Harvesting Systems and Equipment in British Columbia

British Columbia
Ministry of Forests
Forest Practices Branch

Forest Engineering Research Institute of Canada
FERIC
Institut canadien de recherches en génie forestier

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A.J. MacDonald

Forest Engineering Research Institute of Canada

FERIC Handbook No. HB-12

1999

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Canadian Cataloguing in Publication Data
MacDonald, A. J.
Harvesting systems and equipment in British Columbia

(FERIC handbook, ISSN 0701-8355 ; no. HB-12)

Co-published by Forest Engineering Research Institute of Canada.
Includes bibliographical references: p.
Includes index.
ISBN 0-7726-3827-6

1. Logging – British Columbia. 2. Logging – British Columbia – Machinery. 3. Forest machinery – British Columbia. I. British Columbia. Forest Practices Branch. II. Forest Engineering Research Institute of Canada. III. Title. IV. Series.

SD388.M32 1999 634.9'8 C99-960106-7

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for
B.C. Ministry of Forests
Forest Practices Branch
1450 Government St.
Victoria, BC V8W 3E7
http://www/for.gov.ca/hfp/hfp.htm

Published by
B.C. Ministry of Forests
Forestry Division Services Branch
Production Resources
595 Pandora Avenue
Victoria, BC V8W 3E7

Copies of this report may be obtained, depending on supply, from:
Crown Publications
521 Fort Street
Victoria, BC V8W 1E7
(250) 386-4636
http://www/crownpub.bc.ca

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Abstract

This handbook describes the various types of equipment and systems used for harvesting timber in British Columbia. Falling, primary transport (ground, cable, and aerial), processing, and loading phases are described in terms of common and distinguishing features and their relationship to operational and environmental considerations. The handbook also discusses the effects of operating techniques, site characteristics, and external requirements from the same operational and environmental perspectives.

Primary operating conditions for the various machine types are outlined in summary tables. A series of flowcharts based on a risk-analysis system is used to rank the probability of conducting successful operations with different equipment on various sites.

Author

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After graduation, Jack worked for 10 years as a logging engineer in coastal British Columbia. Since joining FERIC in 1986, Jack has worked on machine and systems evaluations, and has published several reports on ground-based and cable-based harvesting systems. His other work at FERIC has included development of a computer program for GIS-based harvest and silviculture planning.

Acknowledgements

The author would like to thank all those who contributed to the handbook.

The extensive knowledge of Bela Hirczy was invaluable during the interviews. Bela's understanding of harvesting systems in general and cable logging systems in particular was most appreciated, and his review comments added much to the project.

Each of the woodlands managers, logging superintendents, and operating personnel who contributed during the interviews is acknowledged and thanked. Without their input, this project would not have been possible.

The project was directed by a steering committee comprised of industry and agency personnel who provided guidance during the formative stages of the project, and reviewed the drafts as they were produced. Thank you all for your input. One member of the steering committee in particular provided valuable liaison with the Ministry of Forests: the contribution of Larry Sluggett to the project is expressly acknowledged.

Tony Sauder and Ingrid Hedin reviewed early versions of the handbook, and provided valuable guidance for its conclusion. Shelley Corradini created the artwork, for which the author is grateful. FERIC researchers who participated in the review workshop are acknowledged and thanked for their contributions.

Disclaimer

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EQUIPMENT SELECTION

The handbook does not attempt to define a single "best" system for any site. Instead, it presumes that readers need to be aware of the key factors that influence the probability of achieving success with any given combination of equipment and site characteristics. Readers will then use their own judgement to evaluate the merits of the various options. The information in the handbook should be considered only as part of an overall process for equipment selection which will vary from company to company.

INTRODUCTION

Many different harvesting systems and equipment are available for today's logger. Options range from small skidders to large skylines to helicopters, with a wide variety in between. Two of the most important tasks faced by the logger are to select the best harvesting system and equipment for a given site, and to use the selected equipment in the best way possible. Each system can operate successfully under a wide range of conditions, and the conditions suitable to each system can overlap considerably. On many sites, several systems could be used successfully, yet the conditions on other sites may favour a single harvesting system.

Sometimes the choice between harvesting systems and equipment may result from personal or corporate preferences, especially if the options are similar. In other cases, the same equipment can be used on different sites, but the operating techniques must be changed to achieve the desired results. Regardless of the selection process, understanding both the economic and environmental ramifications of choosing a particular type of equipment for use on any given site is necessary.

In addition to economic, corporate, and environmental considerations, harvest-system selections can have legal implications. Depending on the jurisdiction, planners may choose equipment that meets criteria or achieves results in certain site conditions as required by various regulations.

With so many factors to consider, how does a person decide which harvesting equipment and system is best suited for a particular site? While there are as many different ways to arrive at a decision as there are loggers, planners, and equipment owners, each decision should be based on a thorough understanding of the implications of selecting the different equipment types. Better understanding will lead to better decisions, and the objective of this handbook is to help improve that understanding.

The handbook describes the various harvesting systems and equipment commonly used in British Columbia. It describes various site characteristics, operating techniques, and external requirements, and their effect on different types of harvesting equipment. The information contained herein can help the logger or planner make better choices. However, the handbook is not meant to be used as a rigid guide — its role is mainly for reference.

About This Handbook

Background

The British Columbia Ministry of Forests approached FERIC in 1995 to prepare an educational resource about harvesting systems and equipment. The new *Forest Practices Code of British Columbia Act* required licensees to identify harvesting systems in logging plans, and ministry personnel to review the intended use of those systems and equipment. However, information was lacking — no common descriptions existed of what equipment was available for timber harvesting in British Columbia, and what the capabilities were of that equipment. This handbook resulted from those discussions.

While this handbook grew out of a requirement of the *Forest Practices Code of British Columbia Act*, FERIC's advisory committee was apprehensive about its possible role regarding harvest planning and the Forest Practices Code. The committee wanted to ensure that the handbook could not be misinterpreted as providing a "cookbook" formula to determine the "correct" equipment to use for any particular harvesting site. In addition, it was recognized that this handbook would likely serve a wider audience than British Columbia; such an audience may not be interested in the legal requirements for timber harvesting in British Columbia. Lastly, it was recognized that legislation is subject to change, and that linking the handbook closely with the requirements of the Forest Practices Code might limit its usefulness if the requirements of the Forest Practices Code were to change.

As a result of these concerns, the handbook provides information about the capabilities of the various systems and equipment, but does not link them directly to the requirements of the Forest Practices Code. That task is left to the reader as a separate exercise.

Organization

The handbook is divided into two parts.

Part 1 reviews the context of equipment selection, summarizes the primary characteristics of various types of equipment, and lists the key factors to consider when matching harvesting equipment to sites. It also includes several examples of using the handbook to select candidate harvesting systems for specific site conditions.

Part 2 provides more detailed reference information about the various types of equipment and working conditions. It describes the harvesting phases, operating techniques, site characteristics, and external requirements, and their effect on the suitability of the different equipment types to various sites. The phases are primary transport, falling, processing, and loading. Primary transport is presented first, even though it occurs after falling, because it is commonly used to describe and classify harvesting systems.

The information in Part 1 is presented as a series of tables outlining the equipment characteristics, and charts outlining the key factors to consider for equipment selection. The reference sections in Part 2 are organized around common characteristics and distinguishing characteristics for the various equipment types. The common characteristics are those that define a particular type of equipment — they make a machine what it is. On the other hand, the distinguishing characteristics separate the various makes and models of equipment from similar machines within the same type.

These characteristics, the basis of the equipment-selection process, are also the factors that make one machine suitable for use on a particular site while rendering another machine unsuitable.

The descriptions in Part 2 explain the effects of each factor from operational and environmental perspectives. The operational perspectives include machine productivity, log quality, safety, and others, while the environmental items include soil disturbance, water quality, and long-term forest productivity.

Intended audience

This handbook is intended for two different audiences. The first group consists of people interested in timber-harvesting processes, but who may have only a rudimentary understanding of harvesting systems and equipment. Resource agency officers or other government officials who deal with timber harvesting only incidentally may find pertinent information in the handbook that can help with their job functions. Inexperienced foresters can also use the handbook to broaden their exposure to harvesting systems and equipment. The second group is people such as equipment operators and planners who are more experienced in timber harvesting in their own locale, but who want to learn about systems used in other regions of the province. The handbook may provide them with new information that can be taken from one region and applied to their local operations.

The handbook can be used in various ways depending on the reader's objectives. The reader can follow the charts from Part 1 to rank the relative risk of using different machine types under various conditions, and then seek specific information about the equipment in Part 2. Alternatively, reading through each section in Part 2 will provide the reader with a more complete overview of the capabilities and limitations of the various equipment types.

The handbook is intended to provide a broad overview of the capabilities and limitations of the various equipment types. After browsing the handbook, the reader will have a basic introduction to the capabilities of the harvesting equipment commonly used in British Columbia.

Background to Equipment Selection

Context for equipment selection

This section provides a very brief overview of the issues involved with equipment selection. It is intended for readers who may be inexperienced with equipment selection, but who are required to specify equipment to use for a particular cutblock. It will focus the reader's attention on those factors that are most important for that cutblock.

However, this handbook does not intend to suggest that any particular make, model, or type of equipment must be used on a specific site. That decision must rest with the various planners and owners responsible for managing the area.

Why is equipment selection important?

Each cutblock has a set of management objectives that likely include aspects of safety, profitability, forest health, water quality, and environmental concerns. If the equipment and system chosen for a cutblock are mismatched to the site and stand conditions, then it may be impossible to achieve any or all of these objectives. The ramifications of improper equipment selection may range from unsafe working conditions to unacceptable costs to charges under the applicable forest-practices legislation. Making sound choices aims to reduce the risk of those events happening.

Who selects the equipment and when?

Many people make decisions about equipment selection at different times. These include:

- Equipment owner or corporate financial officer — matches the equipment fleet to the long-term expected site conditions to ensure that the equipment is profitable to operate over the long term. Decisions made when buying the equipment.
- Layout personnel — ensures that the road and cutblock boundary locations are suitable to the type of equipment that will be used for harvesting. Decisions made at layout time.
- Planner and woodlands manager — ensures a balance between equipment availability and number of cutblocks laid out for particular equipment types. Decisions made periodically (e.g., monthly or annually).

- Woodlands supervisor or contractor — assigns specific machines to work on specific sites. Fine-tunes the layout and operating techniques to match the site characteristics. Decisions made at harvest time.

What factors affect equipment selection?

Terrain The factors to consider include slope, ground profile, streams and wetlands, gullies, and roughness. These factors affect the ability of the equipment to travel over the ground to reach the operating sites. Driving access is required to all parts of the cutblock for ground-based equipment, while cable and aerial systems allow for remote access. Ground-based systems may cause more soil disturbance than cable or aerial systems, especially on steep slopes or rough ground. The ground profile is critical to the success of cable systems — the layout must be engineered with adequate deflection and ground clearance to support the intended payload. In general, ground-based systems are less expensive to own and operate than cable systems, which are less expensive than aerial. Sensitive areas must be considered carefully to ensure that soil disturbance or other environmental damage does not occur.

Soil Soil characteristics to consider during equipment selection include texture, moisture content, and seasonal impact. These factors affect the bearing strength of the soil, and its ability to withstand machine traffic without degradation. Fine-textured soils and moist soils are more sensitive to machine traffic than coarse-textured or dry soils. Frozen or deep-snow conditions allow ground-based machines to access ground that may not support traffic during non-frozen conditions.

Timber characteristics The following timber characteristics can influence equipment selection: tree size, volume per hectare, and timber quality. There are two primary concerns: (1) the physical ability of the equipment to handle the trees without causing unsafe working conditions or causing damage to the equipment, site, or timber; and (2) harvesting economics for both per-tree and per-cutblock costs. Small trees are less economical to harvest than large trees, and small cutblocks are less economical than large cutblocks. Fixed costs such as road construction must be amortized over the volume harvested from the cutblock, and lower volumes per hectare result in smaller cutblock volumes and higher costs. Harvesting systems with high mobilization costs, such as cable or aerial systems, are especially susceptible to the effects of low volumes per hectare. The timber quality affects the timber value, and thus the harvesting economics. Large trees may be too heavy for some equipment to handle, and small trees may be damaged by large equipment.

Business requirements The timber must be harvested safely and economically for the licensee and its contractors to ensure worker safety and to remain in business. All costs, including ownership, operating, and maintenance costs, must be considered

Business requirements, as opposed to site characteristics, may impose conditions on the harvesting operations. These business requirements may include the operating season, timber flow, mill's log specifications, amount of work available, unique operating methods, labour availability, and equipment availability, service, and transportation.

Each company chooses harvesting equipment and methods that it feels best meets its corporate objectives, and different corporate objectives can be reflected in the equipment selection. For example, the mill may be equipped to accept a certain wood form as input (e.g., whole stems, logs, short logs); therefore, the harvesting system must be geared to produce that wood form. This choice can have ramifications throughout all phases of harvesting.

Weather and climate Inclement weather such as rain or wind can affect the severity of soil disturbance or can cause more hazardous working conditions. Saturated soils are more susceptible than dry soils to damage from machine traffic. Wind is especially problematic for hand-fallers. Deep snow can provide a protective ground covering for machines to travel upon, although it can also impair machines' mobility. Snow on steep terrain creates a safety hazard for on-the-ground workers because of slippery footing.

Silvicultural system The silvicultural system is significant for equipment selection because some machines can maneuver better than others between the standing trees and extract logs from a partial cut without damaging the residual stand or affecting future growth potential. Machine size and maneuverability are important issues to consider in relation to silvicultural systems.

Legislation, regulations, or permit requirements Some of the operating parameters in the cutblocks result from legislative requirements or permit conditions required by government. For example, utilization standards may include acceptable limits for stump heights and levels of breakage. Soil disturbance guidelines can limit the number of roads, trails, and other access structures that are allowed to be constructed on various sites, and thus affect the range of candidate equipment.

Planning horizon for equipment selection

Selecting the equipment for a particular site must be made within the current corporate and regulatory environment. Some typical questions to ask might be: What equipment is available? What is the long- and short-term budgeted production? What are the log quality requirements for the mill? What capital is available? What special environmental factors must be considered? Sometimes, different equipment can be selected upon short notice, but more often the equipment available for any specific site is limited by budgets or by other long-term commitments. Therefore, harvesting equipment selection must be considered over both the long term and the short term.

Over the long term, the general site and timber characteristics that are expected must be examined, and the equipment fleet selected to suit those conditions. The time horizon, which is related to budget and capital amortization, is generally three to five years or longer for major capital purchases.

Contractual and corporate obligations mean there is less flexibility to choose different equipment in the short term, and the equipment selection question is reversed. The site and stand characteristics remain important, but instead of asking "What equipment is suited to this site?" the question becomes "What site is available to use this equipment?" The process of matching equipment to sites becomes a matter of ensuring an adequate number of suitable sites for the available equipment.

These long- and short-term considerations apply not only to large companies, but also to independent contractors and planners with the Ministry of Forests Small Business Forest Enterprise Program. The difference between them is a matter of degree, especially regarding the control over each planning level. Large companies that incorporate both planning and operational functions control their long- and short-term planning — to a large extent, they control their own destiny within their corporate structure. On the other hand, long- and short-term plans are provided to contractors — their equipment selection decisions are based on the information contained in the plans provided to them.

Planners for the Ministry of Forests Small Business Forest Enterprise Program do not purchase equipment themselves, but they do influence the choices made by logging contractors by way of their future timber sale opportunities and the conditions placed on specific timber sales.

What constitutes successful harvesting operations?

The success of a particular harvesting system can be measured against operational and environmental criteria. The operational criteria include such factors as safety, profitability, and log quality, while the environmental criteria include water quality, soil disturbance, and residual stand protection. These objectives will change in importance depending on the site and the outlook of the observer. For example, the contractor may rank profitability before residual stand protection, while the forester may reverse their importance. However, both operational and environmental criteria must be considered to harvest timber successfully in today's corporate and environmental climate.

EQUIPMENT DESCRIPTIONS

The various types of harvesting equipment are described in two sets of graphics. The first set summarizes the costs and characteristics of various equipment types in a tabular format using a High-Medium-Low rating system. By scanning the "characteristics" tables, the reader can quickly determine whether a particular type of equipment is suitable to various site conditions and operating environments.

The second set identifies the key factors that affect the likelihood of conducting successful operations with various equipment types. By following through these charts, the reader can quickly identify those site characteristics that imply high risk with any given type of equipment.

Neither set of graphics attempts to identify the "correct" equipment for a particular site because there are usually too many variables for there to be just one feasible solution. Instead, these graphics can help to focus the reader's attention on those equipment types that have the lowest risk and the highest probability of achieving success.

After reading this section, the reader may wish to consult Part 2 of the handbook for more detailed information about specific equipment types.

What Equipment To Consider?

The tables and charts presented later in this section have been developed assuming that all equipment types are available to be used on any given site, and that a selection process will eliminate the less suitable types. Given the full range of equipment to choose from, cost is often the first selection criteria. However, cost is not the only consideration, and depending on the circumstances, may not even be the primary consideration. For example, a cutblock with sensitive soils may require specialized equipment for harvesting to proceed at all, and costs become a secondary consideration.

The planner must carefully consider all available options for harvesting systems, and a starting point is to consider the range of equipment costs. Relative cost ranges of various equipment types are shown in Table 1.

Costs can be considered in various ways, including unit production costs, ownership costs, and total costs. Unit production costs include the machine's operating and maintenance costs coupled with an estimate of productivity. Ownership costs include the machine's purchase price, plus interest on capital and other fixed costs such as insurance. Total costs represent the total cost of owning, operating, and repairing the equipment over its lifespan. Low initial costs may not necessarily result in the lowest total costs over the equipment because of high maintenance costs or low productivity.

Costs can also vary widely depending on operating conditions and techniques. For example, Table 1 lists loader-forwarders in the low-cost category for unit production costs, which is accurate for easy terrain with large timber, but is inaccurate for rough terrain or small timber. The unit production costs for Table 1 are applicable under ideal conditions.

Total costs are important to consider, but also difficult to quantify because of different operating conditions and techniques, and widely varying maintenance regimes. Total costs are omitted from Table 1 because of their even wider variability than unit production costs and capital costs.

Unit production costs and ownership costs should be considered separately because they are not always related. For example, helicopters have both high unit production costs and high ownership costs, while clambunk skidders have high ownership costs but low unit production costs. Furthermore, different companies place different emphasis on unit production and ownership costs.

In the long term, all options from Table 1 should be considered, but in the short term only those machine types that are available need be considered.

Table 1. *Relative cost ranges for primary transport equipment under ideal conditions*

Cost range	Unit production costs	Ownership costs
Low cost	Wheeled skidder Loader-forwarder Cherry picker/Super snorkel Grapple yarder	Wheeled skidder Horse Small-scale equipment
Medium cost	Crawler skidder Clambunk skidder Forwarder Horse Small-scale equipment Highlead Small single-span skyline	Crawler skidder Flex-track skidder Highlead Small single-span skyline Multi-span skyline
High cost	Flex-track skidder Large single-span skyline Multi-span skyline Medium-lift helicopter	Clambunk skidder Forwarder Cherry picker/Super snorkel Loader-forwarder Grapple yarder Large single-span skyline Medium-lift helicopter
Very high cost	Heavy-lift helicopter	Heavy-lift helicopter

Equipment Characteristics Summarized by Phase

After using ownership costs or unit production costs to rank the various types of available equipment, the next step is to use equipment characteristics to match equipment to operating conditions. To help with this process, this section presents tables for each harvesting phase that summarize the major features of different equipment types. Four tables are presented: primary transport in Table 2, falling in Table 3, processing in Table 4, and loading in Table 5.

The rows in each table list the important characteristics that can be used to match equipment to operating conditions. The various types of equipment that can be used for each phase are listed in columns across the tables, and the entries in the tables contain a variety of information. In some cases, a High-Medium-Low system is used to rank the various equipment according to each characteristic. In other cases, the tables list actual values such as maximum yarding or skidding distances or maximum slope limits for ground-based equipment. Lastly, "+" or "-" symbols are used to indicate whether a particular feature will enhance or detract from the various characteristics.

In keeping with the objectives of this handbook, the terms "high, medium, and low" are left undefined in the tables. Defining these terms would tend towards a "cookbook" approach for determining the single "correct" answer, which the handbook tries to avoid. Instead, the tables should be used only to rank equipment types *relative to one another*. For example, the required operator skill level for skidders is listed as low, implying only that less skill is required to operate skidders than clambunks, forwarders, or other machines. This list does not say that skidder operators are unskilled. On the contrary, skidder operators require a significant amount of skill and training, especially considering the consequences if the machines are operated in an unsafe or environmentally risky fashion. However, the mechanical simplicity of skidders as compared with forwarders and the reduced manual dexterity as compared with yarding cranes places skidders in the "low" operator skill category.

Using the list of equipment ranked by cost, the reader should determine whether each type of equipment remains a candidate for consideration. As stated previously, costs may not be the primary consideration, and the list of candidate equipment could be ranked by different criteria. Items such as skidding distance, tree size, slope, and susceptibility to high soil moisture will help to eliminate types that are unsuitable for the anticipated site conditions. Other items such as safety hazards, daily productivity, ability to work independently, and capital investment will help to determine whether the equipment will fit within the corporate organizational structure.

After completing the rankings from these tables, the reader should move on to the next section — determining various risk levels.

Risk-level Assessment

Risk levels

Acceptable results by a specific equipment type cannot be guaranteed on a given site because too many variables are involved — prescription, operator skill and attitude, weather, business objectives, and quality of site description. Instead, an element of uncertainty or risk is implied, especially when operating techniques are considered. For example, wheeled skidders can be operated safely on gentle slopes, but become unstable on steep slopes especially if turning is required. To increase the safety factor, skidders can be operated straight down the slope or from excavated trails. However,

Table 2. *Characteristics of primary transport equipment*

Characteristics of primary transport equipment	Ground												Cable						Aerial	
	Wheeled skidder - line	Wheeled skidder - grapple	Crawler skidder - line	Crawler skidder - grapple	Flex-track skidder - line	Flex-track skidder - grapple	Clambunk	Forwarder	Loader-forwarder	Cherry picker/Super snorkel	Horse	Small scale	Highlead	Swing yarder - grapple	Swing yarder - dropline	Small single-span skyline	Large single-span skyline	Multi-span skyline	Heavy-lift helicopter	Medium-lift helicopter
PERSONNEL																				
Safety hazards	H	M	H	M	H	M	L	L	L	L	H	H	H	M	H	M	H	H	H	
Crew size	M	L	M	L	M	L	L	L	L	L	L	L	M-H	L	M	M	H	M	H	M
Operator skill level required	L		L		M		M	M	M	H	M	L	M	H		M	H	H	VH	
Level of supervision required	M		M		M		L-M	M	M-H	L	M	L	M	M		M	H	H	VH	
LAYOUT																				
Layout skill level	L		L		M		M	M	M	L	L	L	M	M		M	H	H	M	
Typical distance to cutblock boundary (m)	200	200	200	150	200	200	300	300	120	50	80	150	200	150	300	200	400	500	1500	
Long-distance operating range (m)	300	250	250	200	300	250	800	800	200	50	100	200	300	200	400	250	700	800	2000	
Road density	M		M		M		L	L	H	n/a	H	H	M	H	M	M	L	L	L	
Requires landings	Y	N	Y	N	Y	N	N	N	N	n/a	N	N	Y	N		Y		Y	Y *	
Suitability to partial cut	M	L	M	L	M	L	L	H	M	L	H	H	L	L	H	H	L	H	M	
SITE																				
Low-risk favourable slope limits (%)	35		35		35		35	35	35	n/a	25	n/a	n/a						n/a	
High-risk favourable slope limits (%)	40		50		60		55	35	35	n/a	25	n/a	n/a						n/a	
Adverse slope limits (%)	10		15		20		10	15	20	n/a	5	5	n/a						n/a	
Preferred direction	downhill									up	downhill		up	dn	uphill				downhill	
Soil strength required	H		H		M		M	M	M	n/a	H	L-M	L						n/a	
Ability to avoid causing soil disturbance	L-M		L-M		L-M		M	M	M-H	n/a	H	H	M	M		M	H	H	H	
Suitability for small trees	H		H		H		H	H	M	M	H	H	M	L	M	M	L	M	L	M
Suitability for large trees	H		H		H		H	H	H	H	L	L	H						load limit	
Adaptability to low volumes/ha	H		H		H		M	H	M	M	H	H	M	L-M	M	M	L	M	L	M
WEATHER RESTRICTIONS																				
Susceptibility to high soil moisture	H		H		H		M-H	M	M-H	n/a	H	M	L-M	L		L		L	L	
Susceptibility to poor visibility (fog)	L		L		L		L	L	L	L	L	L	M	H	M	M	H	M	H	
Susceptibility to high winds	L		L		L		L	L	L	L	L	L	M						H	
Restricted by deep snow	M		L		L		L	L	M	L	H	M	H	M	H	H		H	H	
Ablility to work at night	L	H	L	H	L	H	H	H	M	M	L	L	L	M	L	L	L	L	n/a	
CORPORATE																				
Ability to work independently of loader	L	H	L	H	L	H	H	H	H	H	H	H	L	H		M	L	L	L	
Capital investment	L	M	M	M-H	M	M-H	H	H	H	H	L	L	M	H		M	H	M	VH	H
Hourly productivity	M	M-H	L	M	M		H	M	H	H	L	L	M	H		M		L	VH	H
Unit production cost range	L-M		M		M-H		L	M	L	L	M-H	M	M	L	M	M	H	H	VH	H

* Helicopters can transport logs either to landings or to water drop-zones.

Table 3. *Characteristics of falling equipment*

Characteristics of falling equipment	Rating*								Modifications**									
	Type					Carrier			Head			Features						
	Hand-falling	Feller-buncher	Feller-director	Single-grip feller-processor	Double-grip feller-processor	Tracked, boom-type	Wheeled, boom-type	Wheeled, drive-to-tree	High-speed disc	Low-speed disc	Director/chainsaw	Leveling cab	Zero-clearance tailswing	Accumulator	Large-range side-tilt	Rigid head-to-boom attachment	High stability at long reach	Overhead visibility
PERSONNEL																		
Safety hazards	H	L	L	L	L	L-M	L	M	+			+			+		-	-
Operator skill level required	H	M	M	H	H	M	M	L-M	+			-		+		-		
SYSTEM																		
Ability to avoid causing soil disturbance	H	M	M	H	H	type limit		L-M				-			+		+	
Suitability for partial cutting in open stand	H	H	M	H	H	M	H	L			+	+	+		+	+	+	+
Suitability for partial cutting in dense stand	L	H	L	M	M	M	M	L				+	++	+	+	++	++	++
Suitability for choker extraction	H	H	H	L	L	type limit***								+				
Suitability for grapple skidder extraction	L	H	M	L	L	type limit								+	+	+	+	
Suitability for grapple yarder extraction	H	H	M	L	L	type limit								+	+	+	+	
Suitability for forwarder extraction	L	L	L	H	H	type limit												
Ability to sort	L	M	L	H	M-H	type limit		M						+	+	+	+	
SITE																		
Maximum slope (%)	n/a	carrier limit				60	30	20				++			+		+	
Immunity to obstacles	H	M	M	M	M	H	M	L	-								+	
Ability to work in dense underbrush	L	H	M	L	L	H	H	L	+		--							
Suitability for small trees	M	H	M	H	L	M-H	M-H	H	+	-	+			++				
Suitability for large trees	H	M	H	L	H	M	L-M	M-H	-	+	-	+			+		+	
Suitability for windfall	L-M	M	M	H	H	M	L-M	L	-	+	+	+			++			
WEATHER RESTRICTIONS																		
Ability to work during high winds	L	M	L	M	M	M	M	M			-							
Ability to work under deep snow conditions	L	H	H	L	M	H	M	L	+	+	-							
Ability to work at night	L	H	H	H	H													
CORPORATE																		
Capital investment	L	H	M	H	H	H	H	M			-	+	+	+	+		+	+
Daily productivity	L	H	M	M	H	H	M	M	+			+		+			+	+
Unit production costs	variable					H	H	L				-		-			-	-

* Rating: Low to High for this characteristic.
** Modification: + indicates that adding this feature will increase the characteristic, - indicates decrease, blank is neutral.
*** Type limit: governed by the type, rather than by the carrier.

Table 4. *Characteristics of processing equipment*

Characteristics of processing equipment	Delimbers/Processors						Other			
	Hand-bucking	Small dangle-head processor	Large dangle-head processor	Small-stroke delimber	Large-stroke delimber	Pull-through delimber	Chain-flail delimber/debarker	Chipper	Hogger	Slasher
SYSTEM										
Safety hazards	H	L		L		L	H	M	M	L
Suitability to landings	H	H		H		H	H	H	H	H
Suitability to roadside	L-M	M	H	H		L	L	L-M	L	M-H
SITE										
Suitability for small trees	L-M	H	M	H	M	H	H	H	n/a	H
Suitability for large trees	H	L	H	M	H	H	M	L	n/a	L
Maximum tree diameter (cm)	n/a	50	80	50	70	n/a	n/a	40		n/a
CAPABILITY										
Delimbing	+	+		+		+	+	-	-	-
Topping	+	+		+		-	-	-	-	+
Log measuring	+	+		+		-	-	-	-	+
Butt-rot removal	+	+		+		-	-	-	-	+
Midstem-rot removal	+	+		+		-	-	-	-	-
Can work without support equipment	-	+		+		-	-	-	-	+
Extraction from log deck	n/a	L	M-H	M	H	n/a	n/a	n/a	n/a	M
Sorting	n/a	M		M	H	n/a	n/a	n/a	n/a	M
CORPORATE										
Capital investment	L	H		H		L	M	H	H	M
Daily productivity	M	H		H		M	H	H	H	H

Table 5. *Characteristics of loading equipment*

Characteristics of loading equipment	Type					Carrier	
	Front-end loader	Hydraulic	Butt 'n top	Line loader	Self-loading log truck	Wheeled carrier	Tracked carrier
PERSONNEL							
Safety hazards	L	L	L	M	M		
Operator skill level required	L	L	M	H	L		
CAPABILITY							
Suitability for small logs	H	M	H	M	H		
Suitablility for large logs	H	H	L-M	H	L-M		
Ability to reach below grade	L	M-H	M	H	M		
Maximum reaching distance (m)	5	15	15	30+	10		
Able to load from side of truck	H	M	H	M	H		
Able to load from front of truck	n/a	H	L	H	n/a		
Able to load from rear of truck	n/a	H	L	H	n/a		
Cherry-picking, primary transport	L	H	L	H	L	-	
LAYOUT							
Space requirements while loading	H	L	M	M	L	+	-
Suitability for landings	H	H	L	H	H		
Suitability for roadside	L	H	H	H	H	-	+
Suitability to load from several sites concurrently	H	M	L	L-M	H	+	-
Required level of travel surface preparation	M	L	L	H	n/a	+	
CORPORATE							
Capital investment	L	M-H	H	H	L		+

excavated trails may have an impact on soil erosion, water quality, or the amount of site disturbance. Similarly, flotation mats can allow excavators to work on soft ground, but may slow machine travel and reduce productivity.

Most importantly, each machine type is suitable to a range of conditions as defined by its basic features. When operating the machine within its appropriate range, the risk of exceeding operational and environmental limits is minimized, but operating outside the range will increase the risk of generating unacceptable results. Even the most benign harvesting system can produce unacceptable results if used inappropriately, and seemingly unsuitable equipment can be made suitable by incorporating appropriate techniques.

Under this concept, selecting the appropriate equipment for each site becomes a matter of matching features to risk. The planner must understand the basic features of the equipment, the range of operating techniques, the influence of site conditions and the external requirements that might be imposed, and how these four factors are related to one another by risk levels. Combinations of equipment and conditions with low risk levels should be considered rather than those with higher risk levels. The use of higher risk combinations may be appropriate under certain operating conditions or to achieve specific goals, but such a selection should be made only with a full understanding of all the potential risks and benefits.

This handbook uses a system of risk evaluation, and Table 6 defines various risk levels on a scale from 1 to 6. These risk levels are not absolute; instead they indicate the relative amount of risk of operating the machine under varying site and objective conditions. A low risk level indicates a good chance of successful operations, while a high number indicates a high risk of failure.

Some high risk activities are constrained by environmental considerations (e.g., high likelihood of soil degradation by wheeled skidders on moist, fine-textured soils), while others are constrained by operational considerations such as productivity (e.g., poor performance of large highlead systems with small trees). In either case, the risk level is shown as a single value, and the underlying cause is not indicated in the charts. The descriptions in Part 2 of the handbook will provide additional detail and explanation regarding the cause of the high risk level.

The high-risk levels as defined in Table 6 and used in the charts that follow are quite definite, whereas the lower levels should be considered more as general guidelines. For

Table 6. *Risk-level descriptions*

Risk Level	Description
1	Minimal risk, best operating conditions.
2	Generally acceptable; normal operating conditions. Unusual circumstances may increase risk.
3	Acceptable under many conditions, but exercise caution.
4	Risky; good reasons or special operating techniques required to operate under these conditions.
5	Highly risky; exceptional circumstances required to operate under these conditions. Special planning and operating techniques will be required.
6	Not recommended.

example, Chart 13 for multi-span skylines lists only four possible outcomes, three of which are risk level 5 or 6, and one of which is risk level 1. This should be interpreted as saying “Three factors rule out multi-span systems. In the absence of these factors, the system is feasible.” In contrast, Chart 15 for large skylines lists more factors, some of which have mid-level risks. These mid-level risks indicate that the equipment and site are compatible, but caution should be exercised.

Risk factors that apply to all harvesting systems are shown in Table 7. These factors should be considered, and used to modify the risk factors shown in the individual charts.

Key factors

The following charts list the key factors to consider when determining the suitability of each machine type for operating on a particular site. Only the most important factors have been listed — clearly, other factors must be considered when choosing equipment, and the reader should refer to Part 2 of the handbook for additional information. This is especially critical for the low- and mid-level risks — whereas the high-level risks are more definite.

The charts are presented as flowcharts starting from the upper-left corner of each chart. The various factors are shown in diamond-shaped boxes, and the risk levels are shown in small rectangular boxes. Choose one of the paths leading from each decision box as determined by the site conditions. The most critical factors are listed first, and may constitute a simple go/no-go decision. For example, using wheeled skidders on fine-textured soils with high moisture content is not recommended. The factors further down in the chart typically have more feasible outcomes — follow the path that most closely

Table 7. *Risk factors applicable to all harvesting equipment*

Factor	Comment
Operator experience, attitude, and history	Risk is decreased with an experienced operator who has worked successfully under similar conditions in the past, and has demonstrated a desire to do a proper job.
Contractor experience, attitude, and history	Risk is decreased with an experienced contractor who has worked successfully under similar conditions in the past, and has demonstrated a desire to do a proper job. Effective communications between the planners and the workers and adequate supervision decrease the risk of a mishap caused by misunderstood instructions.
Weather	Inclement weather, especially excessive rainfall, increases the risk. The risk of causing soil disturbance increases with higher soil moisture content. Maintaining a flexible schedule, with the ability to work on different areas as required by weather conditions, reduces the risk.
Sensitive zones	Working in the vicinity of riparian zones, or other sensitive zones, increases the risk. Operators should always take extra care when working in sensitive zones.
Tree size	Risk is minimized when the tree size is matched to machine size. Trees that are too small decrease productivity and increase costs, while trees that are too large can overwork the machine, causing mechanical failure or environmental damage.
Timber quality	Risk is increased with poor-quality timber because of reduced values. Poor-quality timber requires as much, or more, time for processing, yet returns a smaller profit.

describes the site characteristic. Proceed through the chart until you arrive at a risk-level box.

In some cases, a first-mentioned factor on the chart may result in a high, but non-limiting, risk level (e.g., in Chart 15, non-clearcuts are ranked as risk level 4). On the same chart, another factor may be ranked with a higher risk level (e.g., poor deflection is ranked as risk level 6). This result should not be interpreted as saying that poor deflection in a non-clearcut will result in risk level 4. Obviously, the higher risk level will prevail.

Comments at the bottom of each chart list additional factors that apply for all types of sites, and should be considered in assessing the risk level. Table 7 lists risk factors that should be considered for all types of equipment. Finally, the contractor and operator may employ special operating techniques that can modify the risk levels.

Key Factors for Primary Transport Equipment

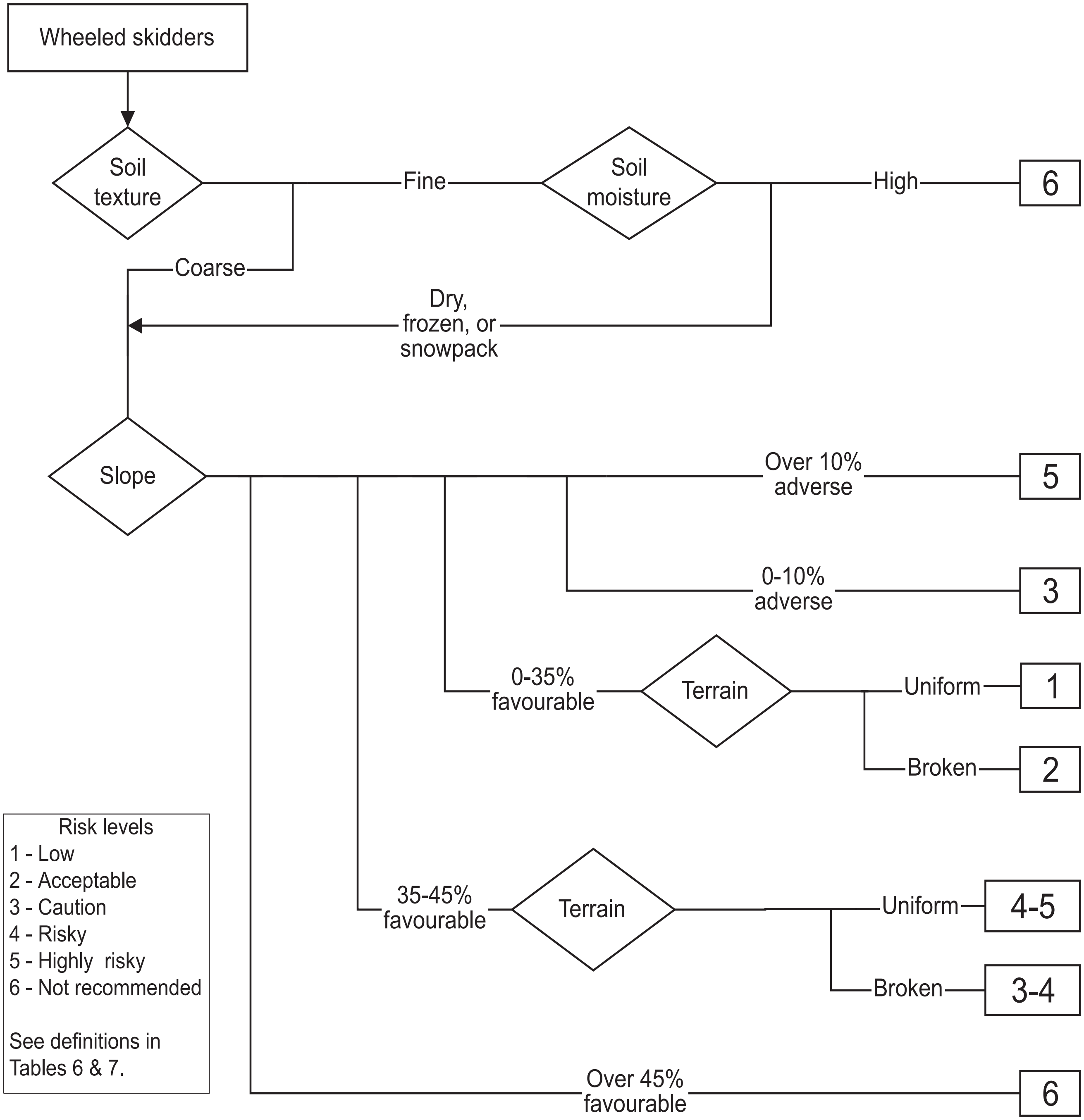

Chart 1. Wheeled skidders.

- The ability to turn skidders safely is reduced on steep slopes. The presence of large obstacles such as boulders, depressions, or windfalls will increase the risk, especially on steep slopes, because they increase the difficulty of turning around the machine. Benches may increase the opportunity for turning safely. Obstacles also reduce the travel speed and increase the travel distance.
- Grapple skidders are best suited for use with mechanical falling and bunching equipment, which requires that the tree size be within the operating range of the falling equipment. Grapple skidders enable roadside operations, which can reduce production costs. Swing-boom grapples reduce the risk on steep ground. On wetter sites, line skidders can drop their load and move forward to more firm terrain before winching the load, thus reducing the risk of soil disturbance.

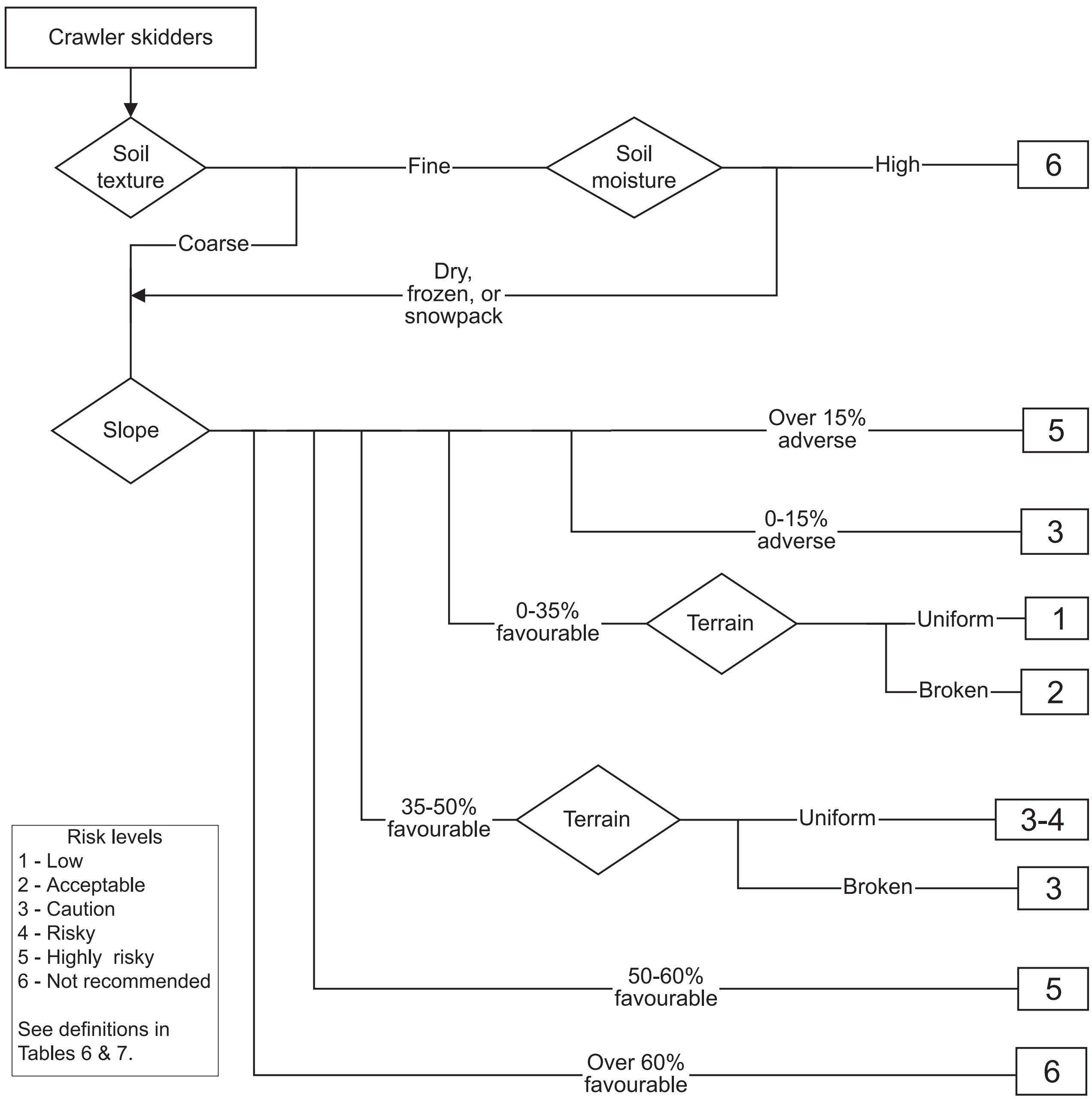

Chart 2. Crawler skidders.

- The ability to turn skidders safely is reduced on steep slopes. The presence of large obstacles such as boulders, depressions, or windfalls will increase the risk, especially on steep slopes, because they increase the difficulty of turning around the machine. Benches may increase the opportunity for turning safely. Obstacles also reduce the travel speed and increase the travel distance.
- Grapple skidders are best suited for use with mechanical falling and bunching equipment, which requires that the tree size be within the operating range of the falling equipment. Grapple skidders enable roadside operations, which can reduce production costs. Swing-boom grapples reduce the risk on steep ground. On wetter sites, line skidders can drop their load and move forward to more firm terrain, thus reducing the risk of soil disturbance.
- Low travel speed makes crawler skidders more suited to short skidding distances.

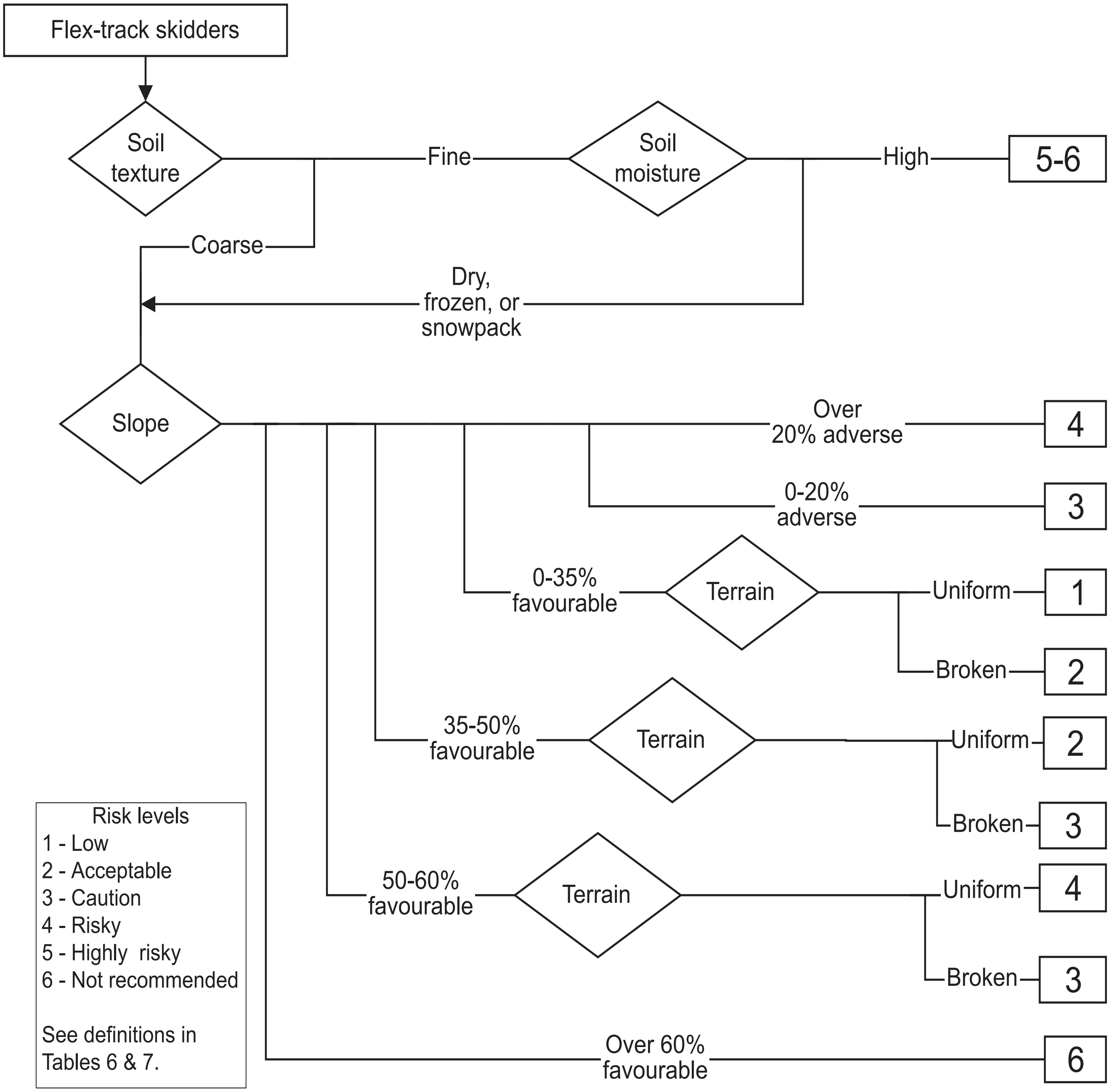

Chart 3. Flex-track skidders.

- The ability to turn skidders safely is reduced on steep slopes. The presence of large obstacles such as boulders, depressions, or windfalls will increase the risk, especially on steep slopes, because they increase the difficulty of turning around the machine. Benches may increase the opportunity for turning safely. Obstacles also reduce the travel speed and increase the travel distance.
- Grapple skidders are best suited for use with mechanical falling and bunching equipment, which requires that the tree size be within the operating range of the falling equipment. Grapple skidders enable roadside operations, which can reduce production costs. Swing-boom grapples reduce the risk on steep ground. On wetter sites, line skidders can drop their load and move forward to more firm terrain, thus reducing the risk of soil disturbance.
- The tracks for flex-track machines conform more closely to the ground profile than for conventional tracked skidders. This feature distributes their weight more evenly, allowing them to operate on soft ground and up adverse slopes with less soil disturbance.

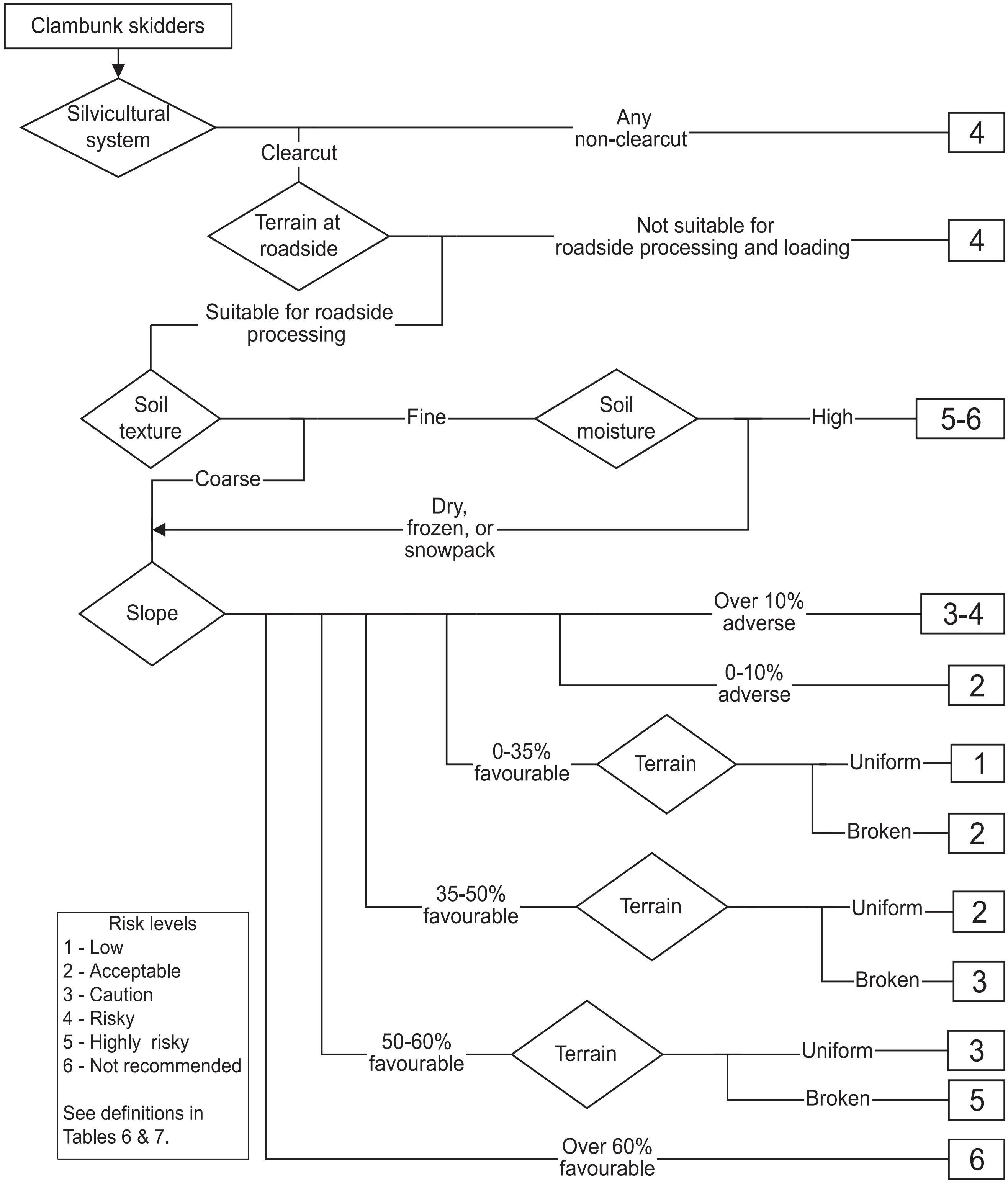

Chart 4. Clambunk skidders.

- The presence of large obstacles such as boulders, depressions, or windfalls will increase the risk because they reduce the travel speed and increase the travel distance.
- The risk level increases for low volumes per trail (i.e., for "shallow" or low volume per hectare cutblocks). The clambunk will be unable to obtain a full load, making it uneconomic to operate unless the skidding pattern is altered to attain full loading.
- Clambunks are best suited for use with mechanical falling and bunching, which requires that the tree size be within the operating range of the falling equipment.

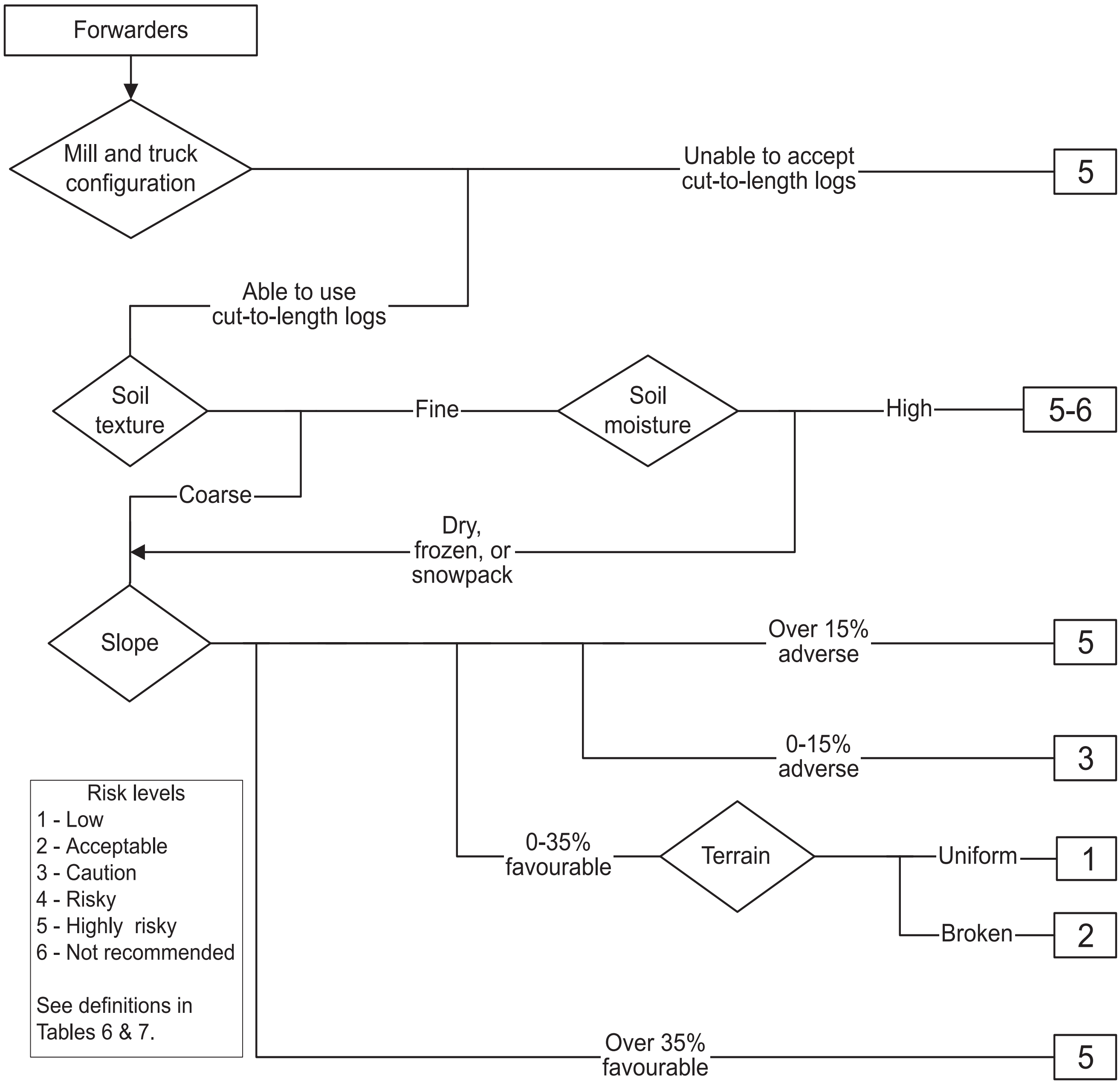

Chart 5. Forwarders.

- The risk level is very high if the mill and truck fleet are unable to accept cut-to-length logs, although these limitations are imposed by business requirements, not by the site characteristics. Timber sales to other companies and other options for transporting the logs should be considered.
- Large obstacles such as boulders, depressions, or windfalls will increase the risk because they reduce the travel speed and increase the travel distance.
- The tree size must be suitable for the feller-processor that works with the forwarder. Large trees may require falling and processing with additional equipment.
- Depending on machine size, the high degree of maneuverability between standing trees makes forwarders well suited to partial cutting operations.

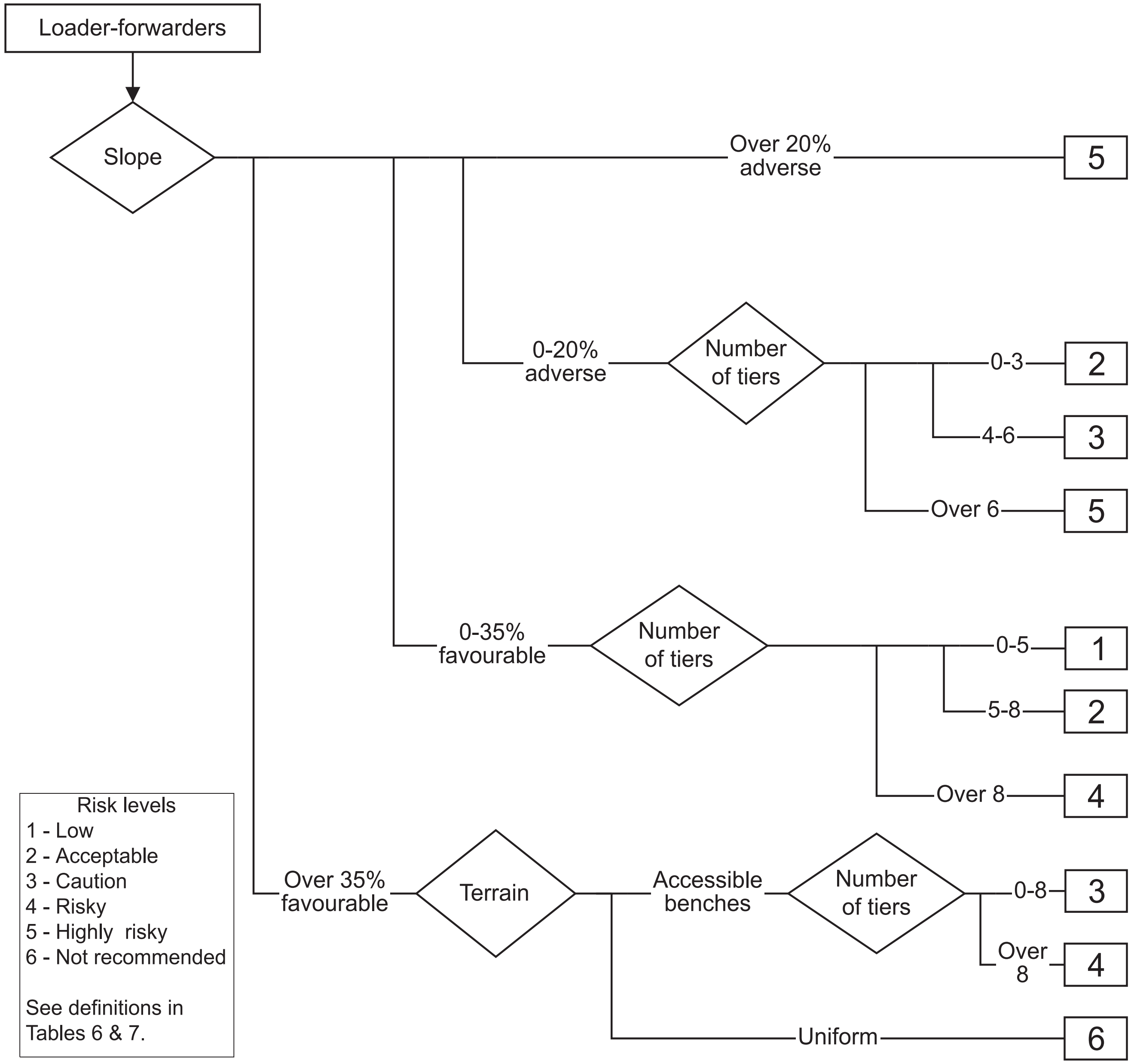

Chart 6. Loader-forwarders.

- Distance for each “tier” or “chuck” will vary depending on the size of the machine, the length of the timber, and the decision to buck trees into log lengths.
- The risk level increases for wet or fine soils and for small trees.

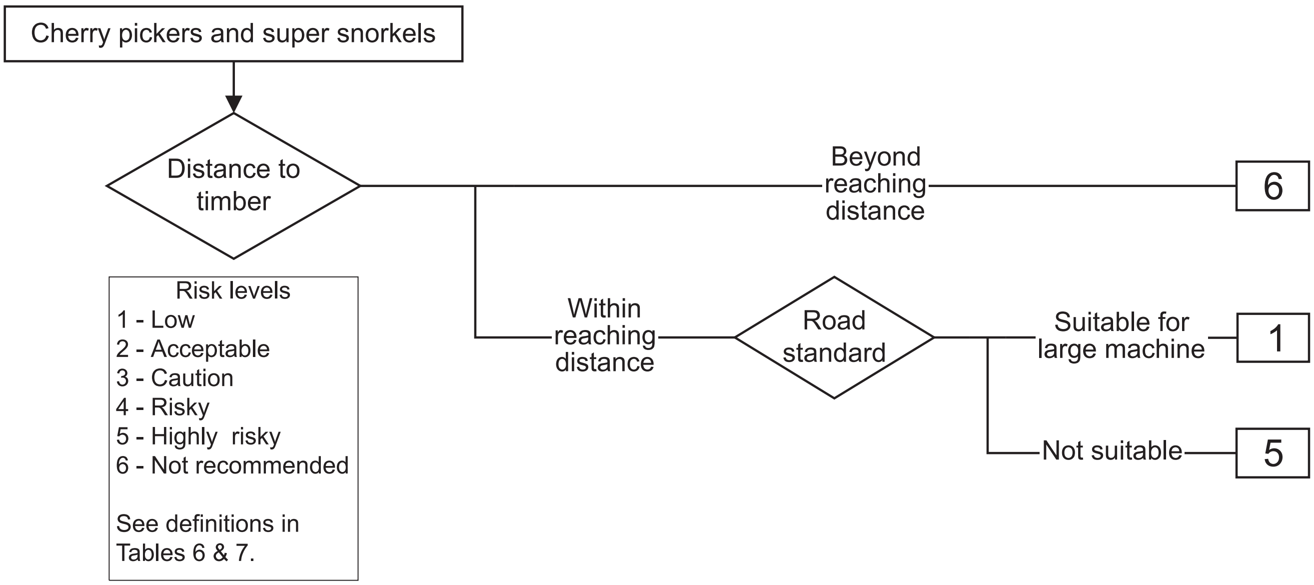

Chart 7. Cherry pickers and super snorkels.

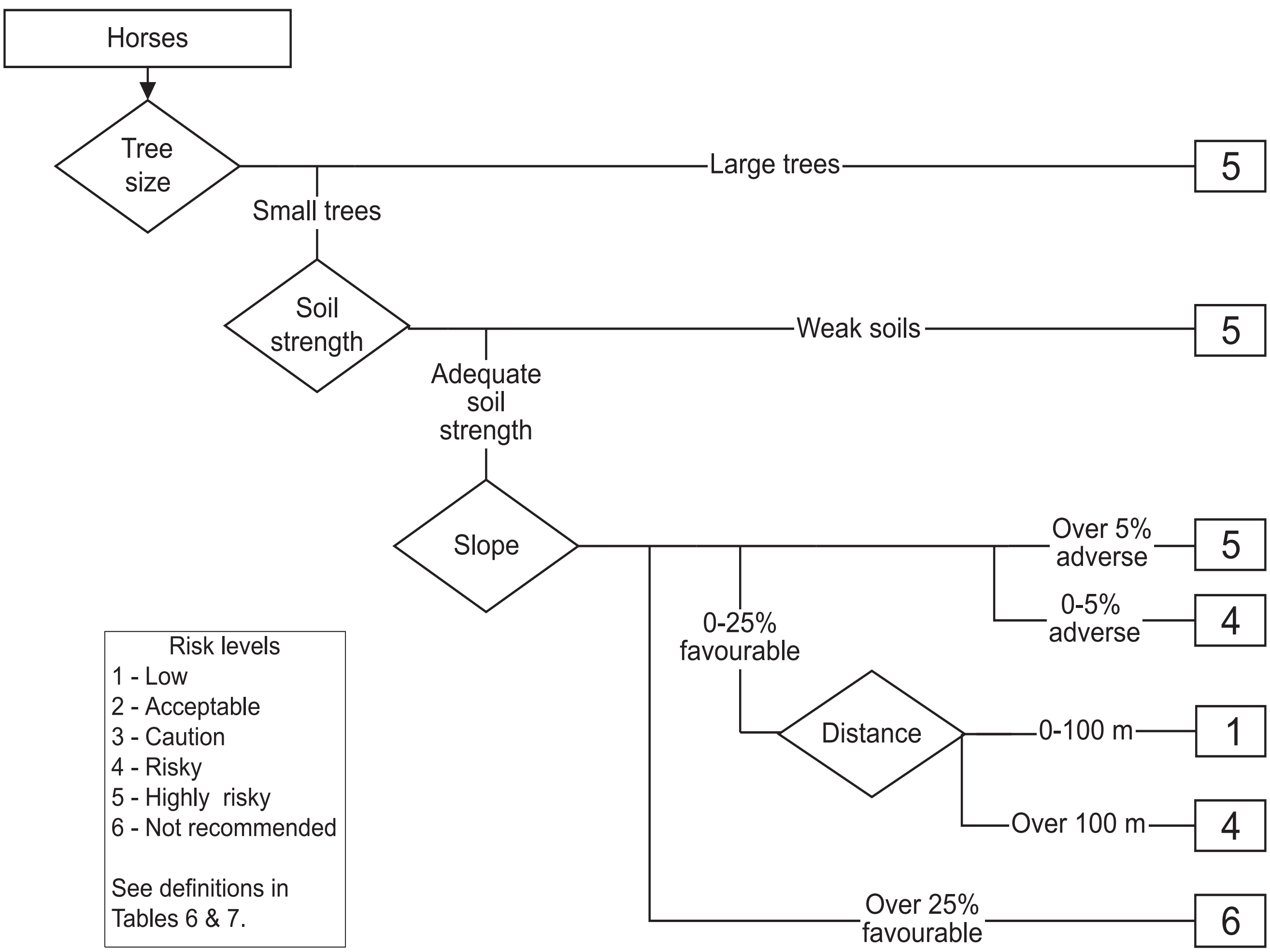

Chart 8. Horse.

- Skidding with horses is enhanced on a snowpack because of reduced friction. Risk increases for slopes over 15% under frozen conditions because of the potential for logs to slide downhill and strike the horse.
- The trails where the horses walk must be cleared of debris before skidding.

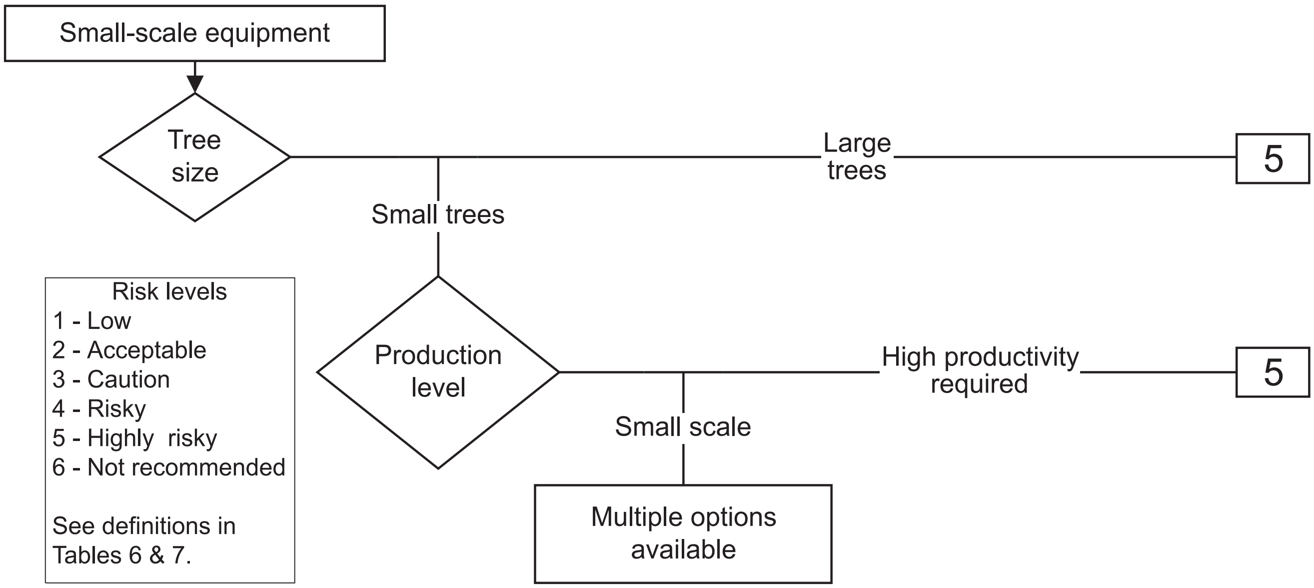

Chart 9. Small-scale equipment.

- Many types of small-scale equipment are available with a wide range of capabilities and key factors. They are used in niche applications, typically where tree size is small and productivity is low. Beyond that, examine the specific type of equipment proposed to determine whether it is usable.

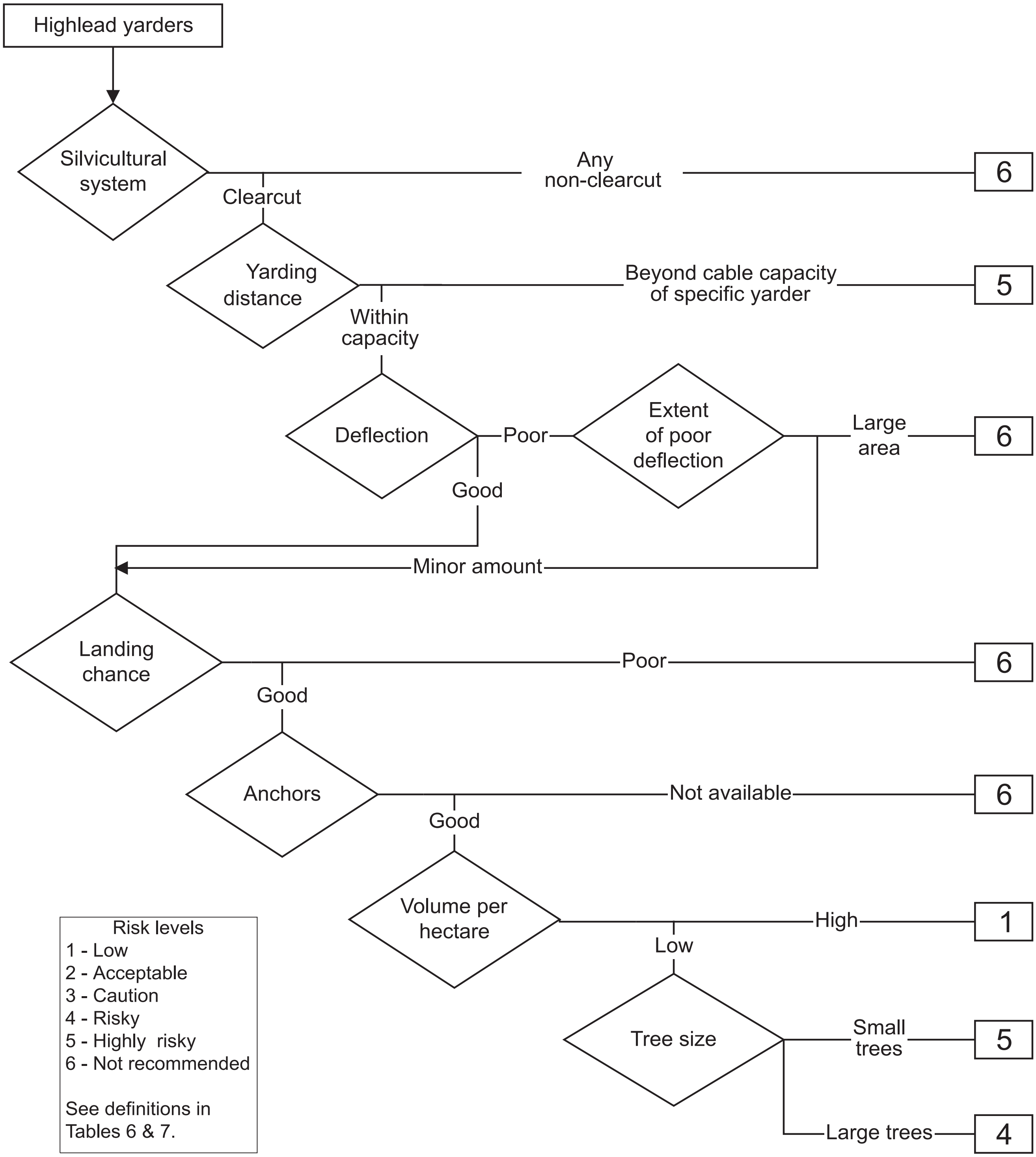

Chart 10. Highlead yarders.

- Highlead yarders can continue to work even if the butt-rigging drags on the ground, although this practice may result in excessive soil disturbance and low productivity.
- Landing chance refers to the ability to build and use suitable landings. Poor landing chance may be caused by difficult terrain or by the combination of terrain, deflection, and the tower location within the landing.
- Tree size and volume per hectare must be evaluated in relation to the specific machine, with a minimum economic volume ranging from 150 to 350 m^3/ha depending on machine size.
- Anchors may consist of large tree stumps, several smaller trees or stumps, or fabricated anchors such as a buried log or rock bolts.
- Cable extensions can be used to reach logs beyond the yarder's normal working distance.

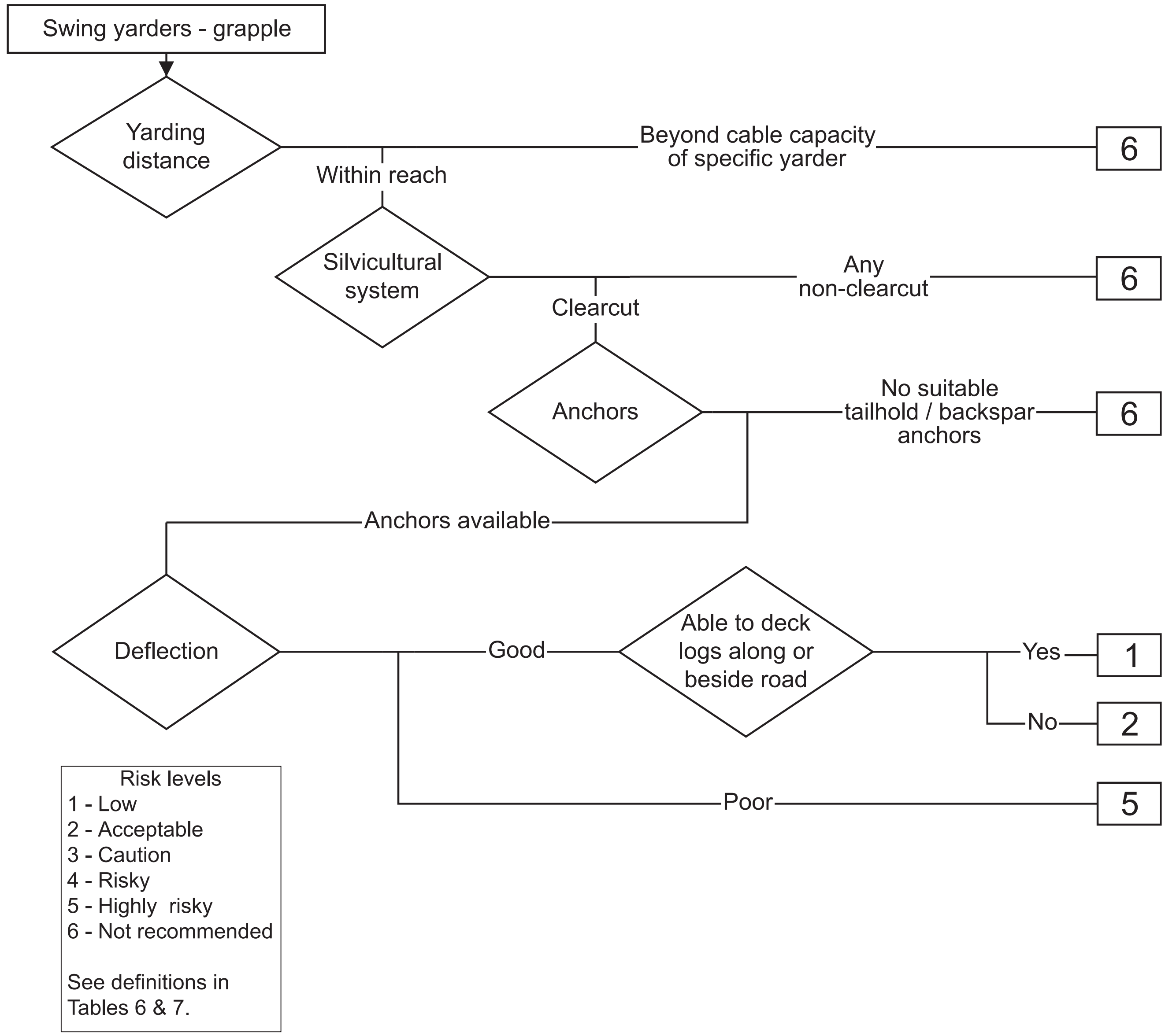

Chart 11. Swing yarders – grapple.

- The risk level is increased where mobile backspars cannot be used — conventional anchors must be available in their place. Anchors may consist of large tree stumps, several smaller trees or stumps, or fabricated anchors such as a buried log or rock bolts.
- The risk level increases for small tree size because the trees are picked up individually. Mechanical falling and bunching can reduce the risk.

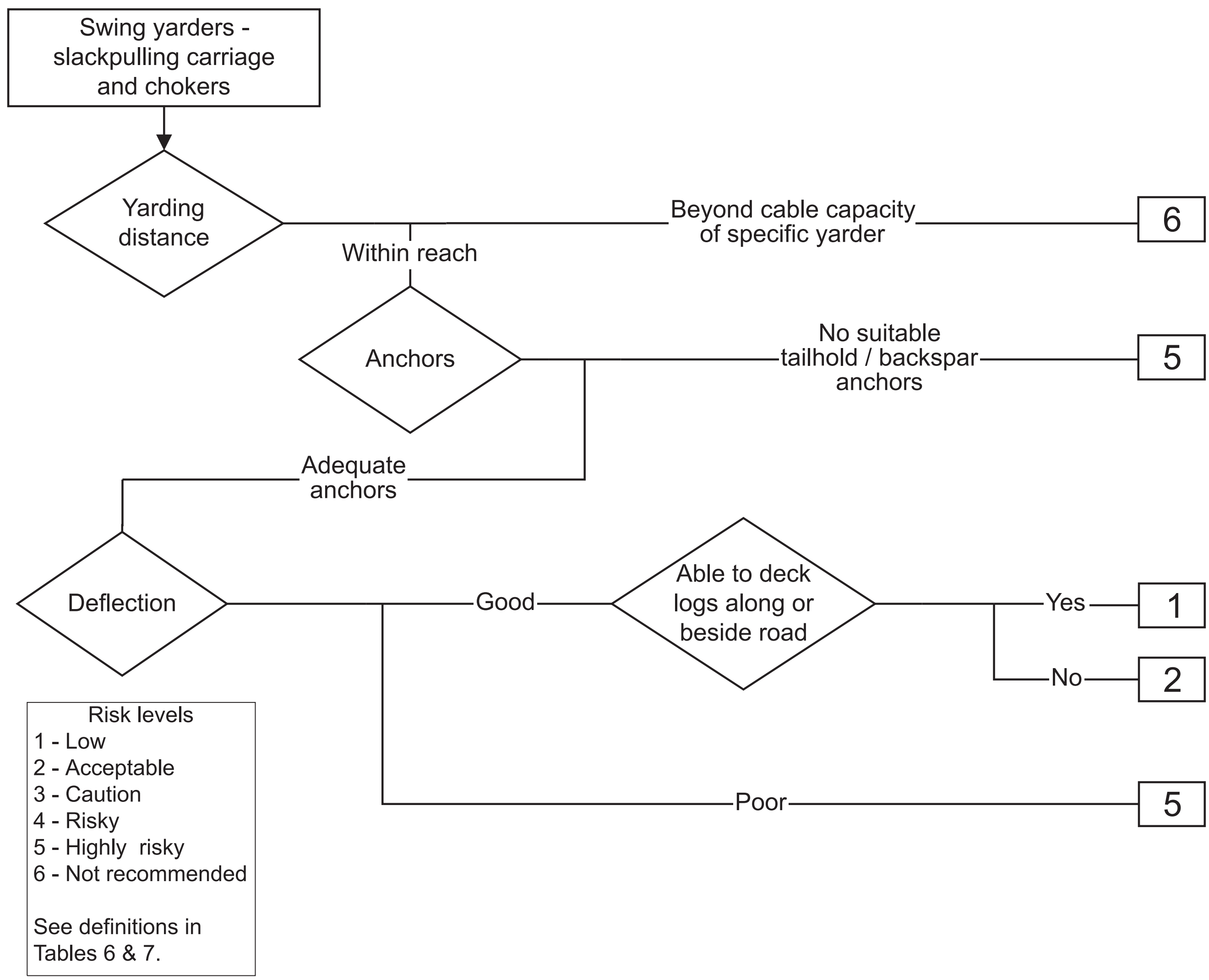

Chart 12. Swing yarders – slackpulling carriage and chokers.

- Anchors may consist of large tree stumps, several smaller trees or stumps, or fabricated anchors such as a buried log or rock bolts.

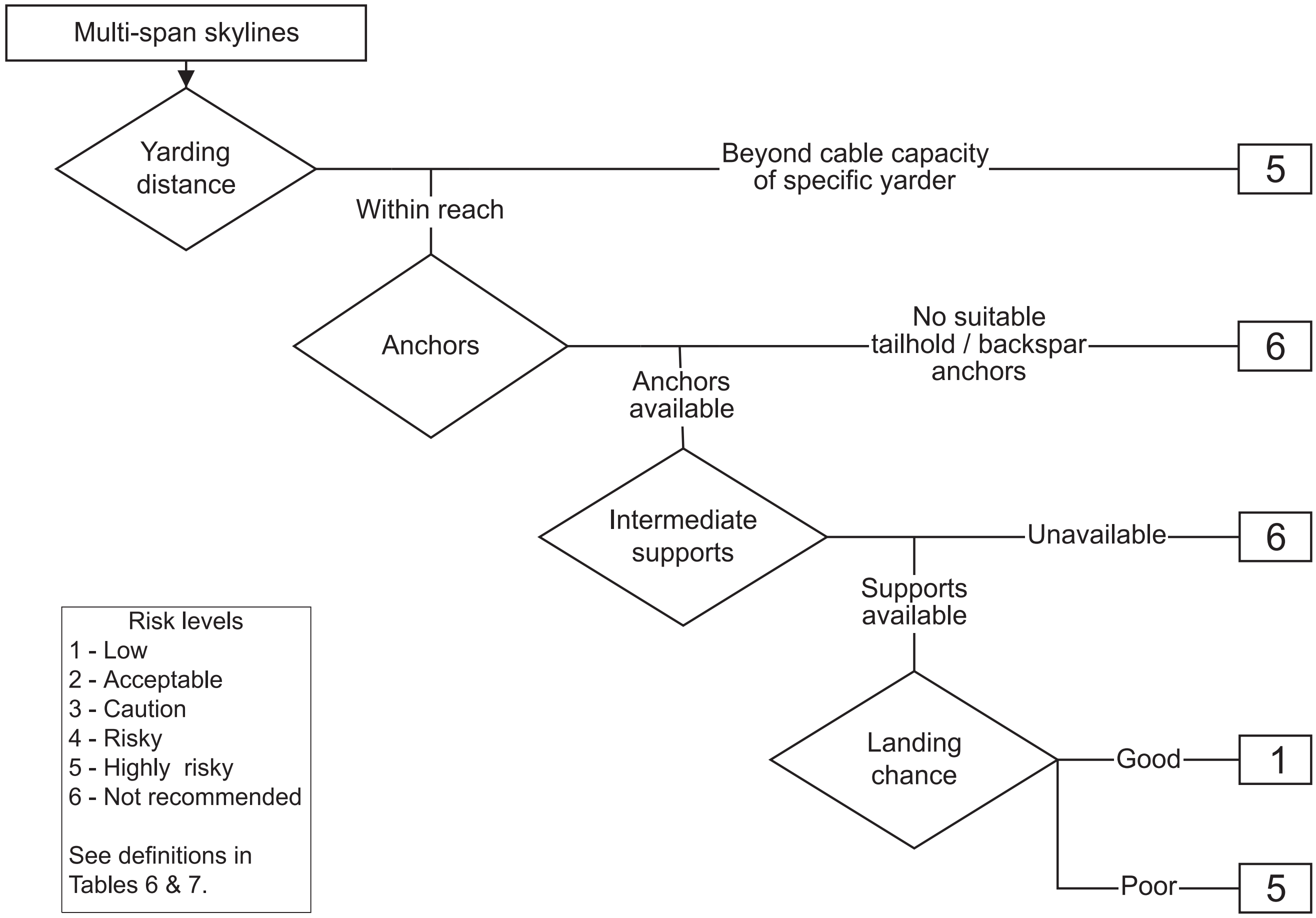

Chart 13. Multi-span skylines.

- Landing chance refers to the ability to build and use suitable landings for extraction and subsequent phases. Poor landing chance may be caused by difficult terrain or by the combination of terrain, deflection, and the tower location within the landing.
- Risk level increases as the volume per hectare decreases.
- Although intermediate supports allow for yarding in areas of poor deflection, risk increases as the number of intermediate supports increases.
- Payloads can be lifted over intervening obstacles depending on the ground profile, the layout, and the equipment capability.
- Anchors may consist of large tree stumps, several smaller trees or stumps, or fabricated anchors such as a buried log or rock bolts.
- Cable extensions can be used to reach logs beyond the yarder's normal working distance.

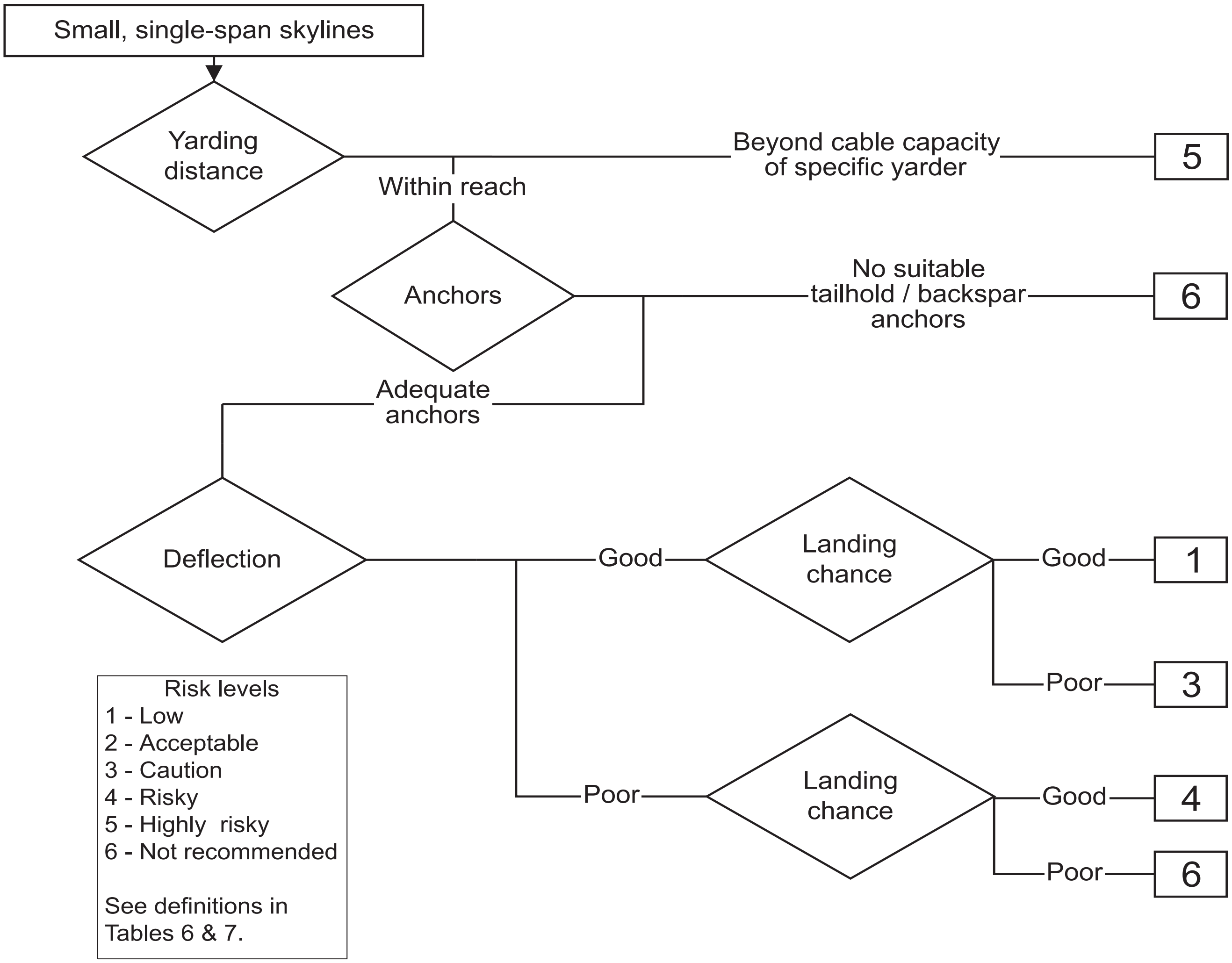

Chart 14. Small, single-span skylines.

- Landing chance refers to the ability to build and use suitable landings for extraction and subsequent phases. Poor landing chance may be caused by difficult terrain or by the combination of terrain, deflection, and the tower location within the landing.
- Risk level increases as the volume per hectare decreases.
- Payloads can be lifted over intervening obstacles, depending on deflection and clearance.
- Anchors may consist of large tree stumps, several smaller trees or stumps, or fabricated anchors such as a buried log or rock bolts.
- Cable extensions can be used to reach logs beyond the yarder's normal working distance.

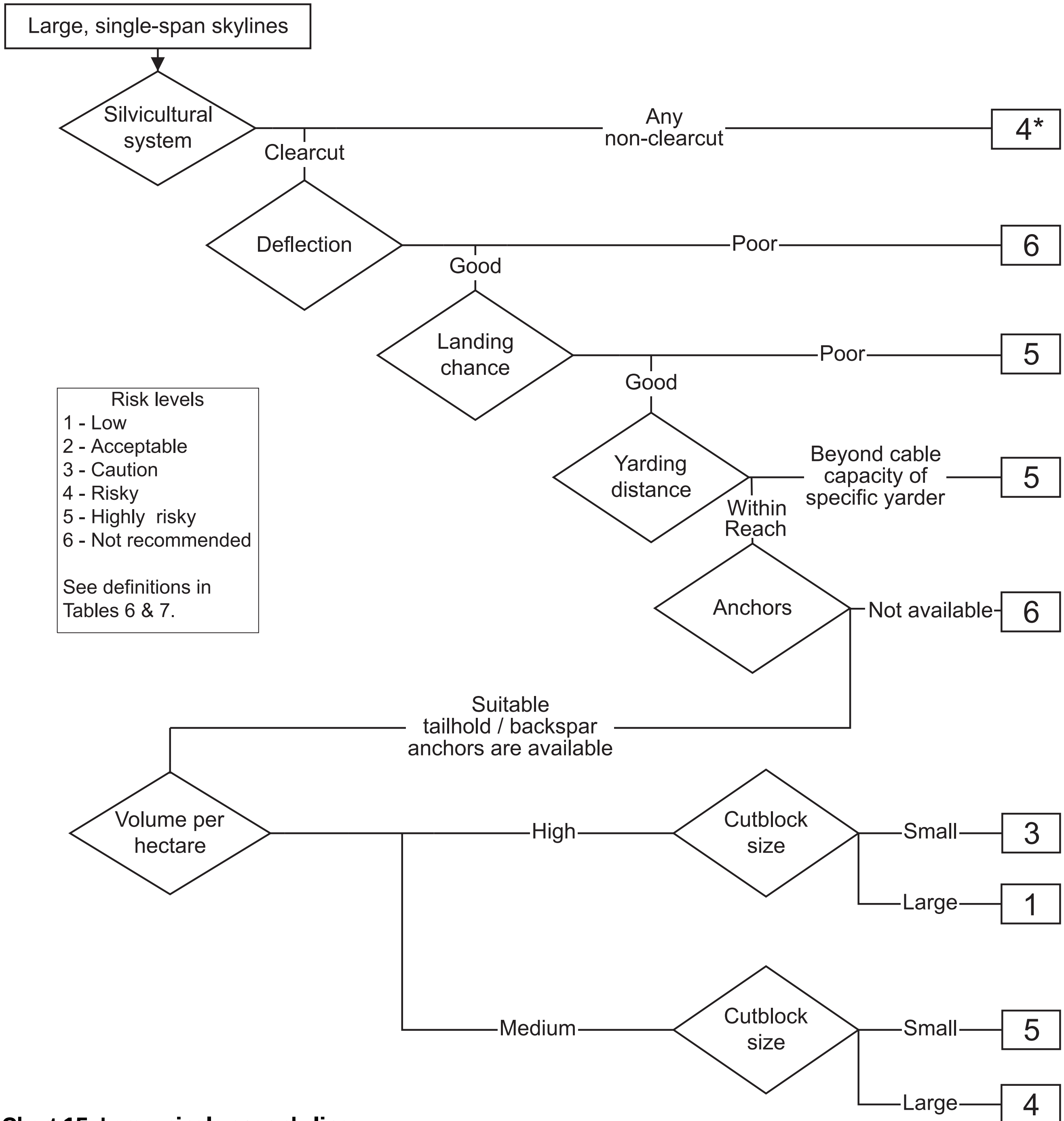

Chart 15. Large, single-span skylines.

* • The term "large" refers both to the yarder size and the skyline span — large tower-mounted yarders and European cable cranes both qualify as "large." However, the European cable cranes are better able to operate in non-clearcut silvicultural systems, and their risk would be lower than shown in the chart.

- Landing chance refers to the ability to build and use suitable landings for extraction and subsequent phases. Poor landing chance may be caused by difficult terrain or by the combination of terrain, deflection, and the tower location within the landing.
- Payloads can be lifted over intervening obstacles depending on deflection and clearance.
- Risk increases with too-large deflection because of the increased time required for the chokers to travel between the carriage and the ground.
- Anchors may consist of large trees or stumps, or fabricated anchors such as a buried log or rock bolts.
- Cable extensions can be used to reach logs beyond the yarder's normal working distance.

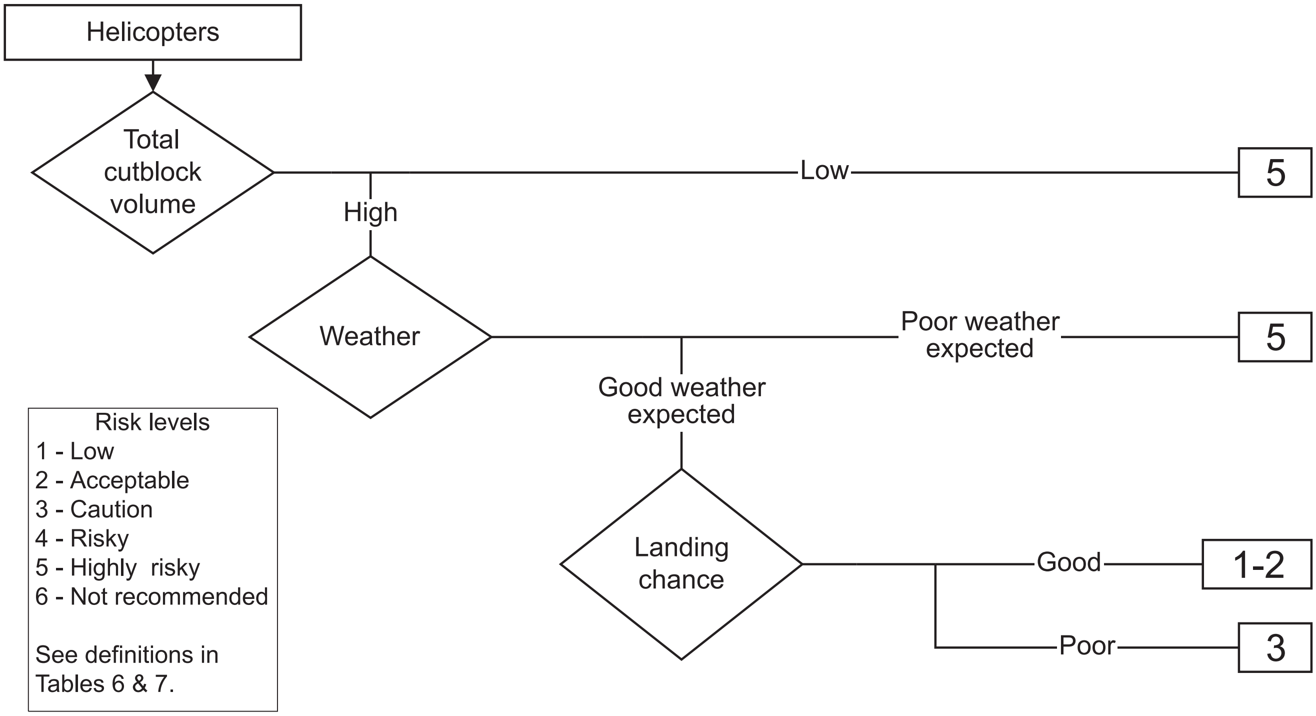

Chart 16. Helicopters.

- Suitable landings are large enough to handle the expected volume of logs without causing delays. Flying, processing, storage, and loading must all be accommodated. A separate landing for helicopter fueling and maintenance is required.
- Risk level increases when multiple hookup sites are not available, with long flying distances, and with adverse or very steep favourable slope between the hookup site and the landing.
- Poor weather such as high wind or reduced visibility can affect the ability of the helicopter to fly safely.
- Payloads can be lifted over intervening obstacles.

Key Factors for Falling Equipment

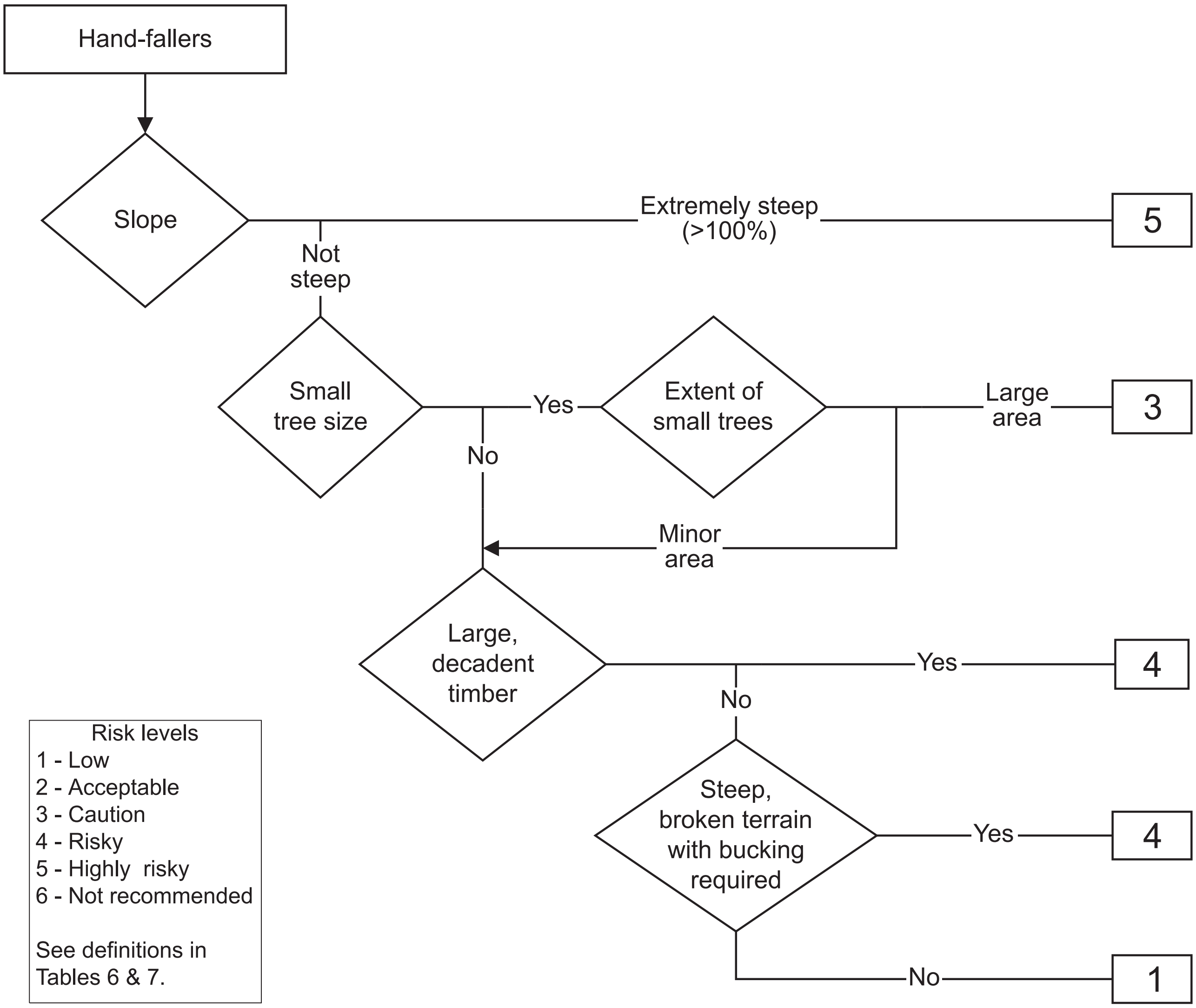

Chart 17. Hand-fallers.

- Hand-fallers can work on almost any site, within the limits of economics and safety.
- Falling small trees by hand is expensive, especially after considering the costs for extraction. Except with very small trees, hand-fallers are unable to build bunches.
- Hand-falling in decadent timber and bucking timber on steep, broken terrain are especially hazardous.

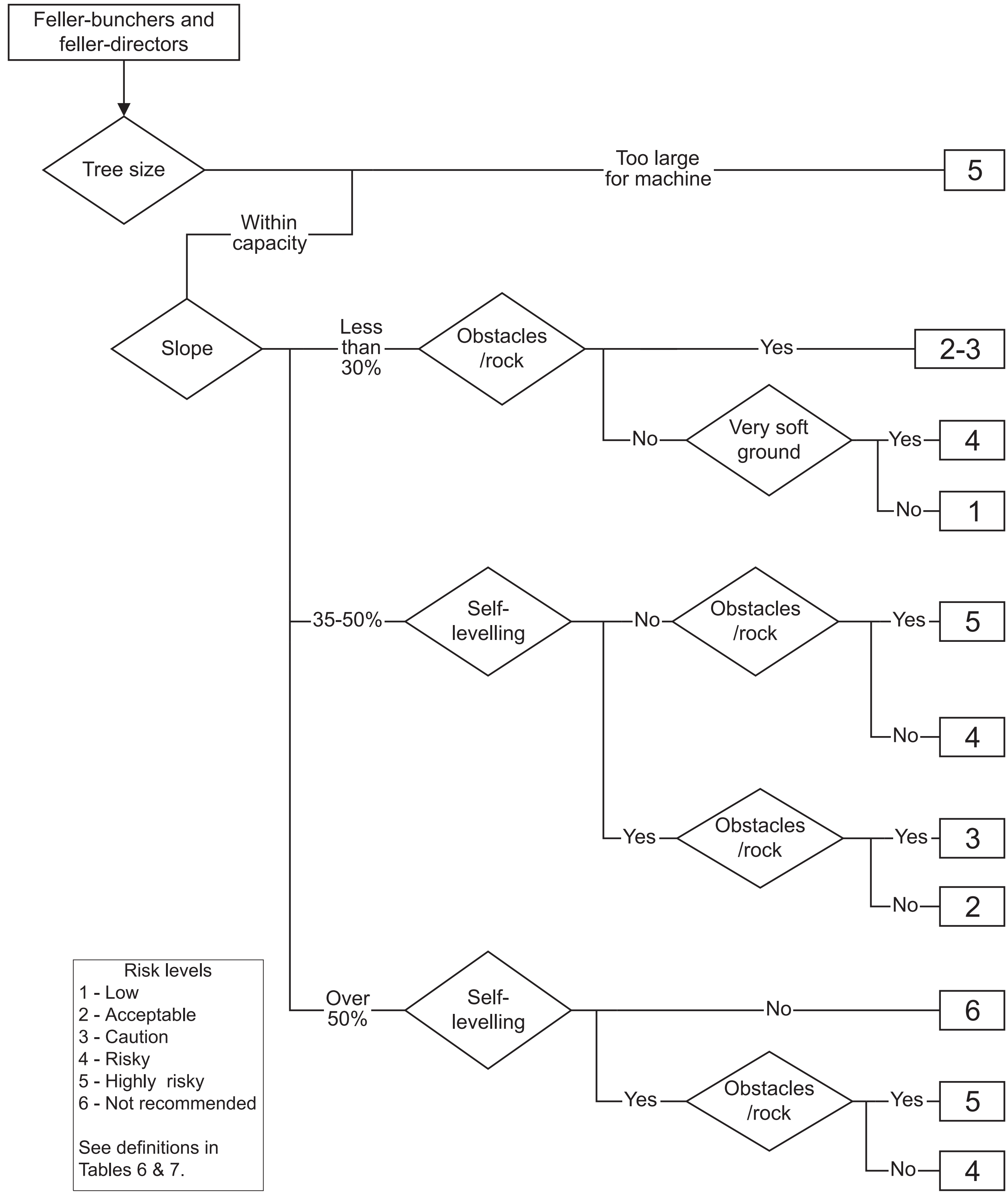

Chart 18. Feller-bunchers and feller-directors.

- Maximum tree size depends on the make and model of the carrier and head. Typical maximum tree diameter is about 60 cm, although larger heads up to 75 cm are available. Larger trees can be cut by approaching the tree from two or more sides.
- Feller-directors can handle larger trees than feller-bunchers, but they are poorly suited to making bunches.

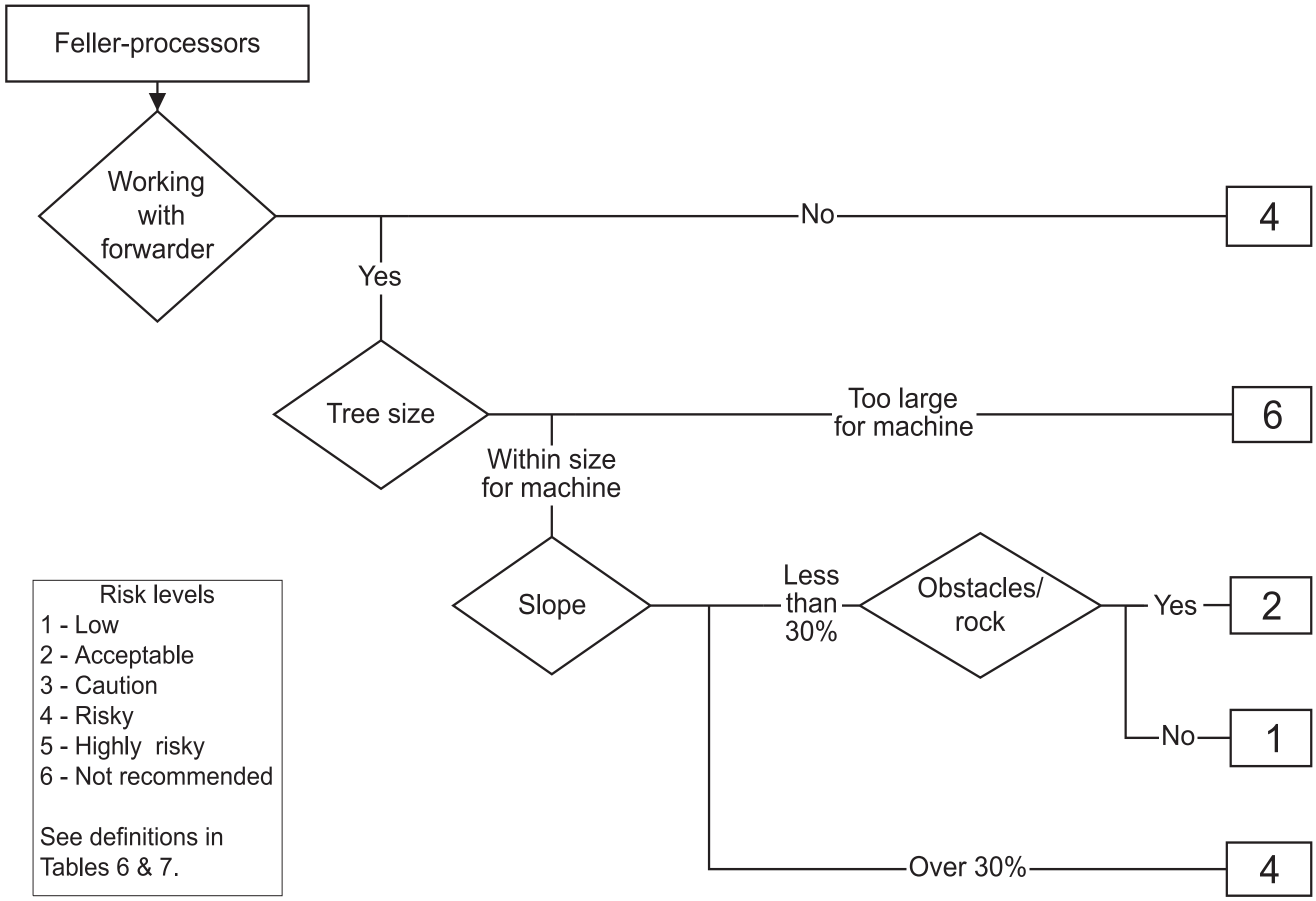

Chart 19. Feller-processors.

- This chart applies to feller-processors mounted on articulated, rubber-tired carriers. Use the “feller-buncher” chart for single-grip feller-processors mounted on excavator-style carriers.
- The maximum tree diameter for current single-grip feller-processors is about 50 cm. Current double-grip feller-processors can handle trees to about 65 cm diameter.
- Feller-processors must be able to accurately and reliably measure log lengths.

Key Factors for Processing Equipment

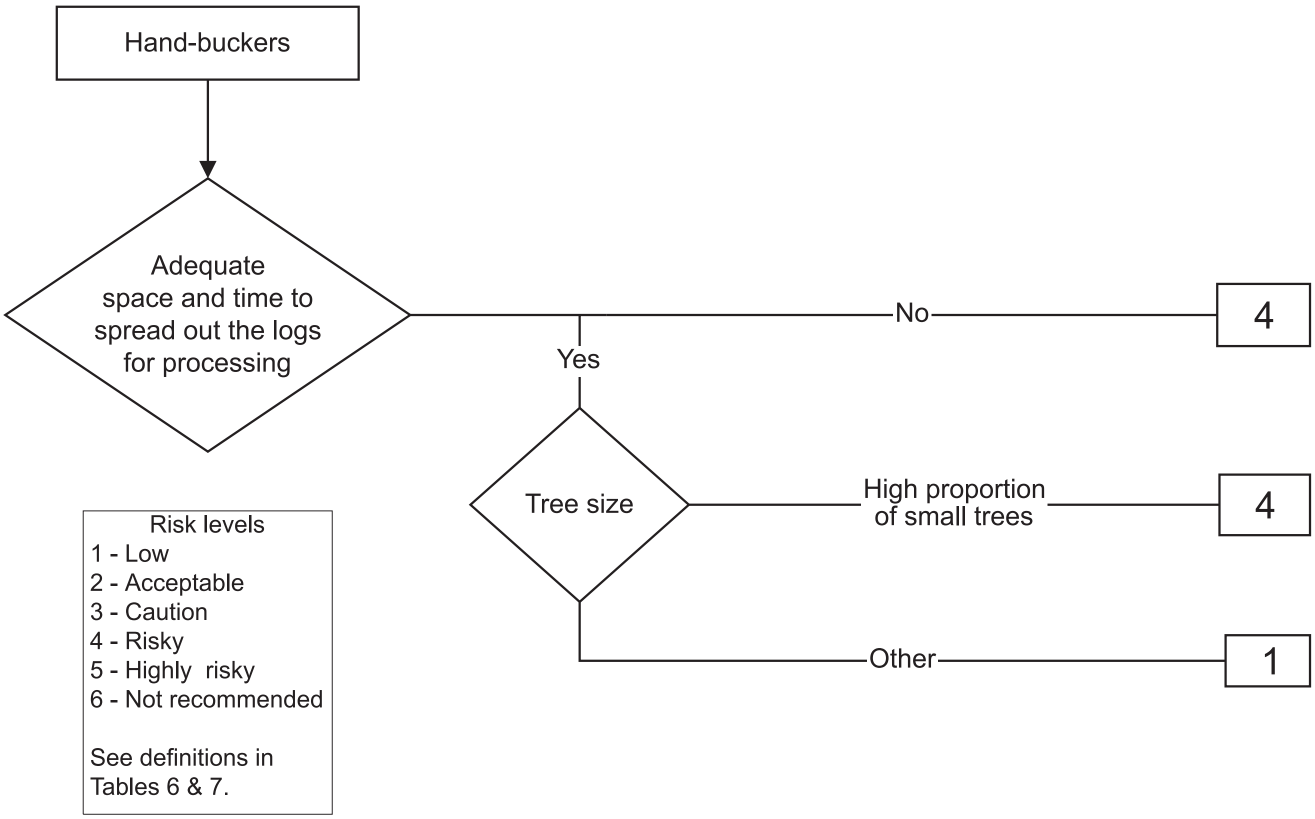

Chart 20. Hand-buckers.

- Hand-bucking can be used on almost any site, within the constraints of safety and economics. Since hand-buckers require support equipment to move the logs, the bucker and support equipment must be able to work together safely. This requires adequate time between cycles of the loading or skidding equipment, and adequate space to spread out the logs for the bucker to examine and cut each log. Such conditions may be impossible to achieve on sites with a high proportion of small trees.

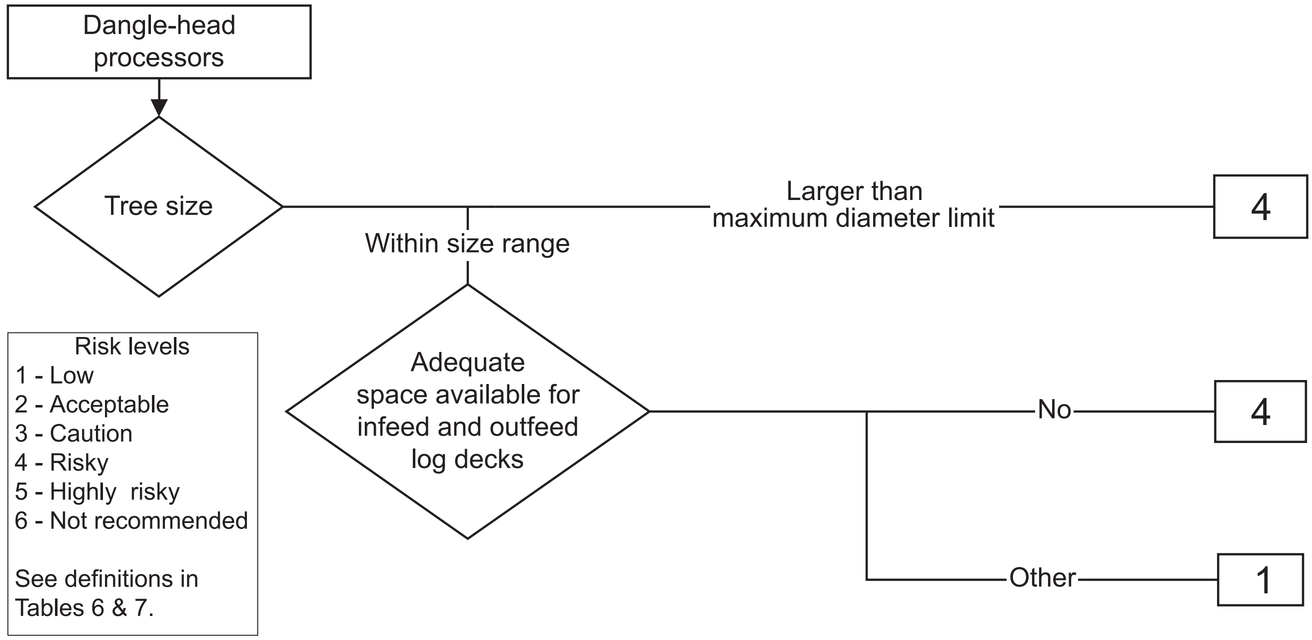

Chart 21. Dangle-head processors.

- Dangle-head processors are typically used for smaller trees, with a maximum diameter of about 50 cm; however, some models can process logs up to 80 cm diameter. Trees larger than the rated maximum diameter can be handled by grasping the tree above the butt, where the diameter is smaller. Trees can also be left lying on the ground, and the processing head passed over them without actually lifting the tree.

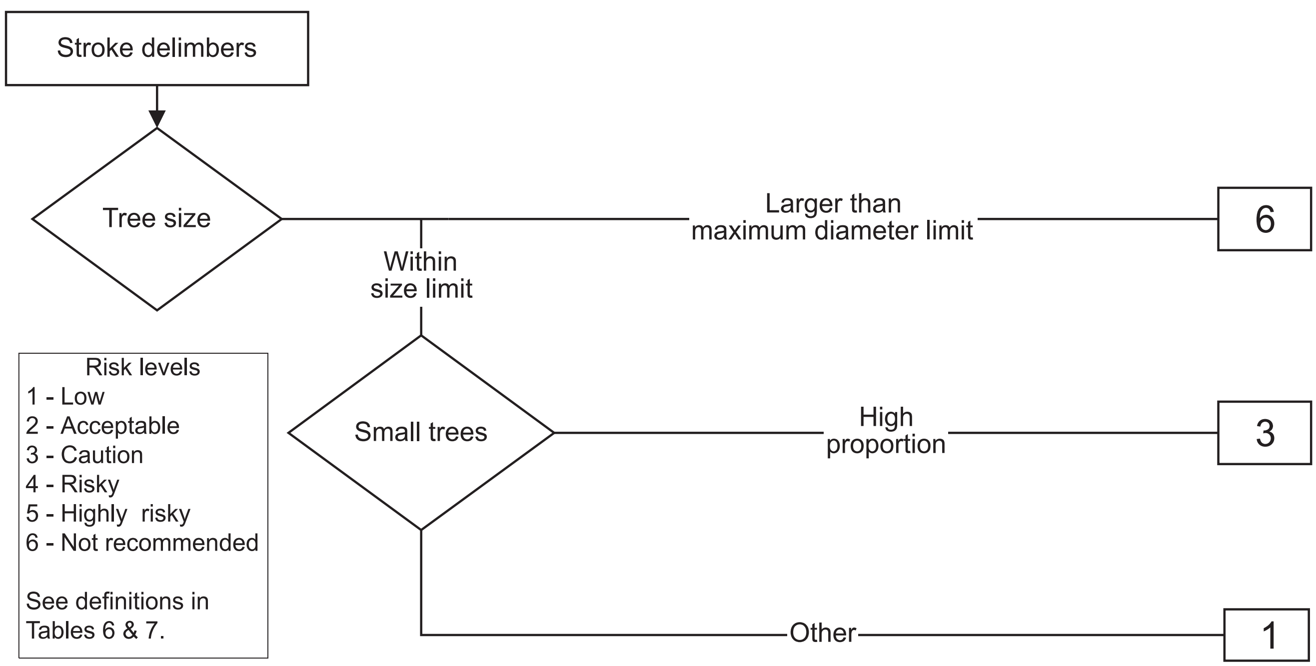

Chart 22. Stroke delimbers.

- The maximum tree size for stroke delimbers is governed by the diameter of the tunnel through the machine — the trees must be able to fit through the tunnel.
- Stroke delimbers are less efficient for small trees than dangle-head processors because they pass over each log twice to complete the processing cycle. However, stroke delimbers can process several small trees simultaneously.

Key Factors for Loading Equipment

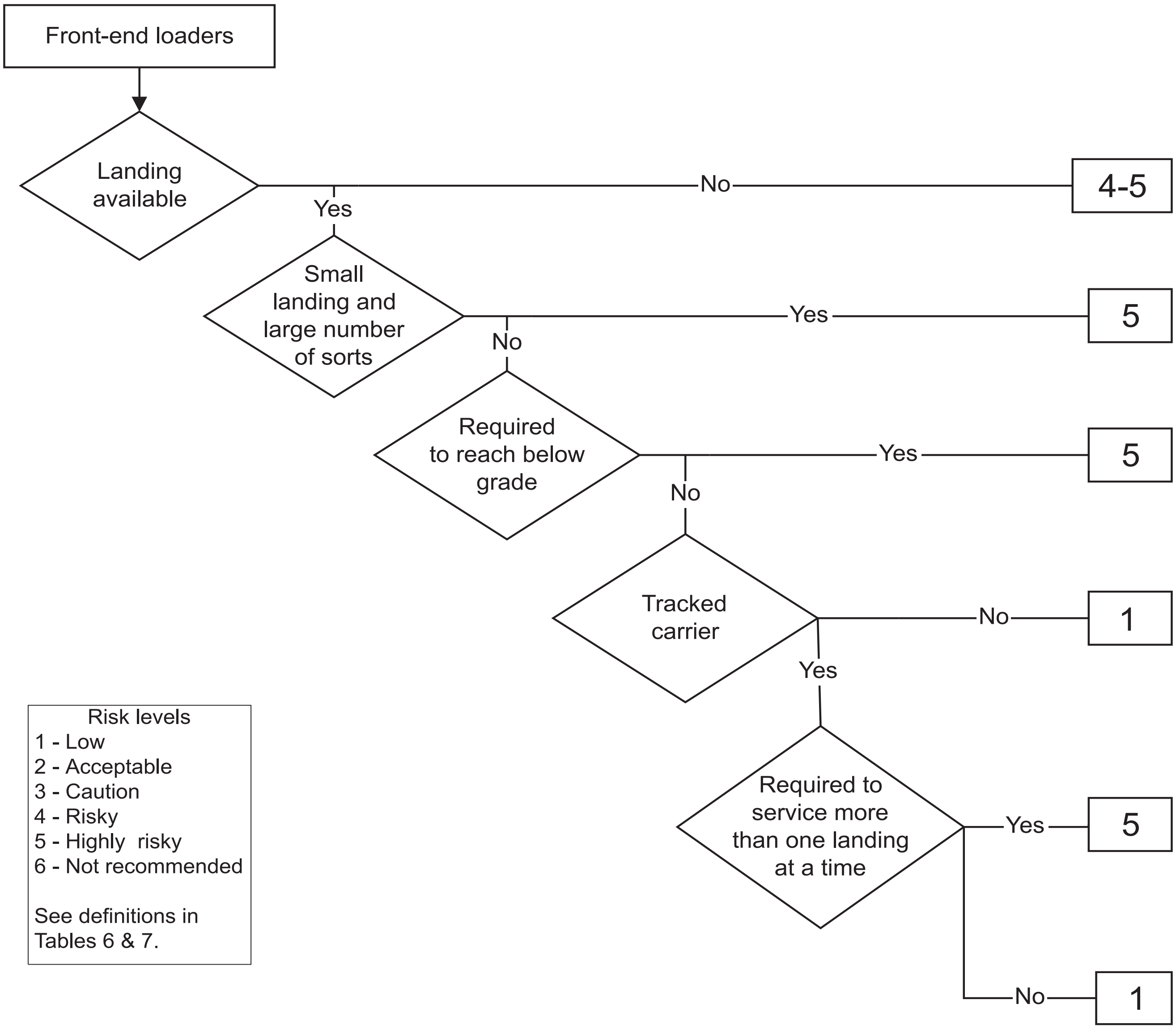

Chart 23. Front-end loaders.

- Wheeled front-end loaders can be moved quickly between sites several kilometres apart. Loaders on tracked carriers require low-bed transportation.

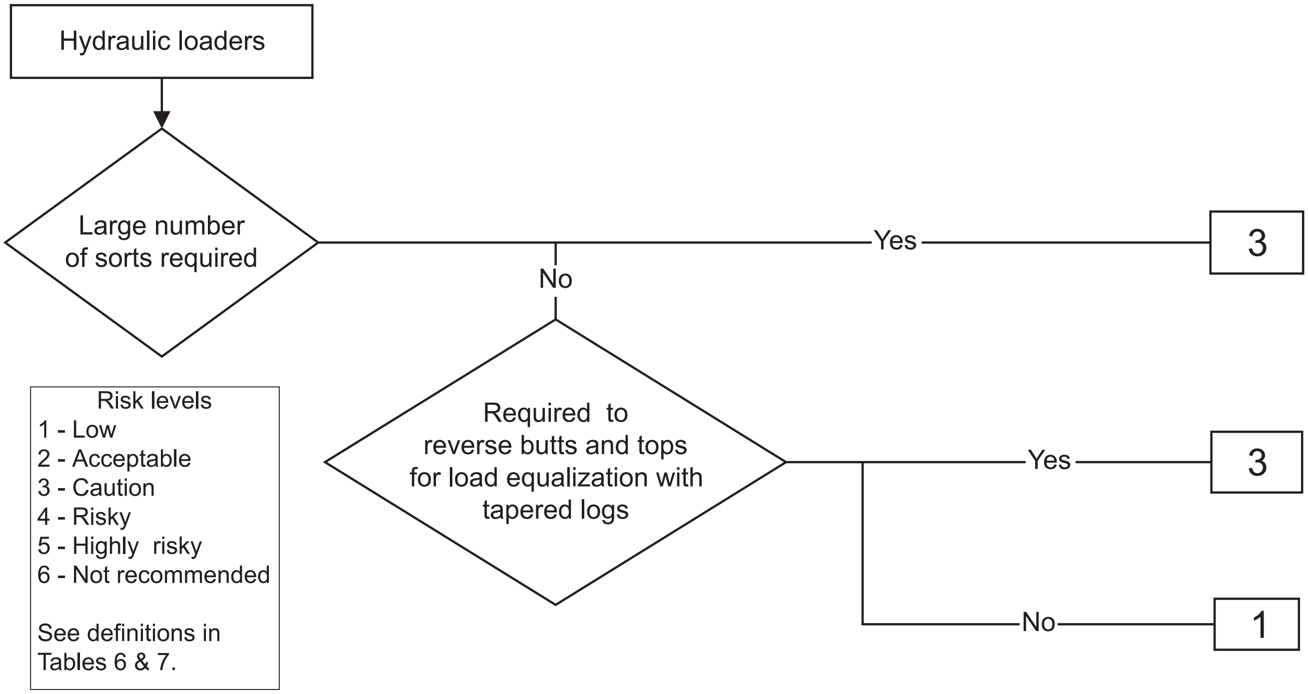

Chart 24. Hydraulic loaders.

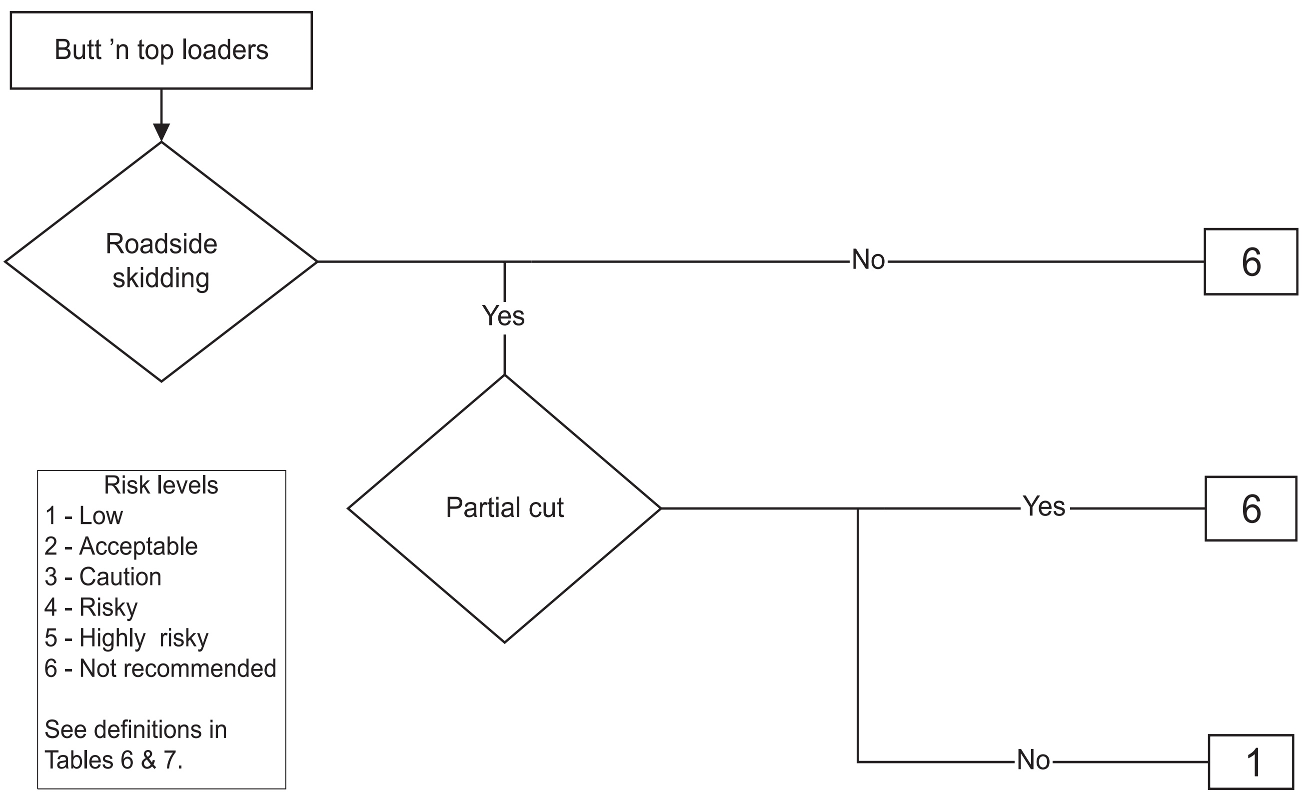

Chart 25. Butt ’n top loaders.

- Suitability of a cutblock for roadside logging is often determined by the ability of the butt ’n top loader to operate adjacent to the road. Sideslopes must be low enough for the loader to operate safely.

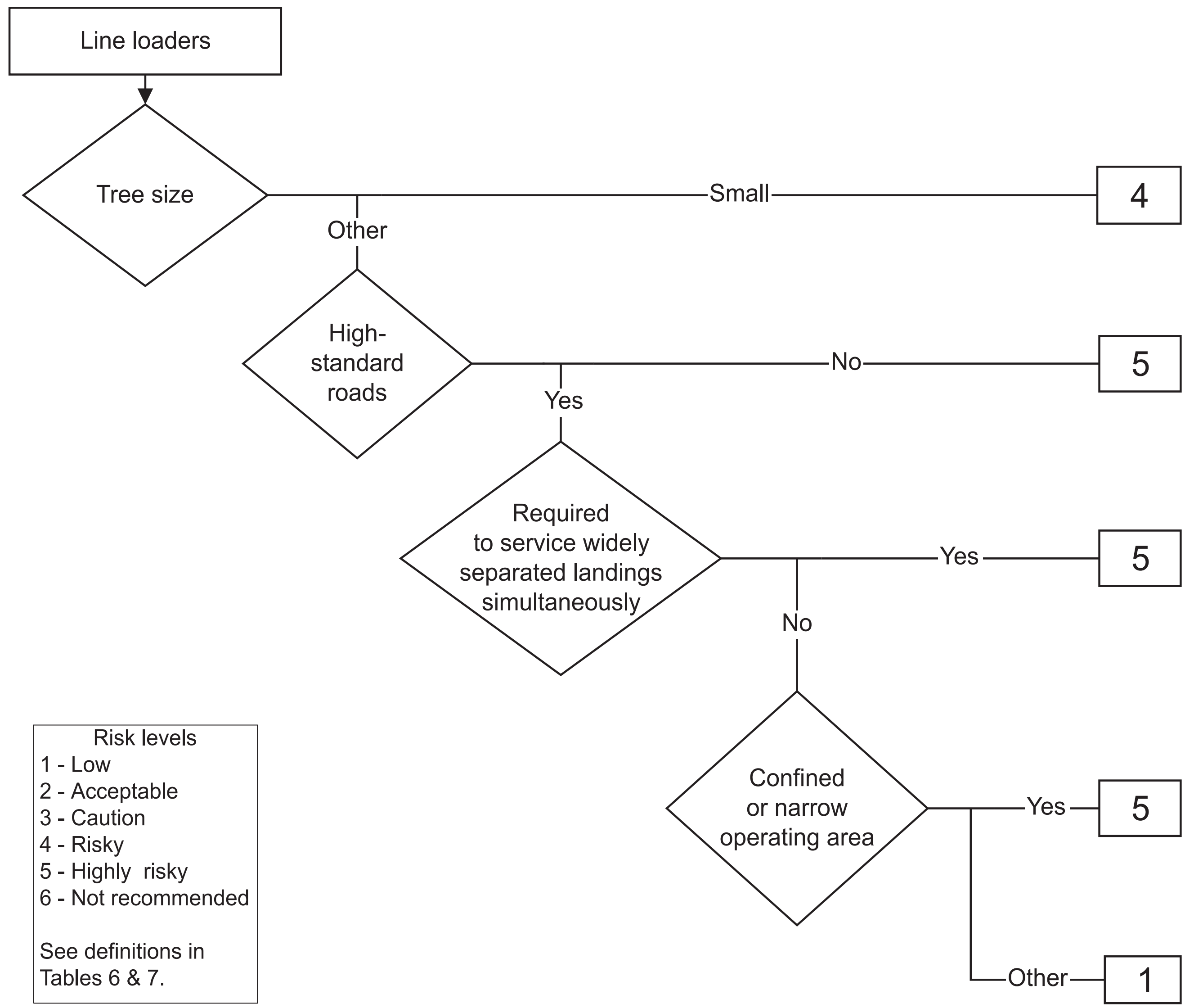

Chart 26. Line loaders.

- Line loaders can be moved relatively easily between loading sites up to several hundred metres apart, and are often used to service two towers simultaneously. Landings further apart pose difficulty for simultaneous operation because of low travel speeds, especially for track-mounted loaders. Low-bed transportation over longer distances is required. Rubber-mounted loaders can travel farther under their own power, but travel remains slow.

EXAMPLES

These examples demonstrate how information can be obtained from the handbook to help match equipment to the site. The examples have been based on hypothetical scenarios that could be encountered by industrial or agency planners.

These examples illustrate that the handbook's purpose is to identify issues and concerns, and to evaluate the risks associated with combinations of site conditions and equipment. The handbook is not meant to provide the single "correct" answer about what equipment is suited to any particular site.

Example 1: Change Harvest Season

A cutblock has been planned and approved for winter harvesting, but corporate log-flow requirements have made it important to advance the harvesting schedule, perhaps to late summer or early fall. What are the important issues that must be addressed with harvesting the cutblock earlier in the season? Will the same equipment be suitable? If not, what different equipment or operating techniques will achieve acceptable results?

The cutblock is proposed for clearcut harvesting, using typical roadside equipment comprising a feller-buncher, grapple skidders, stroke delimbers, and butt 'n top loader. The timber is small-diameter pine on rolling terrain, and the roads were laid out for a maximum of 250 m skidding. The maximum sideslope is about 30% and the soils are fine-textured. The proposed plan specifies harvesting under dry or frozen conditions.

Scan the column labelled "wheeled skidder - grapple" in Table 2 to determine what impacts could result from the proposed change to the harvesting schedule. Wheeled skidders require high soil strength, and have low to moderate ability to avoid ground disturbance, especially when the soil moisture content is high.

Figure 1
Rubber-tired skidders may be a high-risk option for non-frozen conditions unless weather conditions are favourable.

Chart 1 confirms this — operating on fine-textured soils under wet conditions is rated at risk level 6 (Table 6). Clearly, soil disturbance will be a significant concern.

The requirements and limitations of the skidding equipment will not be changed under a different harvesting schedule, so the planner must evaluate the risk of operating under non-frozen conditions. What is the likelihood of experiencing a period of sustained dry weather when the skidders may be able to operate successfully? If the likelihood of dry weather is low, resulting in a high risk of soil disturbance, then changes to the operating techniques or equipment will be required. Information listed in the Index under "soil disturbance - compaction - skidder" and "soil disturbance - rutting" describe wide tires and devices to fit over the skidder tires to reduce their ground pressure. These devices could reduce the risk of causing soil disturbance.

However, the rubber-tired skidder remains a high-risk option even with tracks or wide tires, so alternative equipment should be considered. Clambunks, forwarders, loader-forwarders, small-scale equipment, and horse logging are the ground-based options with greater ability to avoid ground disturbance (Table 2). The latter two options are high risk for this scenario because of their low productivity. Although the forwarder is less susceptible to high soil moisture, it could be high risk because it requires specialized trucks and mill configuration (Chart 5) that may not be available. Specialized falling and loading equipment will also be required. Clambunks (Index: clambunk) may be better suited to the soil conditions than the skidders. Loader-forwarding could be an option, but the small timber size and long skidding distances increase the risk. Flex-track skidders are also rated in Table 2 with a low–moderate ability to avoid ground disturbance, but their risk on moist, fine-textured soils is rated slightly lower than skidders (Chart 3). They may be worth considering.

Cable equipment may provide an alternative more suited to reducing soil disturbance, but higher operating costs will increase the risk. Furthermore, the yarder must be suitable for roadside operations to fit with the processing and loading equipment, eliminating highlead yarders from consideration. The small tree size eliminates large equipment, although bunching could help to reduce the risk. Adequate deflection and clearance will be critical to avoid soil disturbance (Chart 14). Rolling terrain with maximum 30% sideslopes over yarding distances of 250 m will make it difficult to achieve adequate clearance with a short yarder. Multi-span skylines could be considered.

The only alternatives to the wheeled skidder that seem viable are the clambunk skidder and the flex-track skidder. The forwarder may be viable if the corporate infrastructure supports shortwood logging.

Clearly, any equipment changes required in this scenario will be short term, and therefore must be confined to equipment that is readily available for hire. Most of the alternative equipment is capital-intensive (Table 1), and is likely to be gainfully employed and unavailable for a short-term rental. Furthermore, all the alternatives are more expensive than the original proposal — the planner must evaluate the benefit of the altered harvesting schedule with the added costs.

Example 2: Review Development Plan

As a Small Business forester for the British Columbia Ministry of Forests, you are responsible for preparing forest development plans for the Small Business Forest Enterprise Program. An area of your development plan includes a coastal cutblock where the layout contractor has proposed skyline yarding over a creek. You are unfamiliar with skyline systems, and want to ensure that the proposed harvesting will achieve all the operational and environmental objectives. What are the issues that should be addressed in your review? What alternatives should be considered?

The cutblock is located in an incised valley with sideslopes averaging about 70%, although the sideslope reaches about 100% at the higher elevations. A road was constructed about 15 years ago to harvest the timber on one side of the creek using a grapple yarder. The cutblock was reforested after harvesting, and now supports a stand of trees about 5–7 m tall. The timber on the far side of the valley was not harvested because of difficult terrain. It has numerous rock bluffs dispersed throughout the standing timber, which would result in extremely expensive road construction. A narrow band of trees left adjacent to the creek after the original harvesting has not sustained any significant amount of windthrow. A similar buffer strip is proposed for the far side of the creek. Two landings are proposed on the existing road for skyline yarding, and the maximum distance from the landings to the cutblock boundary is about 700 m.

Figure 2
Large skyline towers can suspend logs over streams providing the conditions are suitable

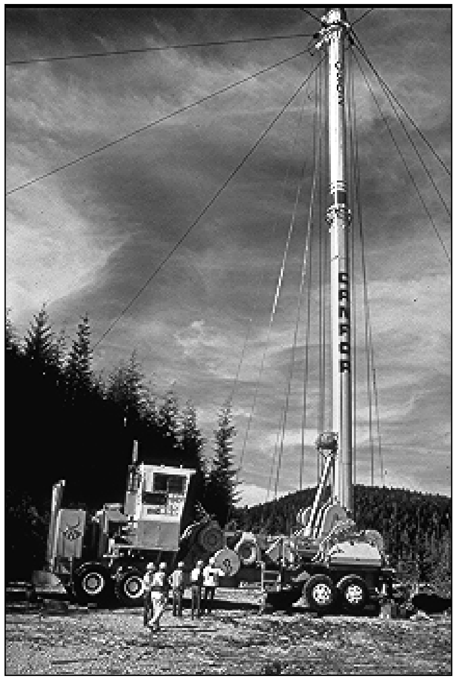

Table 2 indicates that the proposed large, single-span skyline will adequately address any concerns about soil disturbance, but the cross-stream yarding concerns you with the possibility of introducing debris into the stream. Will the skyline be able to lift the logs clear of the buffer strip? Chart 15 indicates that deflection is a primary consideration for large skylines, and the Index points to several areas with information about deflection. Clearly, both deflection and clearance are important, so you make a note to ask the layout contractor for representative deflection lines. You will ask about the amount of deflection, and the amount of clearance below the carriage. You also note to ask whether the trees will be yarded full-length, or will they be bucked beforehand? This will affect the required amount of clearance over the standing trees. You learned from the information under “hand-falling” and “hand-bucking” that on-site bucking is difficult and dangerous in such steep terrain. If clearance is inadequate, you will ask what plans have been made for corridors through the standing timber.

You also notice from Chart 15 that the landing chance and anchors are critical for successful skyline operations, so you will ask about the landings (Index: landing - yarding). The original harvesting was done by grapple yarders, which do not require landings, but the skyline yarders will need landings. Will the landings encroach on the plantation, and will they have adequate space to accommodate the yarding debris? What anchors are available at the landing to hold the tower (Index: anchor - guyline), and what anchors will be required at the tailholds? Will the anchors be located at the cutblock boundary, or will they be extended above the cutblock boundary to increase deflection (Index: anchor – backspar)?

You make another note to ask the layout contractor whether alternatives to cross-stream yarding have been considered. Clearly, ground-based systems are impractical because of the steep and difficult terrain (Table 2), but you want to ensure that all the options have been considered. Alternative yarding systems would involve building a road on the other side of the creek, so you make a note to ask whether a road survey was conducted on the far side, and if so, why it was not chosen for construction. You know from Chart 10 that highlead systems are more tolerant of poor landings than large skylines, so you will ask about potential landings on the alternative road location. You also know from the Index information on “yarding - slope - downhill” that safety in the landing is a major concern.

You also consider helicopter logging. You know from Table 1 and Table 2 that helicopter extraction is more expensive than skylines, but you want to ensure that all alternatives have been explored. You know from the descriptions of helicopters (Index: helicopter) that the helicopter must be matched in size to the timber resource and that bucking the trees by weight rather than by length is important. Bucking on the steep, broken ground may be difficult. Also, landing size and safety in the landing are major concerns — you note to ask whether helicopter logging was considered, and if so, what landing location would be used.

Armed with your new knowledge about skylines, you feel more confident that you can ask pertinent questions about the proposed system, and any alternatives that were considered.

Example 3: Encounter New Operating Conditions

XYZ Forest Products had been operating in consistent timber and terrain types for more than 10 years, but is now faced with new conditions as it moves into a different area. Previously, the average cutblock had been laid out for clearcut logging with roadside processing, but the planners for XYZ realize this system is unsuitable for the new operating area. The slopes are steeper, and visual-quality objectives make large clearcuts unacceptable. Partial cutting will be required. The timber size is about the same, although the soils are generally of finer texture.

XYZ has four contractors, each producing about 120 000 m^3/yr in roadside operations for a total of 480 000 m^3/yr. The total cut for the operating division will be reduced to about 450 000 m^3/yr, with the new area comprising about 50 000 m^3/yr. One option among several being considered is to retain three contractors at their current levels, and to reduce one of the contractors to 90 000 m^3/yr, working in a combination of the new and existing operating areas.

The company, and its contractors, must determine whether the equipment that was used previously will be acceptable for the new operating area.

Three of the contractors have very similar equipment: two feller-bunchers, two grapple skidders, two stroke delimbers, and one butt 'n top loader. Each of the contractors has at least one levelling-cab feller-buncher, and all of the feller-bunchers are equipped with high-speed disc saws. The fourth contractor has different equipment: two feller-bunchers, but neither have levelling cabs, one grapple skidder that is used as required, one clambunk skidder, two dangle-head processors, and a butt 'n top loader.

What is the best equipment allocation for the new area?

The new operating conditions have five critical differences: steeper terrain, finer-textured soils, partial cutting, less operating volume, and the requirement for flexibility between the new and old operating conditions. Taking these in order, Table 2 indicates that wheeled skidders are best suited to slopes less than 35%. Depending on the amount of area over 35% or over 50%, the wheeled skidders may be marginally suited or completely unsuited to the new conditions (Chart 1). Furthermore, the requirement for partial cutting makes grapple-based equipment poorly suited because of its limited reach (Index: skidder - grapple). Will the clambunk skidder be any better suited? Table 2 indicates that clambunks can work on steeper terrain and require less soil strength, but there are three major factors that make clambunks poorly suited to this situation: they are grapple-based, they are

Figure 3
Clambunk skidders may be able to work on the steeper slopes of the new operating area.

large, and difficult to maneuver within a partial cut (Index: clambunk - partial cutting), and they require a large operating volume to make them cost-effective (Index: clambunk).

It appears that the present equipment fleet is not well suited to the new conditions. What features should the company and contractor be looking for in replacement equipment?

The steep terrain, fine-textured soils, partial cutting, and low operating volume will all be critical factors in the specification. Wheeled-based equipment may be unsuited, depending on the steepness of the terrain, even if operations could be confined to frozen or deep snowpack conditions to address the soil disturbance concerns. Track-based equipment would have better stability for improved safety. For grapple-equipped machines to work effectively, especially in partial cutting, they must be matched with suitable felling equipment (Index: skidder - grapple), which means that a zero-clearance feller-buncher with a levelling cab will likely be required (Index: feller-buncher – partial cutting). Without the appropriate falling equipment, line skidders will be required (Table 2).

Forwarders may be an option, depending on the terrain steepness, but the mill and trucking fleet must be configured to accept the different log specifications. Different felling equipment would also be required to manufacture the short logs.

Cable equipment should also be considered, but only carriage-based yarders because of the partial cutting (Table 2). With the projected volume (50 000 m^3/yr), and typical daily production rates, year-round operations will be required. Costs may be prohibitive with the small trees unless feller-bunchers can be used. As before, a levelling cab will be required, but the soils must be examined carefully to ascertain if a feller-buncher can be used during the summer. Depending on the typical ground profiles and deflection, multi-span capabilities may be necessary (Chart 13, Chart 14, Index: deflection).

Processing and loading equipment must also be considered. The traditional operating area used roadside processing, but the new area will likely use landings because of the steeper terrain. The butt ’n top loaders will not be suited, although the processors can be used in roadside or landing configurations.

Lastly, the company and contractor must consider the overall effect of annual production levels. Under the scenario as presented, one contractor would be downsized to 90 000 m^3 – 50 000 m^3 from the new area and 40 000 m^3 from the traditional operating areas. The previous equipment fleet was based on high-volume roadside logging, and will no longer be cost-effective. What equipment will be used on that area? The overall scenario seems unworkable, and should be reconsidered. The new operating area requires different types of equipment, but changes cannot be made without considering the impacts on the traditional operating areas.

As stated before, the purpose of this handbook is not to identify the single “correct” answer, but to identify issues that must be considered and how the characteristics of the various types of equipment address those issues. The preceding examples illustrate how to use the information in the handbook to improve equipment selection.