motor-manual debranching:
- Risk of minor fuel and oil spills;
- Poses long-term health risk due to noise and vibration levels;
- Cannot work at night;
- Difficult to debranch side of tree facing the ground;
- Severe physical injuries to operator (high risk operation);
- Slash discarded into water ways and riparian zones;
- Low production.

### Methods of reducing the likelihood of negative impacts:
- Train operators adequately;
- Wear and use prescribed personal protective equipment and clothing;
- Avoid debranching on steep slopes in wet and slippery conditions;
- Work according to the plan and standards to facilitate the next activity (e.g. debarking, crosscutting, stacking and extraction);
- Follow safe work procedures;
- Make adequate allowance for rest breaks;
- Ensure adequate food and water intake;
- Only refuel at designated areas;
- Do not deposit slash in streams, riparian zones, fire breaks, roads or other designated SMZ’s;
- Cut branches in manageable sizes.
Mechanised Debranching

For the recommended terrain conditions for harvesters and processors being used as mechanised debranchers, refer to mechanised felling equipment recommendations. Various systems and equipment solutions are available. Application ranges vary and are primarily determined by the equipment carrier.

### Recommended terrain conditions for chain flail delimber debarker (CFDD) and ring debarker

<table>
<thead>
<tr>
<th>Limitation/application matrix</th>
<th>Chain flail delimber debarker</th>
<th>Ring debarker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%)</td>
<td>≤5 – depending on feeding system</td>
<td>≤5 – depending on feeding system</td>
</tr>
<tr>
<td>Ground condition</td>
<td>1 – 3 depending on feeding system</td>
<td>1 – 3 depending on feeding system</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 3 depending on feeding system</td>
<td>1 – 3 depending on feeding system</td>
</tr>
<tr>
<td>Load size (m³)</td>
<td>≤0.8 for infield systems</td>
<td>≤0.3 for infield systems</td>
</tr>
</tbody>
</table>

**NOTE:** these criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.

### Most common machinery:
- Chain flail delimber debarker (CFDD);
- Multi-functional machines (harvester or processor);
- Stroke-boom delimiters;
- Static (pull-through) delimiters.

### Positive results of mechanised debranching:
- High productivity;
- CFDD facilitates the use of residue for biomass utilisation (can be used with tub grinders etc.);
- Less labour intensive;
- Multi shifts (can be operated at night);
- The cab provides a safer and more favourable working environment for the operator;
- Generally a multi-functional machine (can debranch, top and stack).

### Potential negative impacts of mechanised debranching:
- Higher skill levels required for operators;
- CFDD need high volumes to be cost effective;
- CFDD require specialised support;
- High capital cost;
- Potential for fuel and oil spills;
- Severe physical injuries to other workers;
- Soil erosion and compaction damage due to machine tracks and wheels;
- Concentration of slash in the compartment, at roadside or landing.
  - Visual impact of slash build-up;
  - Fire hazard;
  - Debris problem;
  - Reduction of site productivity due to the removal of nutrient-rich foliage and branches;
  - Damage to remaining trees in thinning operation.
Methods of reducing the likelihood of negative impacts:

- Train operators adequately;
- No other operation or person should be allowed inside a safe distance of the operation without proper notification and acknowledgement from the operator;
- Follow safe work procedures;
- Work away from streams, riparian zones and other designated SMZ’s;
- Keep machines out of stream beds and river banks;
- Keep to designated extraction routes, forest roads and landing sites as far as practical;
- Make use of slash beds to reduce compaction;
- Ensure capacity is in balance with other equipment;
- Ensure sound daily maintenance;
- Refuelling and maintenance done only in designated areas, rehabilitate soil if spills occur;
- Ensure prompt machine servicing as specified by the manufacturer;
- Operate the machine within its capabilities as specified by the manufacturer.

5.2.1.3 Crosscutting

Factors that influence productivity and product quality during crosscutting operations include:

- Tree size (log diameter);
- Tree species;
- Tree spacing (walking or traveling distance between the felled trees);
- Felling direction (uphill, downhill or parallel to the contour);
- Felling layout;
- Method and place of presentation (e.g. stacked at roadside or scattered infield);
- Measuring instruments and methods;
- State of conversion required (number of products);
- Landing layout and management;
- Method of conversion;
- Place of conversion (e.g. infield, landing);
- Terrain (i.e. slope, roughness and condition);
- Operator skills;
- Mechanical availability;
- Machine utilisation;
- Serviceability and suitability of equipment.

Motor-Manual Crosscutting

For the recommended terrain conditions to be adhered to for motor-manual crosscutting, refer to motor-manual debranching recommendations in this Chapter.

Machinery:

- Chainsaw.

Positive results of motor-manual crosscutting:

- Minimum impact on soil in sensitive areas;
- Can be used on a wide variety of terrain conditions.
Potential negative impacts of motor-manual crosscutting:

- Severe physical injuries to operator (high risk operation);
- Rejected products due to faulty measuring equipment or method;
- Loss of revenue due to sub-optimal utilisation of raw materials;
- Low production.

Methods of reducing the likelihood of negative impacts of motor-manual crosscutting:

- Train operators, log scalers and assistants adequately;
- Quality controls;
- Wear and use prescribed personal protective equipment and clothing;
- Take special precautionary measures regarding the potential downhill slide of trees and logs when crosscutting on slopes;
- Make adequate allowance for rest breaks;
- Ensure adequate food and water intake;
- Follow safe working procedures;
- Remove debris from streams, riparian zones and other surrounding indigenous vegetation;
- Log-scalers must be fully competent in scaling for maximum value;
- Check and calibrate measuring equipment regularly.

Mechanised Crosscutting

For the recommended terrain conditions for harvesters and processors performing mechanised crosscutting, refer to mechanised felling equipment recommendations in Section 5.2.1.1. Slashers usually operate on landings and therefore terrain limitations are not applicable.

Machinery:

- Slasher;
- Multi-functional machines (harvester or processor).

Positive results of mechanised crosscutting:

- The cab provides a safer and more favourable working environment for the operator;
- Improved safety;
- Optimal utilisation of materials where machinery is equipped with on-board computers;
- More consistent standards.

Potential negative impacts of mechanised crosscutting:

- Physical injuries to other workers;
- Soil erosion and compaction damage due to machine tracks and wheels.

Methods of reducing the likelihood of negative impacts:

- Train operators adequately;
- Work according to the plan and standards to facilitate the next activity (e.g. debarking, extraction and stacking);
- Operators must be fully competent in scaling for maximum value;
- No other operation or person should be allowed inside an unsafe distance of the operation without proper notification and acknowledgement from the operator;
- Follow safe working procedures;
• Keep machines clear of stream beds, riparian zones and river banks;
  • Avoid areas with sensitive soils as far as practical;
  • Keep to designated extraction routes, forest and landing sites as far as practical;
  • Make use of slash beds to reduce compaction;
  • Check and calibrate measuring equipment regularly;
  • Ensure sound daily maintenance;
  • Ensure prompt machine servicing as specified by the manufacturer;
  • Operate the machine within its capabilities as specified by the manufacturer.

5.2.1.4 Debarking

Factors that influence productivity and product quality during debarking operations include:

- Tree species;
- Tree form (branchiness and crookedness);
- Market requirements (specifications);
- Piece size (diameter and length);
- State of conversion (standing or felled trees, short lengths or long lengths);
- Tree spacing (walking or travelling distance between the felled trees);
- Felling direction (uphill, downhill or parallel to the contour);
- Felling layout;
- Place of conversion (e.g. infield, landing);
- Trees affected by insect attacks, fire damage, disease and drought stress;
- Season (dry or wet season);
- Bark-wood bond strength (bark type, age, vitality);
- Period from felling to debarking (the drier the logs the more difficult to debark);
- Time of day (temperature);
- Terrain (i.e. slope, roughness and condition);
- Method and place of presentation (e.g. stacked at roadside or scattered infield);
- Serviceability and suitability of equipment (e.g. type of debarking tool or machinery used);
- Sharpness of the tools;
- Operator and labourer skills;
- Mechanical availability;
- Machine utilisation;
- Labour health and fitness;
- Economic value of bark.

Manual Debarking

<table>
<thead>
<tr>
<th>Recommended terrain conditions for manual debarking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Limitation/Application Matrix</strong></td>
</tr>
<tr>
<td>Slope (%)</td>
</tr>
<tr>
<td>≤ 60</td>
</tr>
<tr>
<td>Ground condition</td>
</tr>
<tr>
<td>1 – 5</td>
</tr>
<tr>
<td>Ground roughness</td>
</tr>
<tr>
<td>1 – 5</td>
</tr>
</tbody>
</table>
Equipment

- Hatchet/Axe;
- Debarking spud.

Positive results of manual debarking:

- Low environmental impact (e.g. noise, fuel and soil damage);
- Job creation;
- Low capital cost;
- Good quality debarking;
- No substantial timber and/or other biomass loss;
- Can operate on steep slopes;
- Flexibility (location, tree size and market changes).

Potential negative impacts of manual debarking:

- Personal injuries (safety risks);
- Ergonomically undesirable;
- Bark discarded into water ways and riparian zones;
- Low production.

Methods of reducing the likelihood of negative impacts:

- Train workers adequately;
- Wear and use prescribed personal protective equipment and clothing (the use of leg protectors which adhere to the FESA standard, FESA 001:1998 as set out in the document “Protective device for users of sharp bladed tools: requirements for leg protectors”: is recommended);
- Follow safe working procedures;
- Do not deposit bark in streams, riparian zones, fire breaks, roads or other designated SMZ’s;
- Use appropriate tools for the task;
- Work according to the harvest plan to facilitate the next activity (e.g. debranching, crosscutting, stacking and extraction);
- Make adequate allowance for rest breaks;
- Ensure adequate food and water intake;
- Supervision;
- Always debark from the opposite side of the log or tree length;
- Avoid standing on debarked timber.

Mechanised Debarking

Various systems and equipment solutions are available. Application ranges vary and are primarily determined by the equipment carrier. For the recommended terrain conditions for harvesters and processors performing mechanised debarking, refer to mechanised felling equipment recommendations in Section 5.2.1.1. For the recommended terrain conditions for chain flail delimber debarkers (CFDD) and ring debarkers performing mechanised debarking, refer to mechanised felling equipment recommendations in Section 5.2.1.1.

Machinery:

- Chain flail delimber debarker (CFDD);
- Ring debarker;
- Multi-functional machine (harvester or processor).
Positive results of mechanised debarking:

- The cab provides a safer and more favourable working environment for the operator;
- Improved productivity for timber which is difficult to debark;
- Improved yield from the chain flail delimber debarker;
- Easier biomass retrieval if processing at the landing;
- Debark crooked stems and crown (chain flail delimber debarker);
- Equipment is mobile.

Potential negative impacts of mechanised debarking:

- When processing at the landing there can be concentration of bark resulting in:
  - Nutrient loss from the plantation;
  - Visual impact of slash build-up;
  - Fire hazard;
- Physical injuries to other workers (e.g. persons feeding the machine);
- Damage to remaining trees in thinning operations;
- High capital outlay;
- Specialised support required.

Methods of reducing the likelihood of negative impacts:

- Train operators and assistances adequately;
- Ensure no other operation or person is allowed inside a safe distance of the operation without proper notification and acknowledgement from the operator;
- Follow safe working procedures;
- Do not deposit bark in streams, riparian zones, fire breaks, roads or other designated SMZ’s;
- Stay clear of stream beds, riparian zones and river banks;
- Keep to extraction routes, forest roads and landing sites as far as practical;
- Make use of slash beds to reduce compaction and rutting;
- Work according to the plan and standards to facilitate the next activity (e.g. crosscutting, stacking and extraction);
- Ensure sound daily maintenance;
- Ensure prompt machine servicing as specified by the manufacturer;
- Operate the machine within its capabilities as specified by the manufacturer.

5.2.1.5 Infield Stacking and/or Loading

Factors that influence productivity and product quality during infield stacking and/or loading operations include:

- Product (short or long lengths);
- Piece size and mass;
- Volume per hectare;
- Tree species;
- Terrain (i.e. slope, roughness and condition);
- Climate (wet and cold conditions have an influence);
- Stack quality and requirements (size and configuration);
- Size of stacking area;
- Stacking method and equipment or machinery used;
• Operator and labour skills;
• Mechanical availability;
• Mechanical utilisation.

Manual Stacking / Loading Infield

Recommended terrain conditions for manual infield stacking and/or loading

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%)</td>
</tr>
<tr>
<td>Ground condition</td>
</tr>
<tr>
<td>Ground roughness</td>
</tr>
</tbody>
</table>

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited by extraction equipment to be used (see respective machine guidelines for appropriate limitations)</td>
</tr>
<tr>
<td>1 – 5</td>
</tr>
<tr>
<td>1 – 5</td>
</tr>
</tbody>
</table>

Equipment:

• Pulp hooks;
• Log tongs.

Positive results of manual stacking and/or loading:

• Job creation;
• Low environmental impact (e.g. noise, fuel and soil damage);
• Improved productivity of extraction (timber concentrated).

Potential negative impacts of manual stacking and/or loading:

• Personal injuries;
• Stacks placed in water ways and riparian zones;
• Ergonomically undesirable;
• Extraction equipment used with manual stacking generally requires gentler slopes, thus limiting the operation;
• Low productivity.

Methods of reducing the likelihood of negative impacts:

• Train workers adequately;
• Follow safe working procedures;
• Use appropriate tools for the task;
• Make adequate allowance for rest breaks;
• Ensure adequate food and water intake;
• Construct the stacks to facilitate the next activity (e.g. extraction);
• Do not construct stacks in streams, riparian zones, fire breaks, roads or other SMZ’s.

Mechanised Stacking Infield / Mechanised Loading Infield

Various systems and equipment solutions are available. Application ranges vary and are primarily determined by the equipment carrier. For the recommended terrain conditions for feller bunchers and harvesters and modified excavators being used for mechanised stacking and/or loading, refer to mechanised felling equipment recommendations in Section 5.2.1.1.
Recommended terrain conditions for mechanised stacking and/or loading using track-based loaders and three-wheeled loaders

<table>
<thead>
<tr>
<th>Limitation/application matrix</th>
<th>Three-wheeled loader</th>
<th>Track-based (swing) loader (Non-levelling)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%)</td>
<td>≤10</td>
<td>≤25</td>
</tr>
<tr>
<td>Ground condition</td>
<td>1 – 2</td>
<td>1 – 4</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 2</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Load size (m³)</td>
<td>≤0.8</td>
<td>≤2.0</td>
</tr>
</tbody>
</table>

NOTE: these criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.

Machinery:
- Dedicated track-based loader (Swing loader) (Levelling and non-levelling);
- Three-wheeled loader;
- Excavator-based loader;
- Multi-functional machines (harvester or processor).

Positive results of mechanised stacking and/or loading:
- Controlled environment for the operator;
- Reduced physical strain on the workers;
- Larger (higher) stacks can save space;
- High productivity.

Potential negative impacts of mechanised stacking and/or loading:
- Physical injuries to other workers;
- Soil erosion and compaction damage due to machine tracks and wheels;
- Soil disturbance;
- Debris trapped between the logs in the stack;
- Potential reduction of stack quality.

Methods of reducing the likelihood of negative impacts:
- Train operators adequately;
- Ensure no other operation or person is allowed inside a safe distance of the operation without proper notification and acknowledgement from the operator;
- Follow safe working procedures;
- Stay clear of stream beds, riparian zones and river banks;
- Keep designated extraction routes, forest roads and landing sites as far as practical;
- Make use of slash beds to reduce compaction;
- Select the correct grapple for the operation;
- Ensure sound daily machine maintenance;
- Ensure prompt machine servicing as specified by the manufacturer;
- Operate the machine within its capabilities as specified by the manufacturer;
- Drive slowly in working area;
- Be on the lookout for other vehicles;
- No passengers on vehicle or loading equipment;
5.2.2 Extraction and Extended Primary Transport

Extraction (primary transport) is the activity of transporting timber from the stump area to a roadside landing. This can be done manually, with chutes, with animals, with equipment and/or machinery or with cables. Extended primary transport also involves the transport of timber from the stump area but continues past the roadside to an intermediate storage site or directly to the processing site. Due to the longer lead distance associated with extended primary transport, it is limited to ground-based vehicles/machines which have either been designed or adapted to carry out the required task.

Factors that influence productivity and product quality during extraction and extended primary transport which have to be considered when choosing a suitable extraction method include:

- Timber size (piece volume and state of conversion);
- Load size (total volume or weight);
- Number of pieces per load;
- Terrain (i.e. slope, roughness and condition);
- Sensitivity of terrain (susceptibility to soil damage and erosion);
- Size of area from which timber is to be extracted;
- Extraction direction (uphill, downhill or parallel to the contour);
- Extraction distance;
- Type and capability of extraction equipment;
- Felling direction (i.e. uphill, downhill or parallel to the contour);
- Presentation (i.e. scattered, bunched or stacked; short lengths, long lengths or tree lengths with branches or debranched);
- Felling layout;
- Mechanical availability;
- Machine utilisation;
- Serviceability of equipment;
- Operator skills;
- Proximity of landing/depot;
- Travel speed of equipment;
- Ensure sound daily machine maintenance;
- Ensure prompt machine servicing as specified by the manufacturer;
- Operate machine within its capabilities as specified by the manufacturer.
5.2.2.1 Manual Extraction

**Recommended terrain conditions for manual extraction**

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%) – up</td>
</tr>
<tr>
<td>Slope (%) – down</td>
</tr>
<tr>
<td>Ground condition</td>
</tr>
<tr>
<td>Ground roughness</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
</tr>
</tbody>
</table>

**Equipment:**

- Pulp hook;
- Lifting tongs.

**Factors influencing manual extraction:**

- Log mass;
- Log dimensions;
- Number of pieces per area (stems per hectare);
- Size of area from which timber is to be extracted;
- Extraction distance;
- Extraction direction (uphill, downhill or parallel to the contour);
- Terrain roughness.

**Positive results of manual extraction:**

- Job creation;
- Low environmental impact (e.g. noise, fuel and soil damage);
- Minimal damage to remaining trees during thinning operations.

**Potential negative impacts of manual extraction:**

- Personal injuries;
- Logs sliding or rolling down steep slopes are dangerous and can overshoot the landing;
- Physically demanding;
- Ergonomically undesirable;
- Low productivity;
- Log size limitation.

**Methods of reducing the likelihood of negative impacts:**

- Train workers adequately;
- Work according to the harvest plan to facilitate the next activity;
- Work downhill if at all possible;
- Follow safe working procedures;
- Use appropriate tools for the task;
- Make adequate allowance for rest breaks;
- Ensure adequate food and water intake;
• Avoid very steep and rough terrain (if unavoidable apply strict safety rules);
• Do not stack or deposit timber in streams, riparian zones, fire breaks, roads or other designated SMZ’s;
• Prevent logs from overshooting the landing (retrieve them if this should occur);
• Only recommended for short extraction distances.

5.2.2.2 Chute Extraction

**Recommended terrain conditions for chute extraction**

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%) – up</td>
<td>Impossible</td>
</tr>
<tr>
<td>Slope (%) – down</td>
<td>≤90 – straight down</td>
</tr>
<tr>
<td>&gt;45 – traverse</td>
<td>1 – 5</td>
</tr>
<tr>
<td>Ground condition</td>
<td>1 – 5</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 4</td>
</tr>
<tr>
<td>Piece size (m³)</td>
<td>≤0.2</td>
</tr>
<tr>
<td>Max. extraction distance (m³)</td>
<td>150</td>
</tr>
</tbody>
</table>

NOTE: These criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.

One should note that recommended terrain conditions for chute operations are hugely influenced by factors such as tree species, presence or absence of bark, weather conditions, piece size and the presence or absence of moisture on timber and the chute. The matrix above serves only as a basic guide. For more detailed information, refer to FESA’s “Chute Operating Manual” (Engelbrecht and Warkotsch, 1994) (www.icfr.ukzn.ac.za).

**Equipment:**

• Full-pipe chutes;
• Half-pipe chutes.

**Factors influencing chute extraction:**

• Log length and diameter;
• Size of area to be extracted and rack size (chute length and lateral movement);
• Number of pieces per rack (function of stems per hectare);
• Extraction distance;
• Extraction direction (straight down or traverse);
• Felling layout;
• Log presentation;
• Climate (especially rain);
• Terrain (slope, roughness and condition);
• Operator skills;
• Type of chute available;
• Method of application.
Positive results of chute extraction:

- Low capital investment;
- Low environmental impact (e.g. noise, fuel and soil damage);
- Can be used over very sensitive soils;
- Suitable for extracting timber through indigenous forest and other SMZ's;
- Minimal damage to remaining trees during thinnings;

Potential negative impacts of chute extraction:

- Logs are presented in a disorderly fashion at the landing;
- Uncontrolled exit of logs is dangerous and can cause serious damage or injury;
- Damage to embankment;
- Lower production;
- Roads are required at the bottom of the slope for timber removal;
- Limited to medium to steep down-hill operations.

Methods of reducing the likelihood of negative impacts:

- Train operators and assistants adequately;
- Follow safe working procedures;
- Rather use round pipe chutes in dangerous terrain;
- Plan extraction routes (chute gradient must be kept as close to, but not less than, the minimum recommended slope);
- Plan the landing carefully and use it to prevent overshooting;
- Do not stack or deposit logs in streams, riparian zones, fire breaks, roads or other SMZ's;
- Retrieve logs that overshoot the landing;
- Maintain equipment and tools according to specifications;
- Work according to the harvest plan to facilitate the next activity (e.g. stacking and loading).

5.2.2.3 Animal Extraction

Recommended terrain conditions for animal extraction

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%) – up</td>
</tr>
<tr>
<td>Slope (%) – down</td>
</tr>
<tr>
<td>Ground condition</td>
</tr>
<tr>
<td>Ground roughness</td>
</tr>
<tr>
<td>Piece size (m³)</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
</tr>
</tbody>
</table>

NOTE: These criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.
Animals:
- Mules, oxen and horses.

Factors influencing animal extraction:
- Log mass;
- Log length;
- Number of pieces per area (stems per hectare);
- Number of pieces per load;
- Extraction distance;
- Extraction direction (uphill, downhill or parallel to the contour);
- Felling layout;
- Terrain;
- Condition and treatment of animals (health);
- Sensitivity of terrain (susceptibility to soil damage and erosion);
- Distance that animals have to cover to and from the working place;
- Handler skills;
- Size of area from which timber is to be extracted;
- Slash management.

Positive results of animal extraction:
- Low environmental impact;
- Low capital cost;
- Can be used through sensitive areas such as indigenous forests;
- Less damage to remaining trees during thinning operations.

Potential negative impacts of animal extraction:
- Animals and handlers require special training;
- Possibility of injury to animals and handlers is high;
- Animals are prone to fatigue and disease;
- Significantly limited log size;
- Significantly limited slopes and extraction distances;
- Animals require a high level of supervision;
- Low productivity.

Methods of reducing the likelihood of negative impacts:
- Only use well trained animals and competent handlers;
- The animals must be well kept and regularly inspected by competent people or veterinarians;
- Rest, feed and water the animals well;
- Ensure the harnesses are the correct size, well-oiled and in good condition;
- Animal handlers must wear appropriate protective clothing;
- Follow safe working procedures;
- Work according to the harvest plan to facilitate the next activity (e.g. stacking and loading);
- Plan extraction routes carefully (avoid very steep slopes that are dangerous for the animals to traverse);
- Cut regeneration low and do not leave sharp edges that could injure the animals.
5.2.2.4 Shovel Logging

Shovel logging involves a self-driven swing loader systematically traversing the compartment, grabbing the timber (generally full trees or tree lengths) and swinging it sequentially closer to the landing with each pass. It is a technique typically used with a continuous roadside landing and over short extraction distances.

**Recommended terrain conditions for shovel logging**

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
<th>Non-levelling machine</th>
<th>Levelling machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%) - up</td>
<td>≤35</td>
<td>≤55</td>
</tr>
<tr>
<td>Slope (%) - down</td>
<td>≤25</td>
<td>≤45</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 3</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Ground condition</td>
<td>1 – 4</td>
<td>1 – 4</td>
</tr>
<tr>
<td>Piece size per grab (m³)</td>
<td>≤2.0</td>
<td>≤2.0</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
<td>150 (3 “swings”)</td>
<td>150 (3 “swings”)</td>
</tr>
</tbody>
</table>

NOTE: These criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.

**Shovel Logging Machines:**

- Purpose-built shovel loggers;
- Modified excavators.

**Factors influencing shovel logging:**

- Timber size (piece volume);
- Load size (total volume or weight);
- Number of pieces per load;
- Terrain (slope, roughness and condition);
- Sensitivity of terrain (susceptibility to soil damage and erosion);
- Size of area from which timber is to be extracted;
- Extraction distance;
- Machine type and capability;
- Felling direction (uphill, downhill or parallel to the contour);
- Felling layout;
- Presentation of the timber (scattered, bunched or stacked, full tree, long lengths or short lengths);
- Mechanical availability;
- Machine utilisation.

**Positive results of shovel logging:**

- Can be effectively used in wet conditions;
- Same machine can be used on the landing (multi-task);
- Low ground impact – only one pass and timber is lifted off the ground when being moved;
- Allows pockets of otherwise unreachable timber to be extracted;
- Opportunity to combine with other extraction methods (e.g. grapple skidders or cable yarders).
Potential negative impacts of shovel logging:
• Limited terrain and slope limitations;
• Sensitive to piece size;
• Sensitive to extraction distance.

Methods of reducing the likelihood of negative impacts:
• Plan harvesting operation carefully;
• Train operators and assistants adequately;
• Follow safe working procedures;
• Directional felling of timber to facilitate shovel logger being able to reach timber;
• Do not reduce piece size before extraction through e.g. crosscutting;
• Use only equipment and machinery specifically designed or equipped for shovel logging;
• Extract according to the planned extraction routes and keep to skid roads as far as practical;
• Ensure sound daily machine maintenance;
• Ensure prompt machine servicing as specified by the manufacturer;
• Operate machine within its capabilities as specified by the manufacturer.

5.2.2.5 Skidding

Skidding is the process in which the timber is attached to the extraction unit, lifted at the one end, and dragged along the ground to the landing site. A number of equipment options are available. Some of these have the option of additional traction aids. While specific machines have some limitation, others can be applied over a wide range of terrain conditions.

---

<table>
<thead>
<tr>
<th>Limitation/Application (with tyre chains or bogey tracks if necessary)</th>
<th>Matrix</th>
<th>Cable Skidder (≤120kW)</th>
<th>Grapple Skidder (≤120kW)</th>
<th>Grapple Skidder (6x6)</th>
<th>Clambunk Skidder</th>
<th>Tracked Skidder</th>
<th>Tractor with winch or A-frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%) - up</td>
<td>≤40</td>
<td>≤30</td>
<td>≤45</td>
<td>≤35</td>
<td>≤50</td>
<td>≤25</td>
<td></td>
</tr>
<tr>
<td>Slope (%) - down</td>
<td>≤45</td>
<td>≤35</td>
<td>≤55</td>
<td>≤40</td>
<td>≤55</td>
<td>≤35</td>
<td></td>
</tr>
<tr>
<td>Ground condition (depends on tyre choice)</td>
<td>1 – 3</td>
<td>1 – 3</td>
<td>1 – 3</td>
<td>1 – 3 (4)</td>
<td>1 – 3</td>
<td>1 – 3</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 3</td>
<td>1 – 2</td>
<td>1 – 3</td>
<td>1 – 3 (4)</td>
<td>1 – 2</td>
<td>1 – 2</td>
<td></td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
<td>350</td>
<td>500</td>
<td>600</td>
<td>1000</td>
<td>200</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: These criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.

Skidding machines:
• Wheeled skidder (cable, clambunk and grapple);
• Crawler tractor;
• Agricultural tractor with skidding accessories.

Factors influencing skidding operations:
• Timber size (piece volume);
• Load size (total volume or weight);
• Number of pieces per load;
• Terrain (slope, roughness and condition);
• Sensitivity of terrain (susceptibility to soil damage and erosion);
• of area from which timber is to be extracted;
• Skidding distance;
• Skidding direction (uphill, downhill or parallel to the contour);
• Machine type and capability;
• Traction;
• Travel speed;
• Reach of cable, boom loader or grapple;
• Felling direction (uphill, downhill or parallel to the contour);
• Felling layout;
• Presentation of the timber (scattered, bunched or stacked, full tree, long lengths or short lengths);
• Operator and chokermen skills;
• Mechanical availability;
• Machine utilisation.

Positive results of skidding:
• Controllable working environment;
• Highly productive on flat to moderately steep terrain.

Potential negative impacts of skidding:
• Severe physical injuries to other workers;
• Debris in water ways and riparian zones;
• Aesthetic impact due to rutting;
• Compaction damage due to machine tracks and wheels;
• Soil erosion and sedimentation from skidding tracks (may cause a reduction in water quality);
• Damage to marketable timber;
• Damage to coppice stumps.

Methods of reducing the likelihood of negative impacts:
• Plan harvest operation carefully;
• Train operators and assistants adequately;
• Follow safe working procedures;
• Use only equipment and machinery specifically designed or equipped for skidding;
• Extract according to the planned extraction routes and keep to skid roads as far as practical;
• Keep clear of streams, riparian zones, and other designated SMZ’s;
• Take special precautionary measures when extracting timber on steep slopes or on compactable soils in wet weather conditions;
• Rehabilitate the site after the operation;
• Ensure sound daily machine maintenance;
• Ensure prompt machine servicing as specified by the manufacturer;
• Operate machine within its capabilities as specified by the manufacturer.
5.2.2.6 Forwarding

Forwarding is the operation whereby timber is “carried” from the stump to the landing site by lifting the whole load off the ground and transporting it in that suspended state to a landing or depot. The timber could either be carried on a custom built forwarder or modified equipment such as a tractor and trailer unit.

Recommended terrain conditions for ground-based suspended extraction

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
<th>Forwarder 4x4</th>
<th>Forwarder 6x6</th>
<th>Forwarder 8x8</th>
<th>Tracked Forwarder</th>
<th>Articulated Timber Truck</th>
<th>Tractor and Trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>(with tyre chains or bogey tracks if necessary)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope (%) – up</td>
<td>≤25</td>
<td>≤35</td>
<td>≤40</td>
<td>≤45</td>
<td>≤20</td>
<td>≤20</td>
</tr>
<tr>
<td>Slope (%) – down</td>
<td>≤35</td>
<td>≤45</td>
<td>≤50</td>
<td>≤55</td>
<td>≤25</td>
<td>≤20</td>
</tr>
<tr>
<td>Ground condition</td>
<td>1 – 2</td>
<td>1 – 2</td>
<td>1 – 3</td>
<td>1 – 4</td>
<td>1 – 2</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 3</td>
<td>1 – 4</td>
<td>1 – 4</td>
<td>1 – 2</td>
<td>1 – 2</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Load size (ton)</td>
<td>6 – 10</td>
<td>8 – 12</td>
<td>11 – 20</td>
<td>11 – 20</td>
<td>20</td>
<td>5 – 8</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
<td>500</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
<td>&lt;10000</td>
<td>&lt;25000</td>
</tr>
</tbody>
</table>

NOTE: These criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.

Forwarding machines:
- Wheeled forwarders;
- Tracked forwarders;
- Articulated Timber Trucks (ATT’s) (Converted from articulated dump trucks (ADT);
- Agricultural tractor and trailer.

Factors influencing forwarding operations:
- Timber size (piece volume or weight);
- Number of pieces per load;
- Terrain (slope, roughness and condition);
- Sensitivity of terrain (susceptibility to soil damage and erosion);
- Size of area from which timber is to be forwarded;
- Forwarding distance;
- Forwarding direction (uphill, downhill or parallel to the contour);
- Machine type and capability;
- Traction;
- Speed;
- Reach of loader boom;
- Size and type of grab;
- Presentation of the timber (scattered, bunched or stacked, short or long length);
- Operator skills;
- Mechanical availability;
- Machine utilisation.

Positive results of forwarding:
- Controllable working environment;
- High production machine on flat to moderately steep terrain;
• No chokermen required;
• Good quality unloading at landing, depot or unloading deck (near stacks and products sorted);
• High timber stacking on landing – good landing utilisation;
• Possibility of 24 hours safe operation;
• Reduced road network required;
• Less damage to timber products;

Potential negative impacts of forwarding:
• Damage to surrounding vegetation;
• Aesthetic impact due to tracks and rutting;
• Reduced water quality as a result of soil erosion and sedimentation from wheel tracks;
• Unloading quality is poor when tipper trailers are used as this reduces the optimal use of the depot or landing;
• Loss of productive forest area or reduction in site productivity due to soil loss and compaction.

Methods of reducing the likelihood of negative impacts:
• Train operators adequately;
• Follow safe working procedures;
• Use equipment and machinery specifically designed or equipped for forwarding;
• Extract according to the planned extraction routes;
• Keep to extraction routes as far as practical;
• Keep clear of streams, riparian zones and other designated SMZ’s;
• Extract on steep slopes and compactable soils (e.g. sandy soils) only during favourable weather conditions;
• Ensure that loads are stable and correctly spread;
• Avoid overloading;
• In steep areas, travel straight up and down the slope rather than parallel to the contour;
• Avoid steep and unstable slopes;
• Make use of slash beds to reduce soil impacts;
• Rehabilitate the site after the operation;
• Sound daily machine maintenance;
• Ensure prompt machine servicing as specified by the manufacturer;
• Operate the machine within its capabilities as specified by the manufacturer.

5.2.2.7 Cable Yarding

Cable yarding refers to the extraction of timber using a stationary or semi-stationary machine with a cable system. Timber is either dragged along the ground, partially suspended (one end lifted) or fully suspended when extracted. The machine which carries this out could be in the form of a conventional tower yarder, a swing tower yarder, a guyless yarder (such as an excavator-based yarder) or another type of machine. For more detailed information, refer to FESA’s South African Cable Yarding Safety and Operating Handbook (www.icfr.ukzn.ac.za).

Machinery and equipment:
• Highlead (HL);
• Skyline (SL);
• Mono cable.
Factors influencing cable yarding operations:

- Terrain (slope, roughness and condition);
- Sensitive terrain (susceptibility to soil damage and erosion), steams and riparian zones to be crossed;
- Size of area from which timber is to be extracted;
- Timber size (piece-volume);
- Load size (total volume or weight);
- Number of pieces per load;
- Degree of planning;
- Yarding distance;
- Landing type and spacing;
- Yarding method used;
- Machine type and capability;
- Carriage type and capability (SL);
- Line speeds and cycle times;
- Felling layout (uphill, downhill or parallel to the contour);
- Presentation (scattered, bunched or stacked; full tree, short or long length);
- Yarding direction (uphill or downhill);
- Operator skills;
- Mechanical availability;
- Machine utilisation.

Positive results of cable yarding:

- Low impact on soil in sensitive areas (compaction and erosion);
- Less visual impact and soil disturbance than skidding systems.

Potential negative impacts of cable yarding:

- Physical injuries to operators, assistants and other workers;
- Debris in water ways and riparian zones;
- Access routes blocked for transport and during emergencies (e.g. fire fighting);
- Landings become clogged and dangerous;
- Inadequate planning (choice of extraction routes) and installation can result in the following:
  - Damage to waterways and vegetation;
  - Soil damages (e.g. rutting) on extraction lines;
  - Insufficient lift at the tail spar and intermediate supports (SL);
  - Loss of production due to sub-optimal load size (incorrect deflection) and long cycle times.

Methods of reducing the likelihood of negative impacts:

- Train operators and assistants adequately;
- Follow safe working procedures;
- Plan for adequate deflection;
- Plan and prepare the landing, intermediate supports and tail spar before yarder installation begins (SL);
- Pay special attention to guy lines (anchor lines);
- Carefully select anchors to ensure that there are an adequate amount available at each of the following: the main tower; the tail spar; and the intermediate supports;
• Use intermediate supports and sufficient tail spar height when additional lift is required;
• Avoid extraction of timber across permanent watercourses, sensitive areas and riparian zones without using full suspension;
• Avoid downhill yarding in steep areas with limited landing sites as logs can slide down onto the yarder;
• Keeping landings clean - consider the use of guyless yarders (swing yarders) or other options such as three wheeled loaders or winches to move timber from roadside landings;
• Clearly mark guylines that cross other extraction paths or roads;
• Drop anchor lines at night to keep access roads clear, if necessary;
• Rehabilitate extraction paths after use (fill, stack slash across and/or provide drainage);
• Ensure sound daily machine and wire rope maintenance;
• Ensure prompt machine service as specified by the manufacturer;
• Operate the machine within its capabilities as specified by the manufacturer.

Highlead

Highleads can be applied on a wide range of terrain conditions (including flat terrain).

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
<th>Buttrigging</th>
<th>Highlead Carriage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Downhill Yarding</td>
<td>Uphill Yarding</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>≤40</td>
<td>≤40</td>
</tr>
<tr>
<td>Ground conditions</td>
<td>1 – 3</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 2</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

NOTE: These criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.

• A highlead requires two winching drums (mainline and haul-back line) and a tower or spar;
• If a highlead carriage is used, it is supported by the haul-back line;
• The drums can be interlocked to equalise the speeds and tension in both lines depending on the type of yarder used;
• It has less lift than skylines but more than groundlead winching;
• Yarding distances decrease sharply when blind leads (where the entire line cannot be seen, e.g. rock, convex slopes and ridges), side hill yarding or larger timber are encountered;
• Multi-spans are not possible;
• It should not be used to extract timber over riparian zones, streams and other sensitive areas, if drums are interlockable and full suspension lift is not generated;
• Recommended for the following terrain:
  o Level, regular or concave slope conditions;
  o Uphill and downhill yarding.
Skyline

Skylines can be applied on a wide range of terrain conditions (including flat terrain).

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
<th>Single Span Skyline</th>
<th>Multi Span Skyline</th>
<th>Live Skyline</th>
<th>Running Skyline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%)</td>
<td>Any slope</td>
<td>Any slope</td>
<td>Any slope</td>
<td>Any slope</td>
</tr>
<tr>
<td>Ground conditions</td>
<td>1 – 5</td>
<td>1 – 5</td>
<td>1 – 5</td>
<td>1 – 5</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>1 – 5</td>
<td>1 – 5</td>
<td>1 – 4</td>
<td>1 – 4</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
<td>600</td>
<td>600</td>
<td>500</td>
<td>500</td>
</tr>
</tbody>
</table>

NOTE: These criteria serve as a guide only and need to be determined by an experienced professional in the context of the operation.

More detail on the exact operation limitations for the different types of skylines is available in FESA’s South African Cable Yarding Safety and Operating Handbook (www.icfr.ukzn.ac.za).

- Skylines comprise of a minimum of three drums for uphill yarding or two for downhill yarding;
- The carriage is normally supported by the skyline, therefore higher lifts are possible;
- Full load suspension is required for operation over riparian zones, streams and other sensitive areas;
- Intermediate supports are required where the lift is insufficient (planning is important);
- Recommended for the following terrain:
  - Uphill and downhill yarding;
  - Over sensitive areas where full suspension is possible;
  - Relatively long yarding distances;
  - Rough or steep terrain but often dependant on terrain roughness or slope shape (less so if intermediate supports are used).

Monocable

Recommended terrain conditions for monocables

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%)</td>
</tr>
<tr>
<td>Ground condition</td>
</tr>
<tr>
<td>Ground roughness</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
</tr>
</tbody>
</table>

- The system consists of a single capstan winch driving a continuous loop of wire which is supported by a series of open-sided blocks;
- Monocable winching is suitable for extracting small sized timber typically found in thinning operations;
- Damage to the remaining standing trees can occur if the pathway is not set out correctly or if the tree-protection straps supporting the blocks are not attached correctly;
- Limited lift is achievable depending on the height and spacing of the support blocks, and the choking method used;
- Only use this system to extract timber over riparian zones, streams or other sensitive areas if sufficient lift is attainable;
Recommended for the following terrain:
° Stable ground conditions;
° Level, regular or concave slope conditions.

Groundlead (winching)

<table>
<thead>
<tr>
<th>Limitation/Application Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope (%)</td>
</tr>
<tr>
<td>Ground condition</td>
</tr>
<tr>
<td>Ground roughness</td>
</tr>
<tr>
<td>Max. extraction distance (m)</td>
</tr>
</tbody>
</table>

• The system usually consists of a one- or two-drum winch with no spar or tower, a capstan winch can also be used;
• Damage, breakages and time losses occur due to logs being forced through or around obstacles;
• This system should not be used to extract timber over riparian zones, streams or other sensitive areas;
• Recommended for the following terrain:
° Stable ground conditions;
° Level, regular or concave slope conditions;
° Short extraction distances;
• Groundlead winching is suitable for pre-bunching timber for other extraction methods (e.g. grapple skidders, forwarders and cable yarders) and for recovering timber close to roads or landings without having to use heavy machinery.

5.2.2.8 Extended Primary Transport

Machinery and Equipment:
• Tractor-trailer combinations (for terrain specifications for tractor-trailer combinations, see Section 5.2.2.6);
• Articulated-Timber Trucks (for terrain specifications for articulated-timber trucks see Section 5.2.2.6);
• Timber trucks.

Factors that influence extended primary transport of timber:
• Transportation unit type and capability;
• Load size (total weight);
• Transport distance;
• Distribution of the load on the vehicle;
• Payloads;
• Loading and unloading method and times;
• Climatic conditions;
• Gradients encountered en-route;
• Road conditions (rolling resistance of road surface);
• Travelling speed (function of unit type, load size, road conditions and driver skills);
• Driver and operator skills;
• Vehicle availability;
  • Vehicle utilisation.

**Positive results of extended primary transport:**
• Security of timber supply under specific conditions for secondary transport (on-road transport);
• Reduced expenditure on road upgrades.

**Potential negative impacts of extended primary transport:**
• Damage to the road surface;
• Logs falling off vehicles whilst in motion;
• Damage to timber due to additional handling;
• Additional costs to the supply chain;
• Overloading of vehicles;
• Underloading of vehicles.

**Methods of reducing the likelihood of negative impacts:**
• Train operators and drivers adequately;
• Adhere to traffic rules and laws on public and private roads;
• Follow safe working procedures;
• Ensure vehicles are roadworthy and in a good working condition;
• Ensure sound daily maintenance;
• Ensure prompt servicing as specified by the vehicle manufacturer;
• Operate the vehicle within its capabilities as specified by the manufacturer;
• Use equipment and machinery specifically designed for the type of transport;
• Avoid overloading;
• Secure loads with suitable load binders (e.g. chains, cables, steel straps, nylon straps or nylon nets).

5.2.3 **Unloading and Loading at Landings and Depots**

**Methods:**
• Manual;
• Gravity (unloading);
• Knuckle-boom crane (truck mounted for self-loading);
• Knuckle-boom loader (independent);
• Three-wheeled loader;
• Front-end loader;
• Gantry crane.

**Factors that influence timber un-loading and loading:**
• Timber size (piece volume);
• Load size (total volume or weight);
• Number of pieces per load;
• Volume of work available;
• Depth of the stack (reach of loader);
• Surface and weather conditions;
• Unobstructed clearance for loader to move (limited by size of area, position of stacks and remaining trees, power and telephone lines/poles);
• Driver visibility;
• Presentation of timber (e.g. stacking method, stack size, sorted/unsorted);
• Moving requirement (centralised or decentralised loading);
• Loader type and capability (e.g. grapple size and boom length);
• Vehicle to be loaded or unloaded (e.g. stanchion height);
• Angle of swing from the stack to the transport vehicle;
• Balancing of the system, i.e. the right equipment (loader and transport vehicle) to suit the conditions (timber size and volume);
• Transport scheduling;
• Driver and operator skills;
• Mechanical availability;
• Machine utilisation.

Positive results of timber unloading and loading:
• Reduced product congestion at landing/depot;
• Timeous loading operations lead to smaller landings and depots required;
• Improved supply chain efficiencies (link between harvesting and transport operations).

Potential negative impacts of timber unloading and loading:
• Physical injuries to workers and damage to vehicles;
• Safety hazards (unstable stacks and insufficient moving space);
• Susceptible to bottle-necks (system unbalanced) causing too much idle time for the loader of the transport vehicle;
• Damage to road surfaces caused by loaders;
• With many vehicles in the area, there is often uncontrolled and unexpected vehicle movement.

Methods of reducing the likelihood of negative impacts:
• Train operators and workers adequately;
• Follow safe working procedures;
• Plan timber harvest and transport operations to ensure efficient interactions;
• Only use equipment and machinery designed or equipped for the specific operation;
• Synchronize and balance the system (schedule transport and loading operations);
• Ensure that the unloading facilities at the conversion site are adequate;
• Keep the approach and exit to and from timber stacks accessible and clear of obstructions;
• Ensure that there is a sufficient volume of timer available to keep the loader optimally utilised;
• Keep the swing cycle of the loader as short as possible (reduced cycle time);
• Keep drainage on the landing and depot open to ensure necessary water drainage;
• Match the loader capabilities with the vehicle configuration;
• Ensure sound daily maintenance;
• Ensure prompt machine servicing as specified by the manufacturer;
• Operate the machine within its capabilities as specified by the manufacturer;
• Keep working area clean and remove slash and debris from the stacking area and stacks;
• No unauthorised vehicle or human movement allowed on load sites.
5.2.4 Stacking at Landings and Depots

Methods:

- Manual (for manual stacking terrain limitations, see Section 5.2.1.5);
- Mechanical (multi-functional machines, loaders) (for mechanical stacking terrain limitations, see Section 5.2.1.5).

Factors that influence stacking operations:

- Piece volume;
- State of conversion;
- Size of stacks;
- Area of landing/depot;
- Depot and landing management and outlay;
- Slope and condition of landing or depot surface;
- Operator skills;
- Machine configuration;
- Stacking method used;
- Mechanical availability;
- Machine utilisation.

Positive results of stacking at landings and depots:

- Better coordination and control of timber stocks;
- Better control of crosscutting;
- Reduced loading time.

Potential negative impacts of stacking at landings and depots:

- Severe physical injuries to workers and damage to vehicles;
- Slippery and dangerous surface when wet;
- Safety hazard (unstable stacks and insufficient moving space);
- Logs covered with mud or soil;
- Damage to timber;
- Uncontrolled vehicle movement.

Methods of reducing the likelihood of negative impacts:

- Train operators and workers adequately;
- Follow safe working procedures;
- Only use equipment and machinery specifically designed or equipped for stacking;
- Construct stacks on level terrain or on suitable supports;
- Sort timber according to size and/or product, if required;
- Remove debris from the stacking area;
- Keep drainage open;
- Ensure sound daily servicing;
- Ensure prompt machine servicing as specified by the manufacturer;
- Operate the machine within its capabilities as specified by the manufacturer.
5.3 Biomass Harvesting, Extraction and Extended Primary Transport

Biomass can be defined as material of biological origin, excluding material embedded in geological formations and/or transformed to fossil. Plantation forestry biomass includes all components of the tree, from tree top to root tip (Figure 31). Some of the biomass will be converted into higher value products (e.g. sawtimber or pulpwood), but a portion of the remainder of the tree can potentially be used as a feedstock for bioenergy production. Woody biomass is renewable and can be seen as a “greener” energy source than current fossil fuels with benefits ranging from the moral ones of reduction of greenhouse gases to the more commercial ones linked to carbon emission trade.

As shown in Figure 31, biomass can be sourced in various forms from trees. Biomass harvested from plantations has traditionally been in the form of the above-ground “residue” which is produced/left behind by the timber harvesting operations (i.e. branches, bark, twigs and/or leaves). Other sources of biomass may be in the form of stumps, roots and full trees (which have been grown completely for bioenergy purposes and generally include the stem as well as the bark, branches, twigs and leaves). For the purpose of this document, biomass will refer to the traditional biomass source of harvesting “residue”.

Removal of nutrient-rich biomass components of trees from plantations accelerates overall nutrient removals from sites. Hence it is important that the intensity of biomass harvesting is based on an understanding of each individual site’s biogeochemical cycle (i.e. the nutrient pools and fluxes within a forest ecosystem). In addition, an understanding of nutrient inputs and outputs associated with the cycle is necessary to determine how much biomass can be removed from the site, which components of the biomass should be removed and which components should be left behind. The larger the nutrient pools and the more rapid the nutrient inputs, the more biomass can be removed from a site. Conversely, the smaller the nutrient pools and the more rapid the nutrient outputs, the less biomass can be removed from a site.
Generally the requirements for efficient biomass conversion to energy are the following:

- Moisture content: as low as possible (below 20% for most reactors);
- Energy content: as high as possible;
- Ash content: as low as possible (below 5% for most reactors);
- Volatile content: as low as possible (around 70-80% for woody biomass);
- Si, S, Cl, K content: as low as possible to prevent corrosion of the reactor vessels;
- Particle size: as uniform as possible.

Different timber species and different components of the tree all result in a wide range of properties of biomass, and thus a wide range of bioenergy conversion outputs. The table below summarises some of the more common properties of the most common commercially grown genera.

<table>
<thead>
<tr>
<th>Property</th>
<th>Wood</th>
<th>Bark</th>
<th>Leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic density [kg/m³]</td>
<td>Acacia: 300-600</td>
<td>Acacia: 350-450</td>
<td>Acacia: 300-600</td>
</tr>
<tr>
<td>Ash [%]</td>
<td>Acacia: 0.5-1.5</td>
<td>Acacia: 0.8-1.2</td>
<td>Acacia: 0.5-1.5</td>
</tr>
<tr>
<td></td>
<td>Euc.: 0.8-1.2</td>
<td>Euc.: 0.8-1.2</td>
<td>Euc.: 0.8-1.2</td>
</tr>
<tr>
<td></td>
<td>Pine: 0.8-1.2</td>
<td>Pine: 0.8-1.2</td>
<td>Pine: 0.8-1.2</td>
</tr>
<tr>
<td>Volatile matter [%]</td>
<td>Acacia: &gt; 90</td>
<td>Acacia: 80-85</td>
<td>Acacia: 80-85</td>
</tr>
<tr>
<td></td>
<td>Euc.: &gt;85</td>
<td>Euc.: 85-87</td>
<td>Euc.: 85-87</td>
</tr>
<tr>
<td></td>
<td>Pine: &gt; 86</td>
<td>Pine: 82-87</td>
<td>Pine: 82-87</td>
</tr>
<tr>
<td></td>
<td>Euc.: 19.7-20.1</td>
<td>Euc.: 17.8-19.5</td>
<td>Euc.: 19.7-20.1</td>
</tr>
<tr>
<td></td>
<td>Pine: 19.7-20.5</td>
<td>Pine: 19.5-20.5</td>
<td>Pine: 19.7-20.5</td>
</tr>
</tbody>
</table>

(FESA Report: The use of forest residue for bioenergy in southern Africa. ICFR Bulletin 03/2013 (www.icfr.ukzn.ac.za))

5.3.1 Biomass Harvesting

For the purpose of this document, it is assumed that “felling” of biomass residue is carried out in the felling operations described in Section 5.2.1, in which the trees are felled for the merchantable round wood timber. Collection, extraction, extended primary transport, chipping, un-loading and loading of biomass will be discussed in this chapter. Secondary intermediate transport and secondary terminal transport of biomass will be discussed in Chapter 6.

Types of biomass harvesting systems:

- Terrain (infield) chipping;
- Roadside/landing chipping;
- Centralised depot (terminal) chipping;
- Plant (mill) chipping.

Biomass can be harvested from clearfelling operations using either a one- or two-pass harvesting system. In the one-pass system, the round wood merchantable timber as well as the residue biomass are harvested and extracted to a roadside landing together in one operation. This operation usually involves a full-tree extraction system (e.g., a skidder extracting full trees with branches attached to roadside). In a two-pass system, the harvesting and extraction of the round wood merchantable timber is dealt with in a different operation to the harvesting and extraction of the residue biomass. The timber harvesting operation in this case is usually either cut-to-length (e.g., a harvester-forwarder combination) or tree-length (e.g., skidder extracting tree lengths to roadside).
The impact of harvesting a low bulk density product such as plantation biomass on system costs and productivity can be overcome to a degree by chipping the product as early in the supply chain as possible or by compacting the residue. Residue compaction can be done using a compactor or through the production of residue bundles. If compaction without bundling is practiced, there must be compaction facilities on all the transport equipment in the system. Bundling need only be done once but requires the inclusion of an additional machine in the system.

**Various forms of biomass within biomass supply chain systems:**
- Loose material;
- Compacted material;
- Bundled material;
- Chips (chipped material).

**Factors that influence biomass harvesting:**
- Terrain accessibility:
  - Without access to the biomass, two-pass harvesting is not possible;
  - With a one pass system, the biomass is removed with the timber so accessibility is dependent on the timber harvesting operation.
- Recovery rate:
  - All components of trees can in principle be used for energy generation, but the recovery rate will have an influence on the productivity, hence cost and also biomass fuel quality.
- Quality of chips (best described by):
  - Moisture content;
  - Particle size distribution;
  - Contamination;
- Storage space (specifically of chips, to allow sufficient drying time and space for the stockpile to be turned);
- Moisture content of biomass;
- Proximity to mill;
- Value of the product;
- Bulk density;
- biomass yields per hectare;
- Nutrient pools and nutrient cycles per site;
- Trees species being harvested.

### 5.3.2 Biomass Collection and Extraction

#### 5.3.2.1 One-Pass Biomass Harvesting

Felling, collection and extraction of timber harvesting “residue” biomass in one-pass systems happens together with the felling, collection and extraction of the merchantable round wood timber. Biomass is extracted as “loose” material which is still attached to the stem.

**One-Pass Biomass Collection and Extraction**

**Equipment:**
- Shovel logger (for terrain specifications for shovel loggers, see Section 5.2.2.4);
- Wheeled skidder (cable, clambunk and grapple) (for terrain specifications for wheeled skidders, see Section 5.2.2.5);
• Crawler tractor (for terrain specifications for crawler tractors, see Section 5.2.2.5);
• Agricultural tractor with skidding accessories (for terrain specifications for agricultural tractors with skidding accessories, see Section 5.2.2.5);
• Highlead (for terrain specifications for skidders, see Section 5.2.2.7);
• Skyline (for terrain specifications for skidders, see Section 5.2.2.7).

Factors influencing one-pass biomass collection and extraction operations:
• Timber harvesting equipment and operation;
• Tree species;
• Extent of processing carried out infield;
• Tree size;
• Load size (total volume or weight);
• Amount of biomass per load;
• Terrain (slope, roughness and condition);
• Sensitivity of terrain (susceptibility to soil damage and erosion);
• Size of area from which timber and biomass are to be extracted;
• Extraction distance;
• Extraction direction (uphill, downhill or parallel to the contour);
• Machine type and capability;
• Traction;
• Felling direction (uphill, downhill or parallel to the contour);
• Felling layout;
• Presentation of the felled trees (scattered, bunched or stacked, full tree, long lengths or short lengths);
• Mechanical availability;
• Machine utilisation.

Positive results of one-pass biomass collection and extraction:
• Revenue generation from the site increased from exclusive timber harvesting operations;
• Fuel load reduction;
• Improved site accessibility for following silvicultural operations;
• Utilisation of an otherwise “waste” product;
• Less operations to be managed than a two-pass system;
• Less capital investment than a two-pass system;
• Better utilisation of extraction equipment.

Potential negative impacts of one-pass biomass collection and extraction:
• Nutrient depletion of site;
• Slowed timber harvesting/processing operations to accommodate biomass harvesting and processing;
• Limited space at the landing for multiple product storage;
• Transport congestion due to multiple product transport and loading operations required;
• Biomass becoming contaminated by soil or mud.

Methods of reducing the likelihood of negative impacts:
• Ensure site-specific sustainable nutrient removal when removing biomass;
• Plan road network and landings well in advance;
• Ensure product storage on landing is kept to a minimum;
• Plan harvest and transport operations carefully;
• Train operators and assistants adequately;
• Follow safe working procedures.

5.3.2.2 Two-Pass Biomass Harvesting

In two-pass biomass harvesting systems, the merchantable round wood and the biomass "residue" are felled in the same felling operation, but they are recovered in separate operations. The residue therefore remains infield following the timber harvesting operation and is recovered at a later stage.

Two-Pass Biomass Infield Collection and Loading

Methods and Equipment:

• Collection and bundling of loose biomass into bundles:
  ○ Slash bundler;
• Collection and chipping of loose biomass into chips which are fed into bins:
  ○ Mobile chipper unit;
• Collection and loading of loose biomass and/or bundled biomass:
  ○ Manual collection and loading;
  ○ Forwarder;
  ○ Agricultural tractor with crane;
  ○ Shovel Logger;
  ○ Tracked-based loader (Swing loader);
  ○ Three-wheeled loader;
  ○ Excavator-based loader;
  ○ Multi-functional machines (harvester or processor).

Factors that influence two-pass biomass infield collection and loading:

• Form of biomass (loose, chipped, compacted, bundled);
• Biomass presentation;
• Timber harvesting equipment and operation;
• Extent of processing carried out infield;
• Biomass extraction equipment;
• Terrain (slope, roughness and condition);
• Sensitivity of terrain (susceptibility to soil damage and erosion);
• Machine type and capability;
• Mechanical availability;
• Machine utilisation.

Positive results of two-pass biomass infield collection and loading:

• Revenue generation from the site increased from exclusive timber harvesting operations;
• Fuel load reduction;
• Improved site accessibility for following silvicultural operations;
• Utilisation of an otherwise “waste” product;
• Reduced product congestion at landing/depot due to timber and biomass being dealt with separately;
• Reduced transport congestion on roads and at landing/depot due to timber and biomass being dealt with separately.

Potential negative impacts of two-pass biomass infield collection and loading:
• Nutrient depletion of site;
• More operations to be managed than a one-pass system;
• Additional traffic on sensitive sites causing damage;
• Higher capital investment than a one-pass system;
• Low bulk density of product;
• Low "residue" biomass yields per hectare.

Methods of reducing the likelihood of negative impacts:
• Ensure site-specific sustainable nutrient removal when removing biomass;
• Train operators and assistants adequately;
• Plan timber harvest and transport operations and biomass harvest and transport operations to ensure efficient interactions;
• Ensure timber harvesting operations leave residue in an easily accessible pattern for biomass operations;
• Maximise biomass recovery per hectare within the confines of nutrient removal limitations;
• Follow safe working procedures.

Two-Pass Biomass Extraction

Methods:
• Chipped biomass:
  ◦ Forwarder (or other ground-based elevated extraction machine) with bin;
• Loose or bundled biomass:
  ◦ Forwarder (or other ground-based elevated extraction machine);
• Compacted biomass:
  ◦ Agricultural tractor with compacting unit trailer (or another ground-based elevated extraction machine with similar compacting capabilities).

Factors that influence two-pass biomass extraction:
• Form of biomass (loose, chipped, compacted, bundled);
• Timber harvesting equipment and operation;
• Extent of processing carried out infield;
• Biomass collection and loading equipment;
• Load size;
• Travel speed;
• Extraction distance;
• Terrain (slope, roughness and condition);
• Sensitivity of terrain (susceptibility to soil damage and erosion);
• Machine type and capability;
• Traction;
• Mechanical availability;
• Machine utilisation.
Positive results of two-pass biomass extraction:

- Revenue generation from the site increased from exclusive timber harvesting operations;
- Fuel load reduction;
- Improved site accessibility for following silvicultural operations;
- Utilisation of an otherwise “waste” product;
- Reduced product congestion at landing/depot due to timber and biomass being dealt with separately;
- Reduced transport congestion on roads and at landing/depot due to timber and biomass being dealt with separately.

Potential negative impacts of two-pass biomass extraction:

- Nutrient depletion of site;
- More operations to be managed than a one-pass system;
- Additional traffic on sensitive sites causing damage;
- Higher capital investment than a one-pass system;
- Low bulk density of product resulting in low payloads.

Methods of reducing the likelihood of negative impacts:

- Ensure site-specific sustainable nutrient removal when extracting biomass;
- Train operators and assistants adequately;
- Extraction of chipped, compacted or bundled residue to increase payload;
- Plan timber harvest and transport operations and biomass harvest and transport operations to ensure efficient interactions;
- Ensure timber harvesting operations leave residue in an easily accessible pattern for biomass operations;
- Maximise biomass recovery per hectare within the confines of nutrient removal limitations;
- Follow safe working procedures.

Two-Pass Biomass Extended Primary Transport

Methods:

- Chipped biomass:
  - Articulated dump truck with bin;
  - Tractor-trailer unit with bin;
  - Truck with bin;
- Loose or bundled biomass:
  - Articulated dump truck;
  - Tractor-trailer unit;
  - Truck;
- Compacted biomass:
  - Agricultural tractor with compacting unit trailer (or another ground-based elevated extraction machine with similar compacting capabilities).

Factors that influence two-pass biomass extended primary transport:

- Form of biomass (loose, chipped, compacted, bundled);
- Timber harvesting equipment and operation;
- Extent of processing carried out infield;
- Biomass collection and loading equipment;
• Load size;
• Travel speed;
• Extended primary transport distance;
• Road condition;
• Terrain (slope, roughness and condition);
• Sensitivity of terrain (susceptibility to soil damage and erosion);
• Machine type and capability;
• Traction;
• Mechanical availability;
• Machine utilisation.

Positive results of two-pass biomass extended primary transport:
• Revenue generation from the site increased from exclusive timber harvesting operations;
• Fuel load reduction;
• Improved site accessibility for following silvicultural operations;
• Utilisation of an otherwise “waste” product;
• Reduced product congestion at landing/depot due to timber and biomass being dealt with separately;
• Reduced transport congestion on roads and at landing/depot due to timber and biomass being dealt with separately;
• Biomass available at an area accessible to secondary transport vehicles.

Potential negative impacts of two-pass biomass extended primary transport:
• Nutrient depletion of site;
• More operations to be managed than a one-pass system;
• Additional traffic on sensitive sites causing damage;
• Higher capital investment than a one-pass system;
• Low bulk density of product resulting in low payloads.

Methods of reducing the likelihood of negative impacts:
• Ensure site-specific sustainable nutrient removal when extracting biomass;
• Train operators and assistants adequately;
• Extended primary transport of chipped, compacted or bundled residue to increase payload;
• Plan timber harvest and transport operations and biomass harvest and transport operations to ensure efficient interactions;
• Ensure timber harvesting operations leave residue in an easily accessible pattern for biomass operations;
• Maximise biomass recovery per hectare within the confines of nutrient removal limitations;
• Follow safe working procedures.

5.3.3 Biomass Chipping

Machinery and Equipment:
• Terrain chipping system:
  ° Highly mobile chipper;
• Roadside/landing chipping system:
  ° Roadside chipper;
• Centralised depot (terminal) chipping system:
  ° Centralised chipping unit;
• Plant chipping system:
  ° Mill chipper unit.

**Factors that influence biomass chipping:**
• Form of biomass (loose, compacted, bundled);
• Volume of biomass;
• Biomass contamination (soil, mud, etc.);
• Composition of biomass (wood, twigs, leaves, bark, etc.);
• Mechanical availability;
• Machine utilisation.

**Positive results of biomass chipping:**
• Improved biomass bulk density;
• Revenue generation from harvesting site increased compared to exclusive timber harvesting operations;
• Utilisation of an otherwise “waste” product;
• Generally in the form of a chipper-loader machine.

**Potential negative impacts of biomass chipping:**
• Nutrient depletion of site;
• Generally a large capital investment required;
• Stockpiles of chips slow the biomass drying rate and form a threat of spontaneous combustion;
• Contamination of chipped biomass if chipped onto the ground;
• Damage to transport vehicles;
• Operation can require a large flat area (not always possible in steeper terrain);
• Susceptible to bottle-necks (system unbalanced/breakdowns);
• Generally high production machines – unable to cater for smaller operations.

**Methods of reducing the likelihood of negative impacts:**
• Ensure site-specific sustainable nutrient removal of biomass to feed chipping operations;
• Turn stockpiled chips to facilitate drying and reduce spontaneous combustion threat;
• Chip biomass directly into bins or cleared storage areas;
• Train operators and assistants adequately;
• Follow safe working procedures;
• Plan timber harvest and transport operations and biomass harvest and transport operations to ensure efficient interactions;
• Ensure the system is well balanced.

### 5.3.4 Biomass Unloading and Loading at Landings and Depots

**Methods:**
• Chipped biomass:
  ° Gravity (unloading);
  ° Front-end loader;
  ° Direct chipping into bins by a chipper (loading).
• Loose or bundled or compacted biomass:
  ° Manual;
  ° Gravity (unloading);
  ° Knuckle-boom crane (truck mounted for self-loading);
  ° Knuckle-boom loader (independent);
  ° Heel-boom loader;
  ° Three-wheeled loader;
  ° Front-end loader;
  ° Gantry crane.

Factors that influence biomass unloading and loading:
• Form of biomass (loose, chipped, compacted, bundled);
• Load size;
• Surface and weather conditions;
• Unobstructed clearance for loader to move (limited by size of area, position of stacks and remaining trees, power and telephone lines/poles);
• Driver visibility;
• Presentation of biomass;
• Moving requirement (centralised or decentralised loading);
• Loader type and capability;
• Vehicle to be loaded or unloaded;
• Balancing of the system, i.e. the right equipment (loader and transport vehicle) to suit the conditions;
• Transport scheduling;
• Driver and operator skills;
• Mechanical availability;
• Machine utilisation.

Positive results of biomass unloading and loading:
• Revenue generation from the harvesting site increased compared to exclusive timber harvesting operations;
• Utilisation of an otherwise “waste” product;
• Reduced product congestion at landing/depot;
• Timeous loading operations lead to smaller landings and depots required;
• Improved supply chain efficiencies (link between harvesting and transport operations).

Potential negative impacts of biomass unloading and loading:
• Nutrient depletion of site;
• Physical injuries to workers;
• Stockpiles of chips slow the biomass drying rate and form a threat of spontaneous combustion;
• Contamination of chipped biomass if chipped onto the ground;
• Damage to vehicles;
• Susceptible to bottle-necks (system unbalanced/breakdowns);
• Damage to road surfaces caused by loaders;
• With many vehicles in the area, there is often uncontrolled and unexpected vehicle movement.
Methods of reducing the likelihood of negative impacts:

- Ensure site-specific sustainable nutrient removal of biomass to feed chipping operations;
- Turn stockpiled chips to facilitate drying and reduce spontaneous combustion threat;
- Train operators and workers adequately;
- Follow safe working procedures;
- Plan timber harvest and transport operations and biomass harvest and transport operations to ensure efficient interactions;
- Ensure the system is well balanced;
- Only use equipment and machinery designed or equipped for the specific operation;
- Ensure that the unloading facilities at the conversion site are adequate;
- Keep the approach and exit to and from biomass piles accessible and clear of obstructions;
- Ensure that there is a sufficient volume of biomass available to keep the loader optimally utilised;
- Keep drainage on the landing and depot open to ensure necessary water drainage;
- Match the loader capabilities with the vehicle configuration;
- Ensure sound daily maintenance;
- Ensure prompt machine servicing as specified by the manufacturer;
- Operate the machine within its capabilities as specified by the manufacturer.
Secondary intermediate transport in forestry can be defined as the transport of timber and/or other biomass from a roadside landing or depot to another intermediate storage site. The timber does not reach the processing site in this phase of transport. Secondary terminal transport in forestry involves the transport of timber and/or other biomass from any landing or intermediate timber storage site to the processing site. This is the final stage of transport. Products can be transported by road, rail, water or air, but this handbook will only deal with road transport unless otherwise stipulated.

Factors to consider for secondary transport operations:

- “Vehicles” refer to all self-propelled vehicles, machinery and equipment, including any attachments or vehicles being towed;
- Vehicles should comply with the National Road Traffic Act and Regulations (Act 93/1996) at all times;
- Vehicles should be registered to their respective title holders;
- Vehicle dimensions as determined in the road traffic regulations should be adhered to;
- The maximum allowable width, height and length of a vehicle should not be exceeded;
- The load should not extend more than 1800 mm from the rearmost part of the vehicle;
- Loads should be contained within the body of the vehicle at all times;
- Principles of permissible mass establish limiting factors which determine minimum and maximum limits in respect to vehicles masses with regard to safety, protection of the country’s roads and infrastructure. These should also be adhered to at all times. Maximum and minimum mass limits of a vehicle are determined by establishing the mass influencing factor of the following criteria:
  - Manufacturer’s ratings;
  - Tyre ratings;
  - Wheel, axle or axle unit;
  - Gross Vehicle Mass (GVM);
  - Engine output (kW);
  - Mass distribution on steering and driving axles;
  - Road loading and bridge loading;
- Only use equipment and machinery designed or equipped for the specific operation;
- No loading of trucks should take place within the road reserve of a provincial road, unless written permission has been obtained from the local roads authority;
- All warning signs, demarcated safety areas and safe operating practices should be respected and adhered to;
- Ensure that the loading and off-loading facilities at the depot or landing are adequate;
- No person, other than the truck driver should be allowed enter the loading area while loading;
- The truck driver should always be in a position where the loader operator can see him and he can give clear instructions;
- While loading, the loader operator should follow the instructions of the truck driver as the truck driver is responsible for the truck and the load (e.g. legal payload and load distribution);
- Keep the approach and exit to and from loading areas accessible and clear of obstructions;
- Transport the older timber/biomass first (First In, First Out principle).
6.1 Road Transport Management System (RTMS)

RTMS is an industry-led, voluntary self-regulation scheme that encourages consignees, consignors and transport operators engaged in the road logistics value chain to implement a vehicle management system that preserves road infrastructure, improves road safety and increases the productivity of the logistics value chain. In South Africa, it was initiated by the South African forestry industry.

The scheme also supports the Department of Transport’s National Freight Logistics Strategy. It is a strategy by road haulage (consignors and consignees) and providers of road haulage (hauliers) to jointly protect the road network, improve road safety and transport productivity for the benefit of the country’s citizens and the industry itself. RTMS is chaired by an independent body and has representatives from the participating industry and haulier companies as well as the Department of Transport (DOT). Within some sections of the South African forest industry, RTMS accreditation is a pre-requisite to qualifying for a haulage contract.

RTMS provides the following:

• The ability to access and monitor over/under-loading and transport efficiency in the supply chain;
• An accreditation system for hauliers wishing to achieve and maintain RTMS compliance;
• The opportunity to investigate the implementation of Performance Based Standards (PBS).

RTMS is focused on attaining concessions for compliant hauliers. These include:

• Eliminating weighing of trusted RTMS-compliant vehicles at provincial weighbridges;
• Discounted insurance premiums;
• A fair and stable environment in which hauliers can operate;
• Providing a foundation for the introduction of Performance Based Standards (PBS/Smart Trucks) into the country.

More information on RTMS and forest transport can be viewed at www.rtms-forestry.co.za

6.2 Performance Based Standards (PBS/Smart Trucks)

Performance Based Standards (PBS), also known as Smart Trucks, seeks to break the traditional limitations of prescriptive legislation (mass and dimensional limits) which determines heavy vehicle regulations within the boundaries of sustainability, safety, reduced road damage, reduced emissions and overall increased productivity and reduced cost. PBS achieves this by an innovative process in which heavy motor vehicles are evaluated against a set of defined standards to ensure road safety and infrastructure protection. The result is trucks which supersede the conventional legislative parameters for heavy vehicle dimensions. Generally these vehicles are longer and heavier than vehicles following the normal legislative standards, leading to increased payloads and improved efficiencies.

Factors to consider for PBS operations (detailed PBS requirements should be investigated should someone wish to operate a PBS vehicle, the points below serve only as a basic summarised guide):

• Any haulier wishing to implement PBS into his/her business would need to be RTMS-compliant before being allowed to apply for a PBS permit;
• The dimensions and technical structure of approved PBS vehicles should not be altered in any way;
• PBS trucks may only run on designated routes, with approved permits from the DOT;
• In the event of either a PBS truck or PBS trailer being out of service, only a PBS registered truck and/or a PBS registered trailer should be interchanged, so that the PBS status is not in any way compromised;
• In the event that any accident repairs of a material structural nature are undertaken, the haulier should ensure that the dimensional integrity of the unit is maintained;
The KwaZulu-Natal DOT reserve the right that at any time the PBS vehicle combination may be required for inspection to ensure that the PBS simulated design and dimensional specifications are being maintained;

- Only vehicle combinations which have received the required official approvals and permits should be built and used on South African roads;
- Drivers of PBS vehicles need to adhere to more stringent requirements and accident-free records than standard heavy vehicle drivers:
  - Minimum of three years driving experience with an EC (Code 14) license;
  - Valid PrDP (Professional Driving Permit) (preferably a “D” class PrDP);
  - Hours of work duty for any driver (inclusive of driving time per driver) should not exceed eight (8) hours.
- Ancillary equipment and technical requirements of PBS vehicles:
  - On-board weighing equipment;
  - Central tyre inflation (CTI) – minimum on drive axles;
  - Intarder / Retarders;
  - Side marker lights – truck and trailer;
  - Flashing amber light on truck cab roof;
  - Abnormal length boards on front and rear of the vehicle;
- The PBS authorising permit should at all times be carried in the vehicle;
- Conditions contained in the operating permit and pertaining to the safe and legal operation of the PBS vehicle combination should be adhered to at all times;
- PBS vehicles should retain a minimum travelling distance between other PBS vehicles of at least one kilometer (1000 m);
- The PBS vehicle should not be used for any other form or kind of transport other than that for which the vehicle’s design and legal permit allows;
- Performance, legal and other criteria pertaining to the retention of RTMS accreditation compliance should be adhered to.

6.3 Secondary Transport Plans

During secondary transport tactical planning, the balancing of compartments, roads and transport systems over a period of time (normally three to five years) is done to ensure a sustained timber/biomass supply and the optimal utilisation and allocation of vehicles. This planning is carried out together with tactical roads planning and tactical harvest planning, as well as considering silvicultural requirements. Costs and environmental considerations are also weighed up.

The most important aspects to be considered in a secondary transport tactical plan are:

- Strategic plan;
- Current road infrastructure;
- Balancing timber/biomass volume over the set time frame;
- Markets for timber/biomass and products;
- Balancing of transport vehicles to harvesting systems, loading systems and volumes;
- Balancing of transport vehicles to lead distances and volumes;
- Environmental factors;
- Selecting the most appropriate vehicle configuration/s for the product/s and conditions which the vehicles need to deal with.
Secondary transport tactical planning includes the following steps:

- Determining the needs of the customer;
- Road plan and schedule;
- Harvest plan and schedule;
- Choosing vehicles to match the terrain, product being transported, distance being travelled and road conditions;
- Identifying wet or dry periods and associated roads and landings/depots.

Secondary transport operational planning includes the following steps:

- Preliminary office work;
- Field work;
- Production and cost information (office work);
- Daily management and production control;
- Return of ownership of roads, depots and landings to silviculture management (signing off);
- Alternative transport routes (e.g. during poor weather or temporary market closures).

Planning success will depend on:

- Experienced foresters and contractors;
- Reliable maps;
- Well defined operating objectives;
- Group reconnaissance trips which include relevant stakeholders;
- Careful system choices;
- Thorough paper planning and field verification;
- Thorough review of implications (impact appraisal);
- Readiness to change the plan if required by having alternative choices;
- Effective communication between planners and operators;
- Market conditions;
- Accurate volume information.

During operational secondary transport planning, the transport of each compartment from roadside or depot is individually planned in detail. The operational plan should include the following:

- The large scale contour map used for the harvesting operational plan, showing landing/depot locations and haulage roads;
- Product dimensions;
- Harvest and transport scheduling to avoid congestion at the loading and unloading sites;
- Harvesting, extraction and transport systems (i.e. method of felling, conversion, extraction and transport) matched to the terrain and balanced;
- Equipment and human resource requirements;
- Direction of timber/biomass flow and haulage;
- Management prescriptions to protect specific values and designated SMZ’s;
- Compartment details (e.g. total volume, average stem volume, spha, dbh, length, species, age);
- Detailed production and cost calculations.
6.4 Timber Secondary Intermediate and Secondary Terminal Transport

Factors to consider for secondary timber transport operations:

- When loading timber for transport (road and rail trucks), the logs in the billets must be correctly indexed to avoid interlocking;
- Try to avoid indexing the timber on bare ground (stones and mud get lodged in the wood);
- The truck driver should make sure that the loader has finished loading a billet of the truck before moving closer to the truck to secure the load and complete the final vehicle checks;
- Loading distribution and securing systems:
  - The principles of the load distribution outlined in clause 5 of SANS 10187-1:2006 should be adhered to;
  - Timber should, wherever possible, be placed against the headboard;
  - Load bindings in the form of chains or webbing which comply with clause 7 of SANS 10187-1:2006 should be used to hold the load together as a unit and to secure loose top logs;
  - Load bindings should be regularly checked during a journey and, if necessary, retightened;
- Stacks on the longitudinal axis:
  - Every outer log or piece of timber which is equal to or less than 3 m in length should be supported by at least two upright stakes;
  - Log pieces shorter than the distance between two upright stakes should be placed in the interior of the pile;
  - If a load pile is supported by only one pair of upright stakes on each side, the ends of the outer logs should extend at least 0.3 m beyond the upright stakes;
  - Logs longer than 3 m should be supported by three or more upright stakes;
  - Not more than half of any log’s diameter should protrude above the top of the upright stakes;
  - Long logs with significant taper should be laid in an alternating “top-to-tail” manner so as to ensure an even balance of the load;
  - Each billet should be lashed together and the lashing secured to the vehicle by a suitable means
  - The number of straps on each billet should be at least:
    - One, if the load consists of undebarked logs (i.e. logs which still have their bark on) with a maximum length of 3 m;
    - Two, if the load consists of undebarked logs with a length of greater than 3 m;
    - Two, if the load consists of debarked logs (i.e. logs which have had their bark removed), irrespective of the length.

6.4.1 Timber Secondary Intermediate Transport

Machinery and Equipment:

- Tractor-trailer combinations;
- Articulated-steering vehicles;
- Rigid truck (may be linked with a drawbar trailer);
- Articulated vehicle with either one or two semi-trailer/s;
- Articulated vehicle with semi-trailer and drawbar trailer;
- Stinger-steer truck/trailer combinations;
- Appropriate rail wagons.
Factors that influence secondary intermediate transport of timber:

- Weather conditions;
- Transportation unit type and capability;
- Load mass (total weight);
- Transport distance;
- Distribution of the load on the vehicle;
- Loading and un-loading method and times;
- Climatic conditions;
- Gradients encountered en-route;
- Road conditions (rolling resistance of road surface);
- Travelling speed (function of unit type, load size, road conditions and driver skills);
- Driver skills;
- Vehicle availability;
- Vehicle utilisation.

Positive results of secondary intermediate transport of timber:

- Security of timber supply under specific conditions for secondary transport;
- Reduced expenditure on road upgrades.

Potential negative impacts of secondary intermediate transport of timber:

- Damage to the road surface;
- Logs falling off vehicles whilst in motion;
- Damage to timber due to additional handling;
- Additional costs to the supply chain;
- Overloading of vehicles;
- Underloading of vehicles;
- Damage to vehicles while loading and unloading.

Methods of reducing the likelihood of negative impacts:

- Train operators and drivers adequately;
- Adhere to traffic rules and laws on public and private roads;
- Follow safe working procedures;
- Where possible, run back-haul operations to ensure the truck is generating an income on more than half of its travel distance;
- Ensure vehicles are roadworthy and in a good working condition;
- Ensure sound daily maintenance;
- Ensure prompt servicing as specified by the vehicle manufacturer;
- Operate the vehicle within its capabilities as specified by the manufacturer;
- Use equipment and machinery specifically designed for the type of transport;
- Avoid overloading;
- Secure loads with suitable load binders (e.g. chains, cables, steel straps, nylon straps or nylon nets);
- Make use of central tyre inflation systems to facilitate travel on differing road surfaces;
- Make use of vehicle tracking and monitoring systems to identify and address problems before they turn into disasters.
6.4.2 Timber Secondary Terminal Transport

Equipment:

• Rigid truck (may be linked with a drawbar trailer);
• Articulated vehicle with either one or two semi-trailer/s;
• Articulated vehicle with semi-trailer and drawbar trailer;
• Stinger-steer truck/trailer combinations;
• Rail “ST” type wagons;
• PBS vehicles.

Factors that influence secondary terminal transport of timber:

• Weather conditions;
• Transportation unit type and capability;
• Load mass (total weight);
• Transport distance;
• Distribution of the load on the vehicle and trailer;
• Legal restrictions;
• Loading and unloading method and times;
• Gradients encountered en-route;
• Road conditions (rolling resistance of road surface);
• Travelling speed (function of unit type, load size, road conditions and driver skills);
• Driver skills;
• Vehicle scheduling;
• Vehicle availability and utilisation;
• Customer off-loading performance;
• Routes – toll fees;
• Smart Truck (PBS) vehicles – restricted to certain routes only.

Positive results of secondary terminal transport of timber:

• Timely and cost effective delivery of timber to the customer;
• Efficiently planned and executed transport operations can save money (unlock value) in the supply chain.

Potential negative impacts of secondary terminal transport of timber:

• Damage to the road surface;
• Logs falling off vehicles whilst in motion;
• Damage to timber due to loading and off-loading method;
• Overloading of vehicles;
• Underloading of vehicles;
• Damage to vehicles while loading and off-loading.

Methods of reducing the likelihood of negative impacts:

• Train operators and drivers adequately;
• Adhere to traffic rules and laws on public and private roads;
• Follow safe working procedures;
• Where possible, run back-haul operations to ensure the truck is generating an income on more than half of its travel distance;
• Ensure vehicles are roadworthy and in a good working condition;
• Ensure sound daily maintenance;
• Ensure prompt servicing as specified by the vehicle manufacturer;
• Operate the vehicle within its capabilities;
• Use equipment and machinery specifically designed for the type of transport;
• Avoid overloading;
• Secure loads with suitable load binders (e.g. chains, cables, steel straps, nylon straps or nylon nets);
• Make use of load cells to ensure maximum allowable and achievable payload;
• Make use of central tyre inflation systems to facilitate travel on differing road surfaces;
• Make use of vehicle tracking and monitoring systems to identify and address problems before they turn into disasters.

6.5 Biomass Secondary Intermediate and Secondary Terminal Transport

Biomass secondary transport systems are directly dependent and have an influence on the timber and biomass harvesting, extraction, loading, unloading and processing operations. In biomass operations, the transport part (specifically the lead distance to the customer) is generally the single biggest factor in determining the viability of these operations. Due to the low market value and low bulk densities and thus low payloads associated with biomass, a factor which can be limiting to potential biomass operations is lead distance to a market.

Factors that influence secondary transport of biomass:

• Composition of biomass;
• Road infrastructure;
• Biomass harvesting operation;
• Volumes;
• Loader type and capability;
• Value of the product;
• Lead distance to customer;
• Bulk density;
• Form of biomass (loose, chipped, compacted, bundled);
• Load size;
• Surface and weather conditions;
• Balancing of the system, i.e. the right equipment (loader and transport vehicle) to suit the conditions;
• Transport scheduling;
• Driver skills;
• Mechanical availability;
• Vehicle utilisation.
6.5.1 Biomass Secondary Intermediate Transport

Methods:

- Various Road truck configurations (loose biomass):
  - The choice of configuration depends on lead distance;
- Bin system (chip transport):
  - Road truck equipped with a hydraulic arm and drawbar trailer;
- Self off-loading transport configurations (Tip trailer system or walking floor system) (Loose biomass or chip transport):
  - Different combinations of trucks are available of which an articulated truck with a full tri-axle trailer are the most common; the key is to maximise volume capacity and not mass carrying capacity – due to relative low density of the product conveyed;
  - The trailer unloads itself through hydraulically driven reciprocating slats, “walking floor” (WFS);
  - Side tippers and back tippers are available in similar and increased dimensions;
- Log track (bundle transport):
  - These trucks are available in different sizes and configurations at present in the forestry industry;
  - Used to transport raw material in the form of logs of different dimensions;
  - Can also be used to transport green logs (biomass bundles) to the beneficiation plant, power or heating plant.

Factors that influence secondary intermediate transport of biomass:

- Weather conditions;
- Transportation unit type and capability;
- Load size (total weight);
- Transport distance;
- Distribution of the load on the vehicle;
- Loading and unloading method and times;
- Climatic conditions;
- Gradients encountered en-route;
- Road conditions (rolling resistance of road surface);
- Travelling speed (function of unit type, load size, road conditions and driver skills);
- Driver skills;
- Vehicle availability;
- Vehicle utilisation.

Positive results of secondary intermediate transport of biomass:

- Revenue generation from the harvesting site increased compared to exclusive timber harvesting operations;
- Utilisation of an otherwise “waste” product;
- Security of timber supply under specific conditions for secondary transport;
- Reduced expenditure on road upgrades.

Potential negative impacts of secondary intermediate transport of biomass:

- Nutrient depletion of site;
- Contamination of biomass if loaded from the ground or unloaded onto the ground;
- Damage to the road surface;
• Biomass falling off vehicles whilst in motion;
• Damage to biomass and/or contamination due to additional handling;
• Additional costs to the supply chain;
• Overloading of vehicles;
• Underloading of vehicles;
• Damage to vehicles while loading and unloading.

Methods of reducing the likelihood of negative impacts:
• Transport chipped, bundled or compacted biomass;
• Ensure site-specific sustainable nutrient removal of biomass to feed transport operations;
• Train operators and assistants adequately;
• Adhere to traffic rules and laws on public and private roads;
• Follow safe working procedures;
• Plan timber harvest and transport operations and biomass harvest and transport operations to ensure efficient interactions;
• Ensure the system is well balanced;
• Ensure that the unloading facilities at the conversion site are adequate;
• Keep the approach and exit to and from biomass piles accessible and clear of obstructions;
• Where possible, run back-haul operations to ensure the truck is generating an income on more than half of its travel distance;
• Ensure vehicles are roadworthy and in a good working condition;
• Ensure sound daily maintenance;
• Ensure prompt servicing as specified by the vehicle manufacturer;
• Operate the vehicle within its capabilities as specified by the manufacturer;
• Avoid overloading;
• Secure loads with suitable load binders (e.g. chains, cables, steel straps, nylon straps or nylon nets);
• Make use of central tyre inflation systems to facilitate travel on differing road surfaces;
• Make use of vehicle tracking and monitoring systems to identify and address problems before they turn into disasters.

6.5.2 Biomass Secondary Terminal Transport

Methods:
• Various Road truck configurations (loose biomass):
  ◦ The viability of this option depends on lead distance;
• Bin system (chip transport):
  ◦ Rigid truck equipped with a hydraulic arm and drawbar trailer;
• Tip trailer system and walking floor system (loose biomass or chip transport):
  ◦ Different combinations of trucks are available of which an articulated truck with a full tri-axle trailer are the most common;
  ◦ The trailer unloads itself through hydraulically driven reciprocating slats, “walking floor” (WFS);
  ◦ Side tippers and back tippers are available in similar and increased dimensions.
• Log track (bundle transport):
  ◦ These trucks are available in different sizes and configurations at present in the forestry industry;
  ◦ Used to transport raw material in the form of logs of different dimensions;
Can also be used to transport green logs (biomass bundles) to the beneficiation plant, power or heating plant;

- Appropriate rail wagons.

**Factors that influence secondary terminal transport of biomass:**

- Weather conditions;
- Transportation unit type and capability;
- Load size (total weight);
- Transport distance;
- Distribution of the load on the vehicle;
- Legal restrictions;
- Loading and unloading method and times;
- Gradients encountered en-route;
- Road conditions (rolling resistance of road surface);
- Travelling speed (function of unit type, load size, road conditions and driver skills);
- Driver skills;
- Vehicle scheduling;
- Vehicle availability and utilisation;
- Customer unloading performance;
- Routes – toll fees;
- Smart Truck (PBS) vehicles – restricted to certain routes only.

**Positive results of secondary terminal transport of biomass:**

- Revenue generation from the harvesting site increased compared to exclusive timber harvesting operations;
- Utilisation of an otherwise “waste” product;
- Timely and cost effective delivery of timber to the customer;
- Efficiently planned and executed transport operations can save money (unlock value) in the supply chain.

**Potential negative impacts of secondary terminal transport of biomass:**

- Nutrient depletion of site;
- Damage to the road surface;
- Biomass falling off vehicles whilst in motion;
- Damage to biomass and/or contamination due to loading and unloading method;
- Underloading of vehicles;
- Damage to vehicles while loading and unloading.

**Methods of reducing the likelihood of negative impacts:**

- Ensure site-specific sustainable nutrient removal of biomass to feed transport operations;
- Transport chipped, bundled or compacted biomass;
- Train operators and assistants adequately;
- Adhere to traffic rules and laws on public and private roads;
- Follow safe working procedures;
- Plan timber harvest and transport operations and biomass harvest and transport operations to ensure efficient interactions;
• Ensure the system is well balanced;
• Ensure that the unloading facilities at the conversion site are adequate;
• Keep the approach and exit to and from biomass piles accessible and clear of obstructions;
• Where possible, run back-haul operations to ensure the truck is generating an income on more than half of its travel distance;
• Ensure vehicles are roadworthy and in a good working condition;
• Ensure sound daily maintenance;
• Ensure prompt servicing as specified by the vehicle manufacturer;
• Operate the vehicle within its capabilities;
• Avoid overloading;
• Secure loads with suitable load binders (e.g. chains, cables, steel straps, nylon straps or nylon nets);
• Make use of load cells to ensure maximum allowable and achievable payload if bulk density lends itself to achieving payload;
• Make use of central tyre inflation systems to facilitate travel on differing road surfaces;
• Make use of vehicle tracking and monitoring systems to identify and address problems before they turn into disasters.
CHAPTER 7: Post Harvesting Operations

Post harvesting operations usually occur prior to the handover of the harvested compartment and the corresponding transport routes and roads back to silviculture. The process involves conducting an assessment of the condition of the sites and, if indicated by this assessment, carrying out of remedial work to rectify any damage or non-compliance caused.

The basic principle is that after a compartment has been harvested, the terrain should be left in a condition which minimises any possible long-term damage, as well as facilitates efficient operations which follow on from it. Soil erosion and soil displacement are responsible for much post harvesting damage caused to compartments and roads.

**Basic Approach:**

- Remove all marketable timber/biomass;
- Remove all waste material (e.g. packing material, containers and old cables);
- Fell all trees, excluding trees that require special management treatment (e.g. trees with active bird nests or perches for birds of prey or research plots – permanent sample plots);
- Rehabilitate, upgrade or restore roads and depots as required and open all drainage systems;
- Drain and restore extraction routes, roads, landings and depots that will not be used again to blend in with their surroundings (rip and replant if necessary);
- Clear roads of debris;
- Ensure that SMZ’s are treated according to management prescriptions;
- Riparian zones, indigenous forests and other sensitive natural features protected and treated according to management prescriptions;
- All temporary crossings removed and riparian zones, streams and stream banks restored (as close as is possible) to their original states;
- All trees close to telephone lines, power lines, public roads, etc. removed according to the prescribed procedures;
- Extraction routes and landings rehabilitated according to prescribed standards;
- Stump damage to be inspected (re-establishment to be considered – planting or coppice or no re-establishment);
- Stumps heights to not exceed management prescriptions.

**When assessing the rehabilitation requirements of an area, the following criteria assist in determining priorities:**

- If the damage does not impact the water quality and will self-correct within one growing season, then no action is required;
- If the damage could pose a water quality problem in the future, then corrective action is required soon;
- If the damage currently poses a water quality problem, the corrective action is required immediately.
Once the area is assessed according to the above criteria, then if necessary:

- Rehabilitate extraction routes and landings according to prescribed standards (depending on silvicultural and environmental requirements);
- Drain and cover extraction routes and ruts, using branches to prevent further damage and water runoff;
- Fill deep ruts with soil and then cover with debris.

Slash Management:

- Keep the compartment’s slash within the compartment boundaries;
- Use remaining slash to slow water runoff, thereby encouraging infiltration and reducing erosion;
- Avoid burning after harvesting where possible to reduce nutrient losses;
- Leave “gates” in the slash rows at regular intervals where applicable to prevent damming of water when wind-rowing or, ideally, scatter the litter according to silvicultural requirements;
- Try to avoid slash rows straight down the slope. If unavoidable, ensure that slash rows are not continuous;
- Leave all watercourses clear of slash;
- Slash and debris must be removed from riparian zones, fire breaks and other special management zones as prescribed;
- Restrict slash rows to the compartment being felled;
- Do not leave marketable timber/biomass in the slash rows.
# APPENDIX 1 – TERRAIN CLASSIFICATION

## National Terrain Classification System for Forestry (ICFR Bulletin 11/1994) summary

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**Excel “% to Degrees” formula:**

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= DEGREES(ATAN (“slope %”)/100)
```