FERIC FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

Timber Development Planning for the British Columbia Interior: The Total-Chance Concept

R.E. BREADON

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FOREWORD

I am grateful that FERIC has prepared this handbook on timber development planning. It effectively addresses one of the key elements in the Ministry of Forests hierarchy of planning systems, resource development planning.

Many ways are available to create an acceptable plan, and all should be used to full advantage to meet the varying circumstances in British Columbia. This handbook outlines an acceptable way of dealing with the most critical areas of development planning. Substantial improvements in forest resource management will result from the application of the procedures and techniques outlined.

By arrangement with FERIC the contents of this handbook have been included in the Ministry of Forests Planning Manual as a general guide for forest development planning on Crown forest lands.

W. Young, R.P.F.
Chief Forester, Ministry of Forests
British Columbia

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INTRODUCTION

Forest operations require plans, schedules and budgets for many different purposes. The land area or time-frame for planning may be broad or narrow.

In British Columbia, most forest lands are under Ministry of Forests (MOF) jurisdiction, and the MOF has documented its planning activities and requirements. Figure 1 and Table 1 are excerpts from the MOF Planning Handbook (MOF, 1983) outlining the five-part MOF planning framework, which starts at the Provincial level and progresses through the Resource Development level. Short-term operational planning is not included in the MOF Planning Manual but has been described by Murray, *et al*. (1976, Handbook for Ground Skidding and Road Building in B.C.) and others.

Holders of major Crown timber rights must prepare Resource Development plans under MOF authorization and according to coordinated resource management guidelines set at the local level. The development area may be a single mountain drainage or an arbitrarily-defined area in rolling terrain. Typically it will require several years to develop, harvest and restock, and will contain a mixture of easy and difficult operating chances.

A development area requires "Total-chance" rather than piece-meal planning. The "Total-chance" concept is the name given to early planning over an entire development area for the best overall realization of all objectives identified by broader planning. As one Interior forest company states, "all of the timber in a given drainage must be assessed for development before dividing it into smaller logging units related to logging or road-building systems". The MOF encourages total-chance planning by licensees as the best way to avoid "short-term gain and long-term pain".

The objectives common to all timber development plans are:

- collection of the best possible information as a planning base;
- choice of the best combination of available systems for cheapest overall road development, harvesting and restoration;
- balanced recognition of the timber, non-timber, environmental and social benefits expected.

Planning Levels

There are five hierarchical decision-making levels. These levels provide a context for setting objectives. Plans for specific geographic areas are developed at only three of these levels.

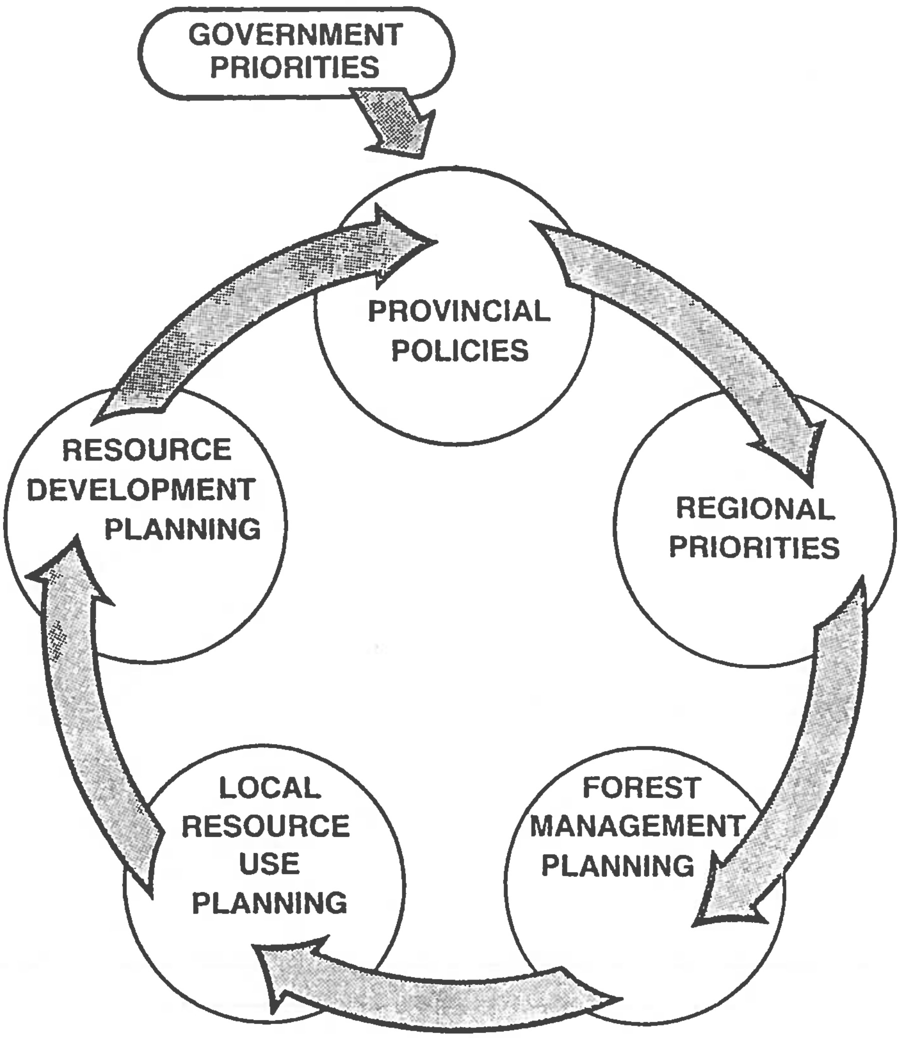


FIGURE 1. THE MINISTRY OF FORESTS PLANNING LEVELS. SOURCE: MOF PLANNING HANDBOOK (1983).

Provincial Policies	Within the context of government priorities, provincial policies give overall direction to the Ministry of Forests. The ministry's Executive formulates ministry policy and sets forest and range resource use goals.
Regional Priorities	Within the context of provincial policies, Regional priorities coordinate ministry activities with those of other ministries and set tentative production targets for timber, range and recreation for the TSAs and TFLs within Regions.
Forest Management Planning	Within the context of Regional priorities, forest management planning lays out broad, long-range management strategies for timber, range and recreation for each TSA and TFL. Program options are examined and, for timber, AACs are set and 20-year supply areas are identified.
Local Resource Use Planning	Within the context of management strategies for a TSA or TFL, local resource use planning establishes integrated resource management guidelines for areas where resource use development is proposed. Local planning can range from extensive appraisal to intensive study and is carried out to enable development planning to proceed.
Resource Development Planning	Within the context of area-specific management guidelines, resource development planning details the logistics for development. Methods, schedules and responsibilities for accessing, harvesting, renewing and protecting the resource are specified to enable site-specific operations to proceed.

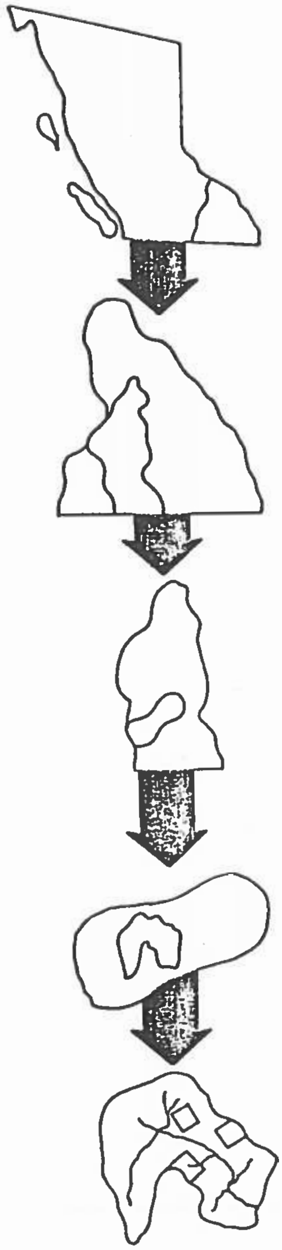


TABLE 1. MINISTRY OF FORESTS PLANNING FRAMEWORK.
SOURCE: MOF PLANNING HANDBOOK (1983).

To help the forest planner meet these objectives, this handbook will:

1. Describe the kinds of information needed for planning a development area;
2. Describe the road construction and harvesting system choices available and their capabilities;
3. Work through an illustrative example of the development area planning process.

Development planners need skill, experience, imagination and flexibility. They must visualize the step-by-step transformation of an undeveloped area into a developed one. They must convince others that the final plan takes all concerns into account on the basis of available information. They must also recognize that plans are usually revised as development proceeds. Obviously, a handbook cannot do the planner's work, but we hope this one will help those getting started by providing a structure, defining the problems faced, and outlining logical steps to overcome them.

To avoid too lengthy a handbook, we have omitted detailed discussion of the mechanics of cruising, surveying, mapping and other basic skills needed in planning. We assume the planner already knows about these.

While this handbook's context is Interior British Columbia, its principles would appear applicable to coastal B.C. or elsewhere in Canada and in other countries.

PART I - PREPARATION FOR PLANNING

A. WHICH PLANNING LEVEL?

Planning at each level in the planning framework affects planning at the level above and below. The first level which has a fixed, self-contained area controlled by a single licensee and is concerned with single-use development is Resource Development Planning. This is the key planning level for the logging company, and the level we will explore. The area and time-frame are comprehensive enough to apply the total-chance concept. The planning information from individual development areas will move upwards to strengthen higher-level licensee and Ministry plans and downwards to provide direction for short-term logging and forestry plans.

B. PLANNING INFORMATION NEEDED

The planner's first step is to collect all existing pertinent information and to supplement this information where necessary.

1. Boundaries

Ideally the development area should be self-contained and delineated by heights of land or firm administrative boundaries. The extent of the area and the need for a development plan must be documented by higher-level plans or by Ministry letter. Confirmation is required before planning starts, to avoid too much or too little mapping, cruising or location work.

2. Reference Information and Contacts

Timber, range and forest recreation objectives are stated in the TFL management and working plan or the TSA plan. More detailed integrated resource management guidelines are specified by local planning which precedes development planning. If further elaboration or clarification is required, the planner should contact the MOF Regional Manager or District Manager.

Information is also available from other government sources. For example, geological maps will show parent rock or glaciation detail from which differing soil types can be inferred. Biogeoclimatic zone maps will help predict climatic conditions, operating seasons and silvicultural requirements. Legal survey maps will show mining, water, grazing or other claims already on the area. Information on fish, wildlife, or watershed requirements should be sought from the appropriate government sources at an early planning stage. Sources of this information include:

Ministry of Forests: Inventory, Research and Planning Branches, Victoria

Ministry of Environment: Surveys and Mapping Branch, Victoria
Terrestrial Studies Branch, Victoria
Fish and Wildlife Branch, Victoria

Fisheries and Oceans (Government of Canada) Vancouver

Information-gathering can be used as an opportunity to make initial contacts regarding company plans for the area. Normally the company will already have working relationships with many of the agencies concerned.

Early, informal contacts will prevent surprises and will pave the way for more specific discussions later.

3. Initial Reconnaissance

Some time before detailed planning starts, key company people and the District Manager or his representative should jointly reconnoitre the whole drainage to get first-hand impressions of road building and logging chance, timber quality and potential problem areas. A helicopter flight, preplanned to visit selected key points and also to provide overall viewing, is an efficient way to cover undeveloped areas. This step will help determine where the main planning time and effort should be concentrated.

4. Pre-planning Maps

MOF forest cover maps, available at scales of 1:15 840 or 1:20 000, will show generalized timber types and planimetric detail plotted from aerial photos. The newer forest cover maps will also show ESA (environmentally sensitive area) categories. Some of these will seriously affect logging or road construction planning if confirmed during field-checking. If the area is simple, of low relief and likely to be harvested by only one system, the forest cover maps may be an adequate base for planning. This is no longer the normal case, however. Usually the company will decide to obtain newer and more precise mapping specifically for the development area. Existing forest cover maps and inventory summaries will still be useful in fixing the area boundaries and in initial work before the new maps are available.

5. Aerial Photos, Topographic Base Maps and Timber Type Maps

High-quality maps for development planning will depend on a complex sequence including ground control, aerial photography, high-order plotting and ground surveys. All or part of the sequence can be done by specialist survey firms, but most companies prefer that their own personnel do as much photo interpretation and field work as possible to become familiar with the area.

Aerial Photos

Recent government vertical photographs of acceptable quality often exist already. In some cases, however, the company will elect new photography. In discussion with the survey firm, the planner must specify the camera, film, flying height, scale, flight-line orientation, degree of overlap, season and flying hours acceptable for the job. Shadow-free photos can normally be taken in one or two clear days between May and September.

Topographic Base Maps

Development planning will require a mapping scale large enough for initial plotting, addition of new detail, alterations and accurate area measurements. Scales ranging from 1:5 000 to 1:20 000 may be used but the most common scale is 1:10 000. Planimetric detail is plotted from the photos using high-order photogrammetric plotters.

If slopes exceed 30% or are irregular, there is no substitute for good quality contour mapping. Its cost is easily offset by the avoidance of planning mistakes. Ten-metre contours are preferred, and can be mapped along with the planimetric detail as each photo-pair is set up in a suitable plotter. The additional cost of contours plotted in this way is about 30% more than for planimetric detail alone.

Timber Type Maps

Mature timber, immature and other cover are interpreted on the photos, plotted, and confirmed or altered by cruising. The type classification system should be mutually agreed upon by the company and the MOF. Cruisers, normally from the company, locate strips and samples in the field to provide type averages for volume, species distribution and tree sizes. Type areas are determined from the maps later.

Erosion Hazard Mapping

Where soil erosion is considered a potential threat during the initial reconnaissance, the planner will require systematic mapping of soil types. This information allows confident planning on areas of low erosion hazard and provides forewarning on areas of high hazard. Relocation, scheduling to catch dry or frozen conditions, or special operating precautions can then be planned for the critical areas. The common variables (ground-sampled or inferred from photos) are ground slope, soil depth, soil texture and moisture conditions. As an example of several procedures used in the Interior, Krag (1979) outlines a practical sampling system based on these variables. Briefly summarized, it consists of five Erosion Hazard Classes ranging from "very low" (class 1) to "very high" (class 5) as outlined in Table 2.

TABLE 2. EROSION HAZARD CLASSES.

SOIL TEXTURE →		COARSE (GRAVEL, SAND, GLACIAL TILL)			FINE (SILTS, CLAYS)		
MOISTURE REGIME →		DRY	MOIST	WET	DRY	MOIST	WET
SOIL DEPTH	SLOPE (%)	EROSION HAZARD CLASS					
GREATER THAN 1 m	0- 35	1	1	1	1	2	3
	36- 50	1	2	3	2	3	4
	51- 70	2	3	4	3	4	5
	71-100	4	4	5	4	4	5
	100+	5	5	5	5	5	5
LESS THAN 1 m	0- 35	1	2	2	2	3	4
	36- 50	1	3	3	3	4	5
	51- 70	3	4	4	4	5	5
	71-100	4	5	5	5	5	5
	100+	5	5	5	5	5	5

Krag also suggests operating methods and limitations for road construction and logging for each hazard class. Similar and more localized hazard classification systems have been developed by others (Comeau et al., 1982; Hammond, 1982). Some of these also include ground vegetation as hazard indicators.

Overall hazard sampling should be done during development cruising. Areas of apparent high hazard can then be examined by specialists for confirmation, more accurate mapping in relation to proposed road corridors, and specific operating recommendations.

6. Company Road and Logging Requirements

The company will require a flow of log sizes and species from the development area, lasting for a specified period. This flow of logs must complement flows from other sources as detailed in TFL or TSA plans. The cruise information now available must be reconciled with these requirements to plan the cutting program and the mix of stands to be cut each year. Roads of the correct standards and in the best locations must then be planned to reach the cutting areas with ample lead time. An example of the matching of higher-level planning constraints, company requirements and resource data will be given later (Part II).

7. Forestry Requirements

The development plan must reflect the company's commitments under higher-level plans to restore harvested areas to productivity. For example, silvicultural requirements will affect the size and shape of openings, the degree of mineral soil exposure wanted, the seasonal distribution of logging, or the scheduling of salvage operations in insect-infested or fire-killed stands. The major requirements on the development area should be identified early in planning. Part II describes some of the decisions which might be made in a specific case.

8. Planning Schedule

The company will normally set a start-up date for operations in the development area. Planning and approvals must be completed before that date. Obviously, a firm schedule is needed at the outset for all the phases of planning. Since we have not yet described all these phases, we will discuss this subject later, but we emphasize that this "plan for the planning itself" should be drawn up at the beginning of the information-gathering stage.

C. HARVESTING SYSTEMS

With the basic information assembled, the planner can now see the range of timber, terrain and other conditions on the whole development area. He can start to examine harvesting systems to match these conditions.

By the time any portion of the area has been logged, most of the following work phases will have occurred:

Construction

- roads and landings located and marked;
- right-of-way felled and logged;
- subgrade and landings built;
- bridges, culverts and ditches installed;
- subgrade surfaced;
- skid trails built (ground skidding).

Logging

- cut block boundaries located and marked;
- trees felled;
- trees or logs skidded or yarded;
- trees delimbed, logs bucked;
- logs loaded;
- logs hauled;
- logs unloaded;
- logs scaled;
- area cleaned up, stabilized and restocked.

Each phase requires a method, usually named after the equipment used. A group of closely-related phases calls for a group of complementary methods, making up a system (eg. Feller-Buncher/Grapple Skidder/Flail Delimber).

The planner knows he must choose systems which will accomplish all phases effectively and with the least environmental damage. He also knows that there are real upper limits to aggregate harvesting and restocking costs. High costs on one part of the area must be offset by low costs on another part, so that aggregate costs will fall within these limits. Conversely, low harvesting costs must not be offset by high restocking costs later.

This section will outline the common Interior construction and logging methods, with enough information about each to assist in preliminary choices. After the choices are narrowed down, contacts with suppliers and users will be needed for more details. One of the main benefits of advance planning is the amount of lead time for review of initial decisions before final decisions must be made.

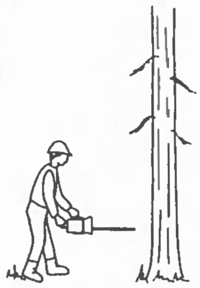
The basic Interior construction and logging methods are listed below by work phase. Operating factors limiting their use are indicated under:

Gr. = Ground conditions, slopes, firmness, snow
Tbr. = Timber factors, chiefly tree size
Eqpt. = Equipment used
Crew = Crew size and functions
Typ. Prod. = Typical per-shift production rates (recognizing that rates vary widely for differing conditions) and factors affecting production
Rem. = Qualifying remarks.

CONSTRUCTION METHODS

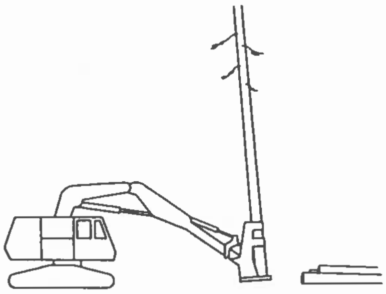
1. RIGHT-OF-WAY LOGGING

1.1 Manual Felling



Gr. - No practical soil, slope or seasonal limits.
Tbr. - No practical size limits.
Eqpt. - Chainsaw.
Crew - 1-2 Fallers.
Typ. Prod. - 50-100 m^3/faller or 40-80 m of R/W (20 m wide). Affected by walking distance, ground, weather, tree size, stand density, brush, snow depth.
Rem. - Fallers can buck and limb logs but not bunch. Best for rough ground or large timber. Safety hazards. Requires skilled crews.

1.2 Feller-Buncher



Gr. - Side slopes to 30%, firm ground.
Tbr. - To 60 cm.
Eqpt. - Tracked feller-buncher with dozer tote road prebuilt on steeper slopes.
Crew - 1 operator.
Typ. Prod. - 250-400 m^3 or 450-650 m of R/W (20 m wide). Affected by ground obstructions & timber.
Rem. - Can bunch but not buck or limb. Safe.

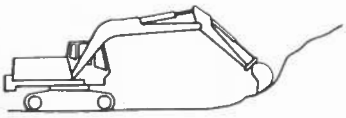
1.3 Right-Of-Way Skidding (see methods 7.1 to 7.5 described later under "Skidding or Yarding").

2. SUBGRADING (grub stumps, burn or bury debris, strip, rip or blast, grade, build landings)

2.1 Dozer

Gr. - Side slopes to 70%. Rough but not too soft.
Tbr. - Tree size may govern dozer choice.
Eqpt. - Tracked dozer, blade, winch, (ripper attachment).
Crew - 1 operator.
Typ. Prod. - 25-150 m. Affected by road width, earth volume, rock.
Rem. - Versatile. Can skid logs. Limited reach from grade. Often teamed with excavator or rock drill. Can rip soft rock.

2.2 Excavator



Gr. - Side slopes to 70%. Better than dozer on soft ground.
Tbr. - Can deck but not skid.
Eqpt. - Tracked excavator, bucket (ripper tooth). May team with dozer, rock drill.
Crew - 1 operator.
Typ. Prod. - 25-150 m. Affected by road width, earth volume, rock.
Rem. - Less off-grade mobility than dozer but better off-grade reach, placement of material and ditching. Attachments can split stumps or break rock.

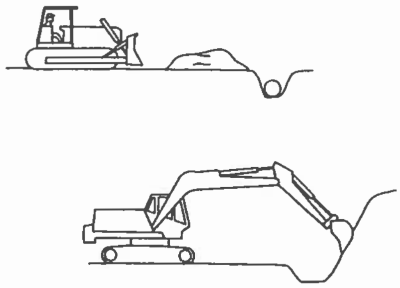
2.3 Rock Drill

Gr. - Side Slopes to 100%+, with dozer-built tote road.
Tbr. - N/A
Eqpt. - Track-mounted drill rig with steel, bits, explosives.
Crew - Operator and helper.
Typ. Prod. - 10-60 m grade through rock. Affected by rock volume, interactions with subgrade machines at face.
Rem. - Only choice in hard rock. Needs dozer or excavator support.

2.4 Scraper

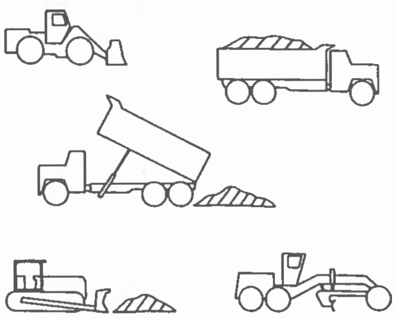
Gr. - Side slopes to 30%. Deep, firm soil.
Tbr. - N/A.
Eqpt. - Wheeled scraper teamed with dozers.
Crew - 1 operator.
Typ. Prod. - Site specific.
Rem. - Used on main roads to speed up high volume, long distance earthmoving.

3. CULVERTS, DITCHES, BRIDGE SITES



Eqpt. - Same dozer or excavator as for subgrading.
Typ. Prod. - Site specific.
Rem. - Ditches and small culverts are part of subgrading. For bridges see Nagy (1980) Log Bridge Handbook.

4. BALLASTING AND SURFACING

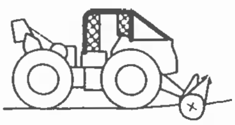


Eqpt. - Front-end loader or excavator, gravel trucks, spreader dozer, compactor, road grader.
Typ. Prod. - 30-100 m subgrade. Affected by number of trucks, haul speed and distance, ballast depth and width.
Rem. - High cost limits surfacing to major roads or soft subgrades. Trucks may be standard for long-distance travel or all-wheel-drive for short, severe hauls.

5. SKID-TRAIL CONSTRUCTION

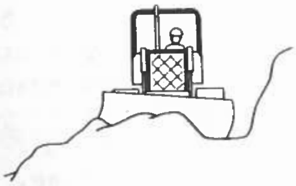
(For ground skidding in deep snow or on steeper slopes. Random skidding preferred on level or soft ground in summer or light snow.)

5.1 Wheeled Skidder



Gr. - Max. 30% slopes, smooth.
Tbr. - Small, easily bladed aside.
Eqpt. - Wheeled skidder, combined use for trail-building and skidding.
Crew - 1 operator.
Typ. Prod. - Incidental to skidding.
Rem. - Light work only, minor soil cuts.

5.2 Dozer

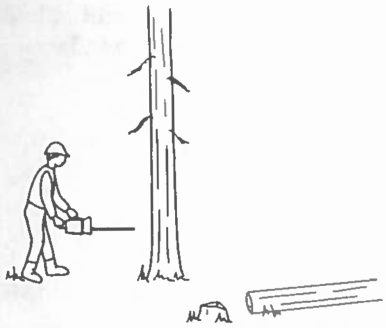


Gr. - Side slopes to 50%.
Tbr. - Tree size determines dozer size.
Eqpt. - Med. or small dozer or low ground pressure tracked vehicle with blade, winch.
Crew - 1 operator.
Rem. - Used on steeper ground. In winter can minimize soil cuts by compacting snow on outer trail edge. Size of dozer governs trail width and depth of cuts.

LOGGING METHODS

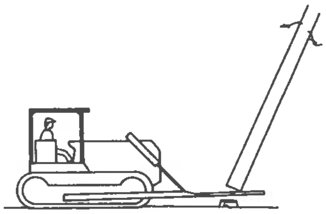
6. STAND FELLING

6.1 Manual Fallers



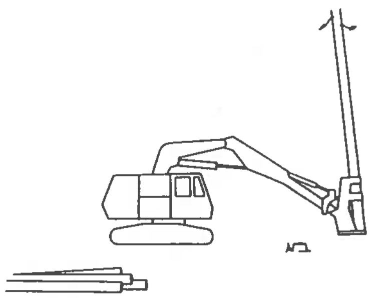
Gr. - Not limiting.
Tbr. - No size limits.
Eqpt. - Chainsaw.
Crew - 1-3 fallers.
Typ. Prod. - 50-100 m^3 per faller. Affected by walk-in distance, ground, weather, tree size, tree lean, stand density, brush, log-bucking, snow depth.
Rem. - Fallers can buck and partially delimb at stump but cannot bunch. Best for rough ground or large timber. Safety hazards.

6.2 Mechanized, Fell Only



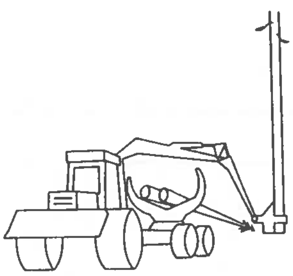
Gr. - Slopes to 40%.
Tbr. - To 50 cm; some machines to 90 cm.
Eqpt. - Crawler or excavator with hydraulic shear or chainsaw head.
Crew - 1 operator (protected cab).
Typ. Prod. - 150-300 m^3. Affected by machine, tree size and spacing, ground.
Rem. - Can direct trees but not bunch. Safer than manual felling. Non-shear heads preferred in winter to avoid butt damage.

6.3 Mechanized, Fell and Bunch



Gr. - Slopes to 30%.
Tbr. - To 50 cm.
Eqpt. - Tracked excavator with shear, chainsaw, auger or circular saw head.
Crew - 1 operator (protected cab).
Typ. Prod. - 250-400 m^3. Affected by machine, stand density, ground, snow.
Rem. - Safe, can bunch turns for grapple skidder. McMorland (1982) describes non-shear feller-bunchers in B.C.

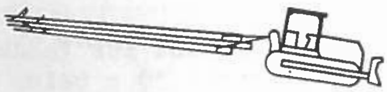
6.4 Combined Fell and Skid



Gr. - Slopes to 25%, downhill to road.
Tbr. - To 50 cm.
Eqpt. - Harvester, clam bunk skidder with grappling chainsaw on boom or feller forwarder.
Crew - 1 operator.
Typ. Prod. - Expect 150-300 m^3 cut and skidded. Affected by slope, traction, travel distance.
Rem. - See McMorland (1982). Feller-forwarders are common in Eastern Canada, not in West to date.

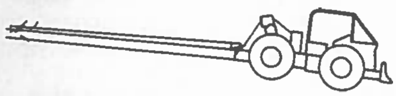
7. SKIDDING OR YARDING

7.1 Medium Crawler



Gr. - Side slopes to 60%. Skid slopes to 40% downhill, 15% uphill.
Tbr. - Chokers - large or medium. Grapple - small, pre-bunched.
Eqpt. - Dozer with choker winch or grapple.
Crew - 1 operator.
Typ. Prod. - 80-120 m^3. Affected by tree size, terrain, skid distance.
Rem. - Reach:* 50 m below road, 250 m above. Can build trail for self and skidders.

7.2 Choker Skidder



Gr. - Side slopes to 40%. Skid slopes to 30% downhill, 10% uphill.
Tbr. - Large or small (unbunched).
Eqpt. - Wheeled skidder, winch, chokers.
Crew - 1 operator (sets and releases chokers).
Typ. Prod. - 80-120 m^3. Affected by timber size, traction, skid distance.
Rem. - Basic ground-skidding machine behind manual fallers. Reach: 50 m below road, 300 m above. Good on broken ground, medium timber size. Can do light trail building, deck and blade-delimb trees. FERIC and others are testing "wide" skidder tires for better traction and reduced site disturbance.

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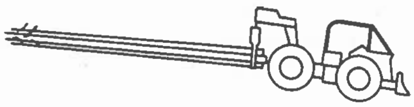
*Skidding or yarding "reach" is defined as the maximum horizontal (map) distance between the roadside landing and the cut boundary. Given distances are typical but may vary widely in practice.

7.3 Grapple Skidder



Gr. - Works behind feller-buncher, same limits as 7.2.
Tbr. - Small, pre-bunched.
Eqpt. - Wheeled skidder with grapple.
Crew - 1 operator.
Typ. Prod. - 120-200 m^3 with good bunching, traction and short skids.
Rem. - Ideal complement for feller-buncher. Reach: 30 m below road, 50 m above. Less uphill capability than choker skidder: cannot winch logs from position on firm ground.

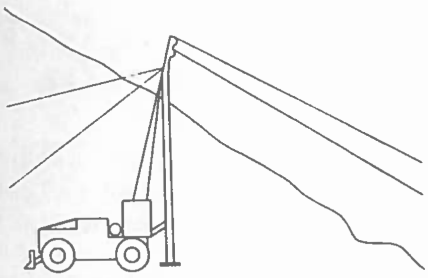
7.4 Low Ground Pressure (L.G.P.) Tracked Skidder

Gr. - Side slopes to 60%. Skid slopes to 50% downhill, 20% uphill. Soft ground or snow.
Tbr. - Chokers - large or medium. Bunk Grapple - small, pre-bunched.
Eqpt. - Soft-tracked skidder with chokers or bunk grapple.
Crew - 1 operator.
Typ. Prod. - 60-180 m^3, long and short skids.
Rem. - May skid alone or team with other skidder types. Good for steep, soft or long-distance skids. Reach: 50 m below road, 400 m above. High skidding or forwarding costs may be offset by reduced road and landing costs and less disturbance.

7.5 Small Crawler

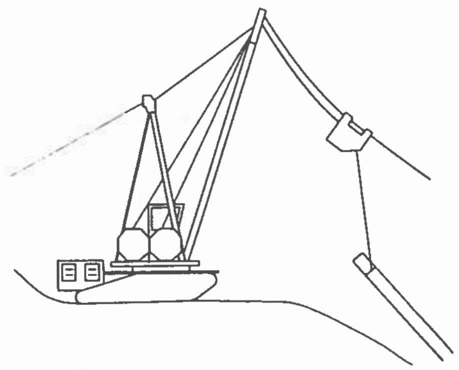
Gr. - Side slopes to 50%. Skid slopes to 35% downhill, 10% uphill.
Tbr. - Small trees and turns.
Eqpt. - Small crawler (eg. 35-75 kw) with blade, winch, chokers.
Crew - 1 operator.
Typ. Prod. - 50-75 m^3. Affected by timber size, traction, distance.
Rem. - Smaller crawlers need least trail width; trail side-cuts can be reduced for minimum site disturbance. Reach: 60 m below road, 250 m above.

7.6 Small Cable Yarder (Fixed Spar)



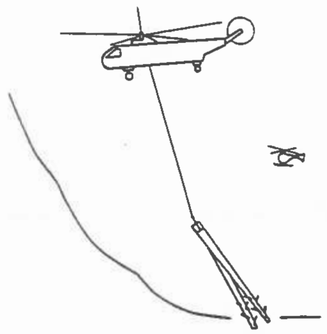
Gr. - Slopes to 80% above road, 100% below.
Tbr. - Small to large, tree lengths or logs.
Eqpt. - Guyed short (8-9 m) tower on tracks, truck or skidder. Rigged for chokers and high-lead or simple skyline.
Crew - 3 (operator, 2 on rigging).
Typ. Prod. - 60-80 m^3. Affected by turn size, line speeds, distance, ground, landing space, snow.
Rem. - Reach is 100 m above road and 150 m below. (Uphill yarding capability is major advantage over ground skidding.) Ground deflection and landing space are critical. Cramped landings may need skidder to swing logs to truck-loading site.

7.7 Medium Cable Yarder (Swing-boom)



Gr. - Slopes to 80% above road, 100% below.
Tbr. - Size not limiting (tree-lengths or logs).
Eqpt. - Tracked or truck-mounted crane or jammer; rigged for chokers or grapple, highlead or skyline. Mobile backspar may improve ground clearance and speed rigging moves.
Crew - 4+ (operator, chaser, 2+ on rigging).
Typ. Prod. - 80-160 m^3. Affected by tree size, line speeds, distance, ground, landing space, snow.
Rem. - Reach is 150 m above road, 200 m below. Swing boom permits better use of loading space. Frequent short moves may avoid need for skidder to clear logs from landings.

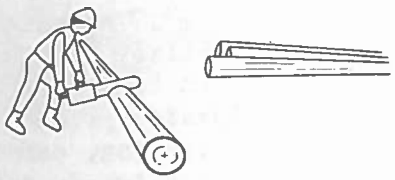
7.8 Aerial Yarder (eg. helicopter)



Gr. - Not limiting.
Tbr. - High value to offset high costs. Logs bucked to payload weights.
Eqpt. - Logging helicopter and small support helicopter.
Crew - 10-11 (pilots, mechanics, ground hooking and chasing).
Typ. Prod. - 350-650 m^3. Affected by flying weather, payloads achieved.
Rem. - Reach is 1500 m above landing. Landings must be large to handle high daily volumes. Aerial yarding will only be competitive if other methods require prohibitive road costs and if timber values are high.

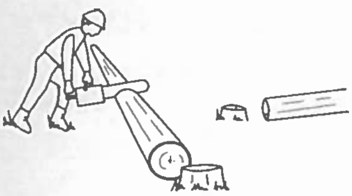
8. DELIMBING AND BUCKING

8.1 Manual, on Landing



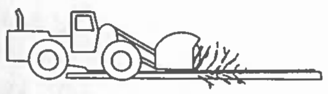
Gr. - Level landing.
Tbr. - Medium or small.
Eqpt. - Chainsaw, tape.
Crew - 1 (assistance from skidder, loader).
Typ. Prod. - 100-200 m^3 per bucker. Affected by limbiness, tree size, log lengths, season.
Rem. - Landings safer, logs can be accurately bucked, delimbing already partly done by skidding or yarding.

8.2 Manual, at Stump



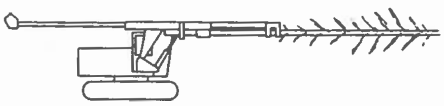
Gr. - Rough or smooth.
Tbr. - Large to medium.
Eqpt. - Chainsaw, tape.
Crew - 1 (faller).
Typ. Prod. - 30-60 m^3 felled, limbed and bucked at stump (approx. ½ of rate for felling only). Affected by tree size, ground, limbiness, snow.
Rem. - Not preferred unless trees too large to skid or yard intack; slower, less safe, bucking accuracy may suffer. Further delimbing needed at landing.

8.3 Chain Flail, at Landing



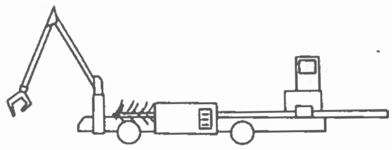
Gr. - Level landing.
Tbr. - Small, bunches.
Eqpt. - Chain flail on skidder or loader (skidder may turn logs).
Crew - 1 operator.
Typ. Prod. - 250-400 m^3. Affected by limb size and brittleness.
Rem. - Complements feller-buncher and grapple skidding; best when limbs are brittle (frozen). (No bucking.)

8.4 Boom Delimber



Gr. - 0.3 ha landing or continuous windrow.
Tbr. - To 50 cm.
Eqpt. - Tracked excavator with boom, grapple and knife-delimbing head.
Crew - 1 operator.
Typ. Prod. - 250-400 m^3. Affected by size and availability of trees.
Rem. - Often double-shifted to match skidding and loading production. High-quality delimbing, safety. Current models top but do not buck.

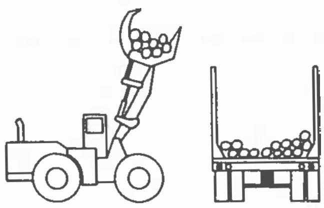
8.5 Delimber/Bucker



Gr. - Landings 0.3 ha, flat.
Tbr. - To 50 cm.
Eqpt. - Grapple feed, rolls with length measurement, knife head, chainsaw cut-off.
Crew - 1 or 2.
Typ. Prod. - 250-400 m^3. Affected by size and availability of trees.
Rem. - Safe. Clean logs from full trees.

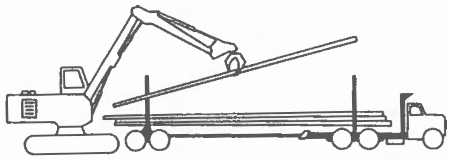
9. TRUCK LOADING

9.1 Front-end Loader



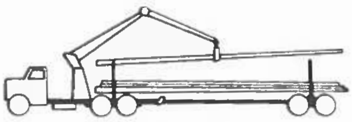
Gr. - Landings 0.1 ha, level or slight slope.
Tbr. - Small-medium.
Eqpt. - Wheeled (tracked) loader with log forks.
Crew - 1 operator.
Typ. Prod. - 200-400 m^3. Affected by availability of logs and trucks.
Rem. - Most common where landing space permits. Highly mobile but cannot reach logs below road grade.

9.2 Boom Loader



Gr. - Steep ground, narrow landings.
Tbr. - Medium-large.
Eqpt. - Tracked or wheeled heel-boom grapple loader, size matching timber.
Crew - 1 operator.
Typ. Prod. - 150-400 m^3. Affected by availability of logs and trucks.
Rem. - Less mobile than front-end loader but better off-grade reach for steep ground.

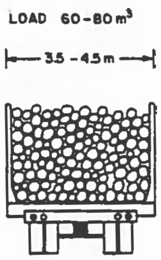
9.3 Self-load Truck



Gr. - Moderate slopes, narrow landings.
Tbr. - Medium.
Eqpt. - Log truck with heel-boom grapple loader added.
Crew - 1 driver-loader.
Typ. Prod. - 60-120 m^3. Affected by travel time.
Rem. - Independent of separate loader. Sacrifice in payload and loading speed. May load self and accompanying conventional log truck.

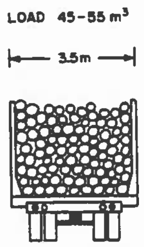
10. TRUCK HAULING

10.1 Off-highway Truck



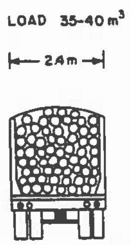
Gr. - Road grade to 18% maximum favourable, 8% adverse.
Tbr. - Small-large, logs over 12 m long for bunks.
Eqpt. - 3-axle tractor and 2-axle pole trailer, 3.5 m bunks, radio.
Typ. Prod. - 120-180 m^3 (varies widely with distance, weather, road quality, loading time).
Rem. - More efficient than highway truck where applicable. Larger loads, less public traffic.

10.2 On-Off Highway Truck



Eqpt. - Highway truck modified for off-highway and public rural road hauling. Performance is intermediate between highway and off-highway.

10.3 Highway Truck



Gr. - Road grade to 15% maximum favourable, 10% adverse.

Tbr. - Small-large, 12 m logs.

Eqpt. - Std. 5-axle truck and trailer with 2.4 m bunks, or 6-7 axles to extend legal load limits. Radio-dispatch.

Typ. Prod. - 75-150 m^3 (varies widely with distance, weather, road quality, legal load, loading time).

Rem. - 5-axle, contractor-owned highway truck is the standard Interior unit. Added axles sacrifice maneuverability but increase load. Highway traffic may cause delays and safety hazards.

We have just identified 6 construction phases using several common methods. These methods fall into systems which vary constantly as the construction jobs change. We have also identified 5 major logging phases using 23 methods. Any of the logging methods can be combined with almost any other, but some combinations are more likely than others. For example:

- Cable or helicopter yarding generally follows manual felling because felling machines cannot be moved to the site.
- Grapple skidders normally work behind feller-bunchers to take advantage of bunched trees.
- Mechanized felling, bunching, delimbing and bucking are normally confined to smaller timber on flatter ground.

Table 3 outlines six typical logging systems (combinations of methods) used in the Interior. The six systems cover the range of conditions usually encountered but there are other ways to combine methods into systems.

In addition to the construction and logging phases covered, there are other essential functions which must be planned while the main systems are chosen. Examples are truck unloading, log marking, log scaling, log sorting, post-logging cleanup, rehabilitation and silvicultural treatment of the cutover area. Harvesting system choices cannot be made final until these functions are tied down.

TABLE 3. SIX TYPICAL INTERIOR LOGGING SYSTEMS (LOGS ON TRUCK).

SYSTEM	PHASE					COMMENTS
	SKID-TRAILS	FELLING	SKIDDING/ YARDING	DELIMBING/ BUCKING	LOADING	
1. GRAPPLE SKID	MEDIUM DOZER (5.2)*	FELLER-BUNCHER (6.3)	GRAPPLE SKIDDER (7.3)	MANUAL (8.1) FLAIL (8.3) BOOM DELIMBER (8.4)	FRONT-END LOADER (9.1)	SMALL TIMBER, MODERATE SLOPES, LARGE LANDINGS
2. MEDIUM CRAWLER SKID	MEDIUM DOZER (5.2)	MANUAL (6.1)	MEDIUM CRAWLER (7.1)	MANUAL, STUMP (8.2) MANUAL, LANDING (8.1)	FRONT-END LOADER (9.1)	SIMPLEST. GOOD FOR LARGE TIMBER, MODERATE SLOPES
3. CHOKER SKIDDER	MEDIUM DOZER (5.2) (SKIDDER (5.1))	MANUAL (6.1) MECH. FELL ONLY (6.2)	CHOKER SKIDDER (7.2)	MANUAL, LANDING (8.1) FLAIL (8.3)	FRONT-END LOADER (9.1)	SIMPLE. WIDE RANGE OF TIMBER SIZE. FIRM, MODERATE SLOPES
4. SMALL CRAWLER SKID	SMALL DOZER (5.2)	MANUAL (6.1)	SMALL CRAWLER (7.5)	MANUAL, LANDING (8.1)	FRONT-END LOADER (9.1) SELF-LOAD TRUCK (9.3)	SMALL TIMBER, STEEP SHORT SKIDS, SMALL LANDINGS. LOW SITE-DISTURBANCE
5. CABLE	N/A	MANUAL (6.1)	CABLE YARDER (7.6,7.7)	MANUAL, STUMP (8.2) MANUAL, LANDING (8.1)	BOOM LOADER (9.2), SELF-LOAD TRUCK (9.3)	CLASSIC METHOD FOR SLOPES OVER 50%. MEDIUM OR LARGE TIMBER. LOW OFF-ROAD DIS-TURBANCE. UPHILL AND DOWN-HILL YARDING MAY PERMIT WIDER ROAD SPACING
6. L.G.P. FOR-WARDER	SMALL OR MEDIUM DOZER (5.2)	MANUAL (6.1)	L.G.P. SKIDDER (7.4) SERVING PRIMARY SKIDDERS	MANUAL, LANDING (8.2)	FRONT-END LOADER (9.1) SELF-LOAD TRUCK (9.3)	HAS PROMISE AS ALTERNATIVE FOR CABLE YARDING FOR STEEP OR SENSITIVE SITES, SMALLER TIMBER. LONG SKIDS REDUCE ROADS AND LANDINGS

*NUMBERS REFER TO METHOD DESCRIBED IN SECTION C.

PART II - PLANNING PROCEDURES

Part I described the things which must be assembled and decided before the planner starts to make a comprehensive total-chance plan for his area. Now the detailed planning can start.

Total-chance planning is harder to describe in words than to do. For this reason, we have created a small and entirely hypothetical development planning area and will use it to illustrate the total-chance planning sequence. To avoid large maps and repetition, our example compresses a wide range of timber, terrain, systems and problems into an unusually small area. Otherwise, we have tried to make it representative of many future development areas in the Interior mountain ranges.

A. EXAMPLE OF TOTAL-CHANCE DEVELOPMENT PLANNING

1. Background

Suppose a forest company operates in one of the Timber Supply Areas in the Interior of B.C. The company needs an annual flow of about 500 000 m^3 (170 000 cunits) of timber for its lumber and pulp-chip production. Most of this volume must come from the company's Forest Licence.

Rainbow Creek is allocated to the company for future development under the TSA Plan. The company logged in lower Rainbow Creek some years ago, and the upper drainage (see Map 1) is now a logical area for new operations. Timbered slopes range in elevation from 1 300 to 1 800 m (4 300 to 6 000 ft) and are steeper than in the lower drainage. Forests are chiefly spruce and lodgepole pine, with lesser volumes of balsam fir, cedar, Douglas fir and hemlock. The main Biogeoclimatic Zones represented (Ministry of Forests, Nelson Region, 1983) are:

ESSFc - Engelmann spruce - subalpine fir, moist climate
ICHa2 - Int. cedar-hemlock, moist climate.

Much of the forest cover is mature or overmature and ready for harvesting, but four areas of immature timber, originating from lightning fires in the 1920s, interrupt the mature stands. Moist climatic conditions and heavy snowfalls can be expected to hamper winter operations on the upper slopes.

The first evidence of a Mountain Pine Beetle (*Dendroctonus ponderosae* Hopk.) outbreak has been noticed in the lodgepole pine stands along the south-facing slopes above Rainbow Lake (Map 1). It is hoped that the spread can be stopped and the beetle-killed timber salvaged. The development plan will require early extension of the road system from the north side of Rainbow Lake into the affected area.

Elk, deer and small game utilize habitat in the lower drainage, including stands of advanced immature timber there, and do not depend heavily on the upper drainage.

Rainbow Lake supports a trout population and sport-fishing resort. Accordingly, special timber-harvesting measures are needed to protect the water quality and fish-spawning habitat upstream from the lake (see E_F and E_W zones on Map 2). During Local Resource Use planning sessions, a combination of selective cutting near the lake and cable yarding further upstream has been agreed upon for these zones.

Limited areas of high erosion potential are identified during development cruising. Map 2 shows their distribution (E_S zones). The company must decide whether to leave them undisturbed or to develop with special care.

Under ordinary circumstances the company would be required to apply the "2-pass" system, under which about half of the mature timber blocks would be cut and allowed time to restock before the remaining timber is removed. In this case, because of overmaturity and the risk of spreading insect attacks, it is decided that the company should not prolong development or observe the customary cut/leave restrictions, but should cut at the rate of 80 000 m^3 each year until virtually all mature timber is removed. This decision permits prompt recovery of decadent stands and the write-off of road costs against the timber over one decade. The alternative 2-pass approach would have serious disadvantages in this drainage, with heavy insect and windfall losses in the leave stands and road write-offs covering 2 or more decades.

The company and its contractors have the equipment for road construction and logging on moderate slopes but will need to add steep-slope capability, notably for subgrading in rock and for cable yarding.

The company sawmill has a large-log and a small-log processing line. Annual logging must provide a basic flow of large and small logs to feed both. Although the 80 000 m^3 annual cut from Rainbow Creek will be only 16% of the company's total cut, high-quality wood from parts of the drainage will be an important supplement to low-quality wood from elsewhere.

Under its Forest Licence, the company is responsible for a forest management program, including fire protection, insect control and prompt rehabilitation of harvested areas. The timber development plan must mesh with existing higher-level planning for the Region, the TSA and the Forest Licence, and also with lower-level operational planning to come after.

2. Development Mapping and Cruising

Old topographic maps (1:50 000, 100-foot contours) and Forest cover maps (1:20 000) are available but are considered inadequate for the development planning. The company orders new topographic maps at a chosen scale of 1:10 000 and contour intervals of 20 m.* These will be plotted from new aerial photos, using government control coordinates and high-order plotters. The maps will show all ground detail visible on the photos by skilled plotters, but it is recognized that some important detail may be obscured by tree cover and will need to be checked on the ground.

Timber types are interpreted on the photos and plotted onto the topographic base. Cruising crews establish strips and plots to determine type labels and final boundaries, and provide data for cruise volume and area summaries. The crews also establish soil pits at selected points to check ESA or erosion hazard ratings. Common photo, map and ground control points established in cruising will be retained to assist location surveys later.

Map 1 shows the topographic/timber type map produced at this stage. Map 2 (blue detail) shows the environmental sensitivity zones identified. For presentation in this handbook, all maps are reduced to half-scale, or 1:20 000.

Cruise statistics for the drainage would be compiled and checked. The resulting cruise summaries are not included here, but planning information based on them will be shown shortly (Table 5).

3. Start-up

At this stage, three important things should take place:

(a) A series of meetings with the appropriate Forest Service Regional and District people to announce the start of development planning, to present the new maps and data, to confirm that development

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*A larger map scale and 10 m contours would often be chosen but would complicate our hypothetical example.

planning will fit within the terms of the Forest Licence and broader programs, and to permit the MOF to start any referrals with other ministries.

(b) A ground or air reconnaissance involving the planner, cruising staff, company operating people and perhaps major contractors.

(c) A series of company meetings to start defining sawmill strategies, road construction and logging programs, broad scheduling and all other implications of the decision to go ahead.

Suppose in this case all parties agree that:

(a) The area will be harvested over a period of about 10 years.
(b) Special measures to protect watershed and fish habitat will be taken. Steepness and erosion hazard will rule out conventional ground-skidding over parts of the area.
(c) The company will prepare a total-chance development plan for the area for company use and MOF District review and approval.

4. Paper Planning

This is a balancing and optimizing process. Instead of arriving directly at the best overall plan, the planner usually starts with a few basic requirements, works through a series of stages and then works back and forth between stages until the best compromises are reached. The hypothetical paper plan which follows is the result of the optimizing process, after various options have been tried, rejected and replaced by better ones. The paper planning steps are outlined below in approximate chronological order.

(a) Select Harvest Systems

Table 3 already outlined six typical Interior logging systems. Suppose that the company decides to try out the same six systems in development planning and also to apply medium crawler skidding in partial cutting as well as clearcutting. The six systems are:

System 1. Feller-buncher, grapple skidder.

System 2. Hand-fell, medium crawler skid.

System 2(a). Same, but partial cut in fish habitat protection zone.

System 3. Hand-fell, choker skidder.

System 4. Hand-fell, small crawler skid.

System 5. Hand-fell, swing-boom cable yarder.

System 6. Hand-fell, L.G.P. forwarding.

Aerial systems are ruled out, at least until further work identifies significant areas combining prohibitive road costs and valuable timber.

(b) Assess Protection Requirements

Insect

If the initial beetle attack spreads, a harvesting response will be necessary. Changes to the harvesting schedule may be difficult or easy, depending on the location of new outbreaks. Road development should extend rapidly over the full length of the drainage and permit early harvesting of the north slopes.

Fire

Local experience indicates that the main hazard is from lightning strikes on the upper slopes. The plan must provide early road access to probable strike areas. Helicopter landings for fire access should be located where road development will be delayed.

Windfall

Suppose there is a history of storm winds coming up the valley from the west and uprooting large spruce trees on the lower slopes. The plan will already reduce windfall losses by removing mature stands over one decade instead of two. Further planning steps should include:

- leaving smaller, windfirm trees in the selectively-cut (System 2a) areas and avoiding logging damage to them.

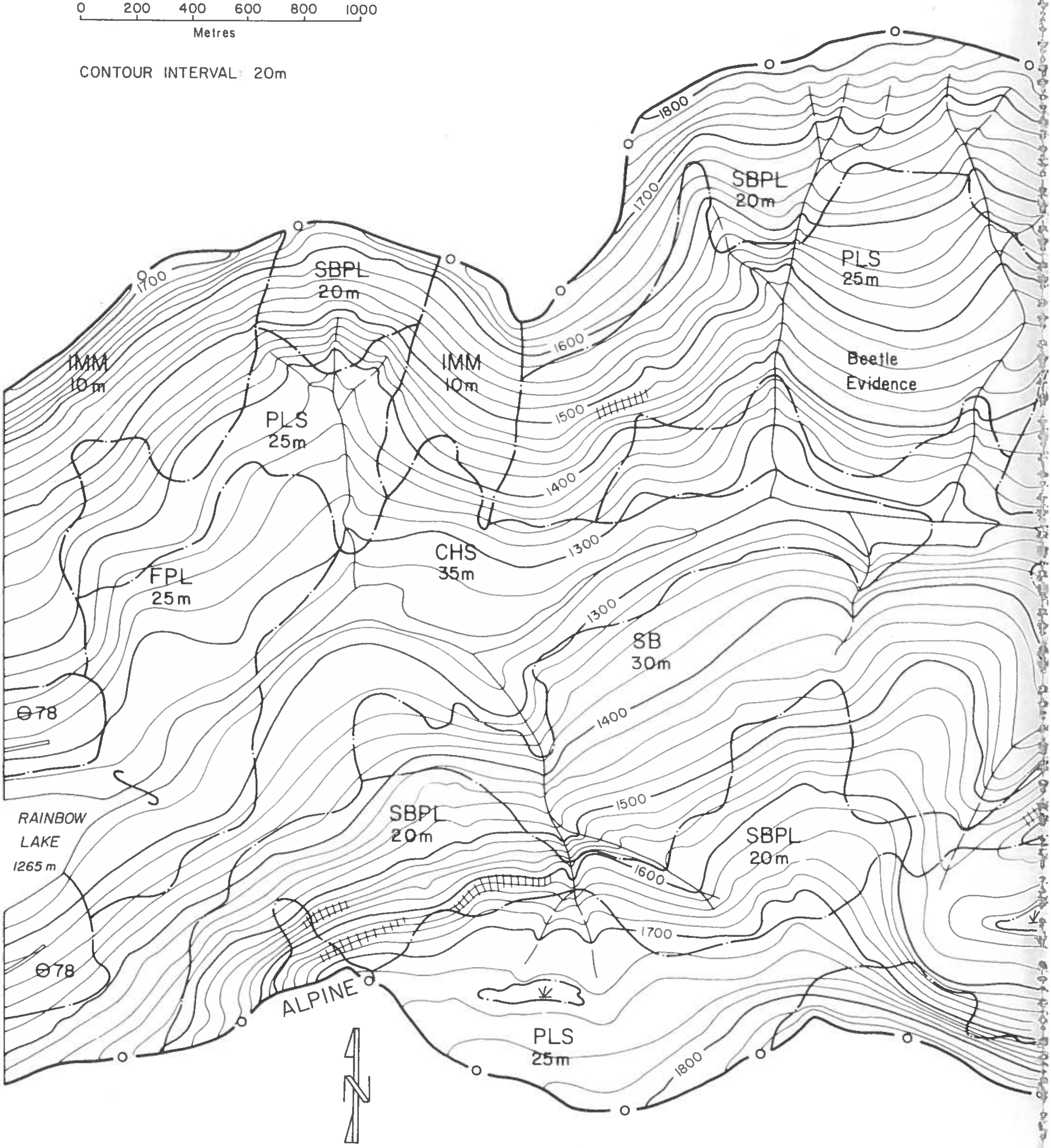
- locating cut boundaries to be longer in the direction parallel to storm winds (E-W) and shorter in the direction perpendicular (N-S).

- scheduling successive cut-blocks to progress into the prevailing storm winds where feasible.

MAP I. TOPOGRAPHY AND TIMBER TYPES

SCALE 1:20 000

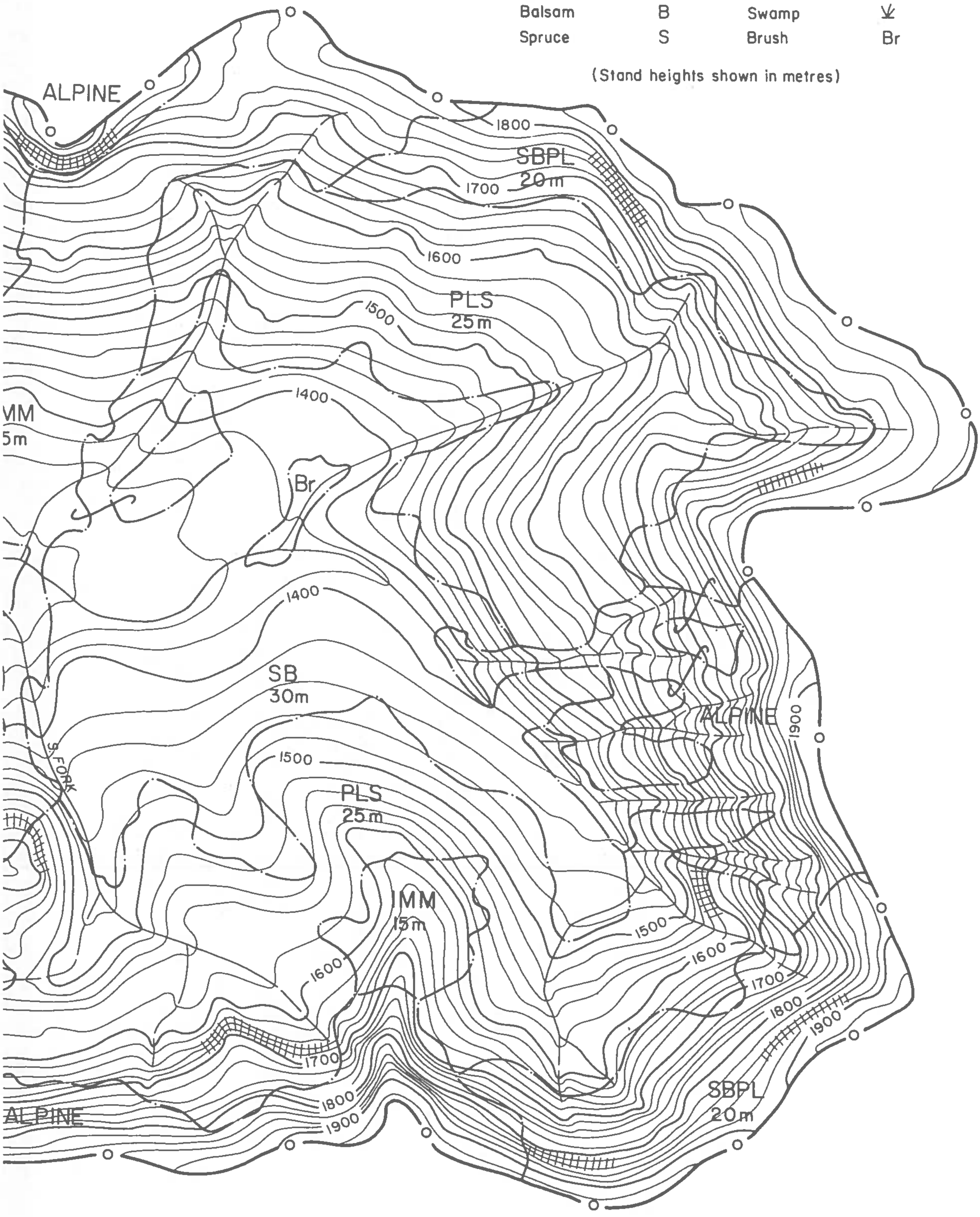
CONTOUR INTERVAL: 20m



TYPE LABELS

Douglas Fir	F	Lodgepole Pine	PL
W. Red Cedar	C	Immature	IMM
W. Hemlock	H	Rock Bluff	/////
Balsam	B	Swamp	⩛
Spruce	S	Brush	Br

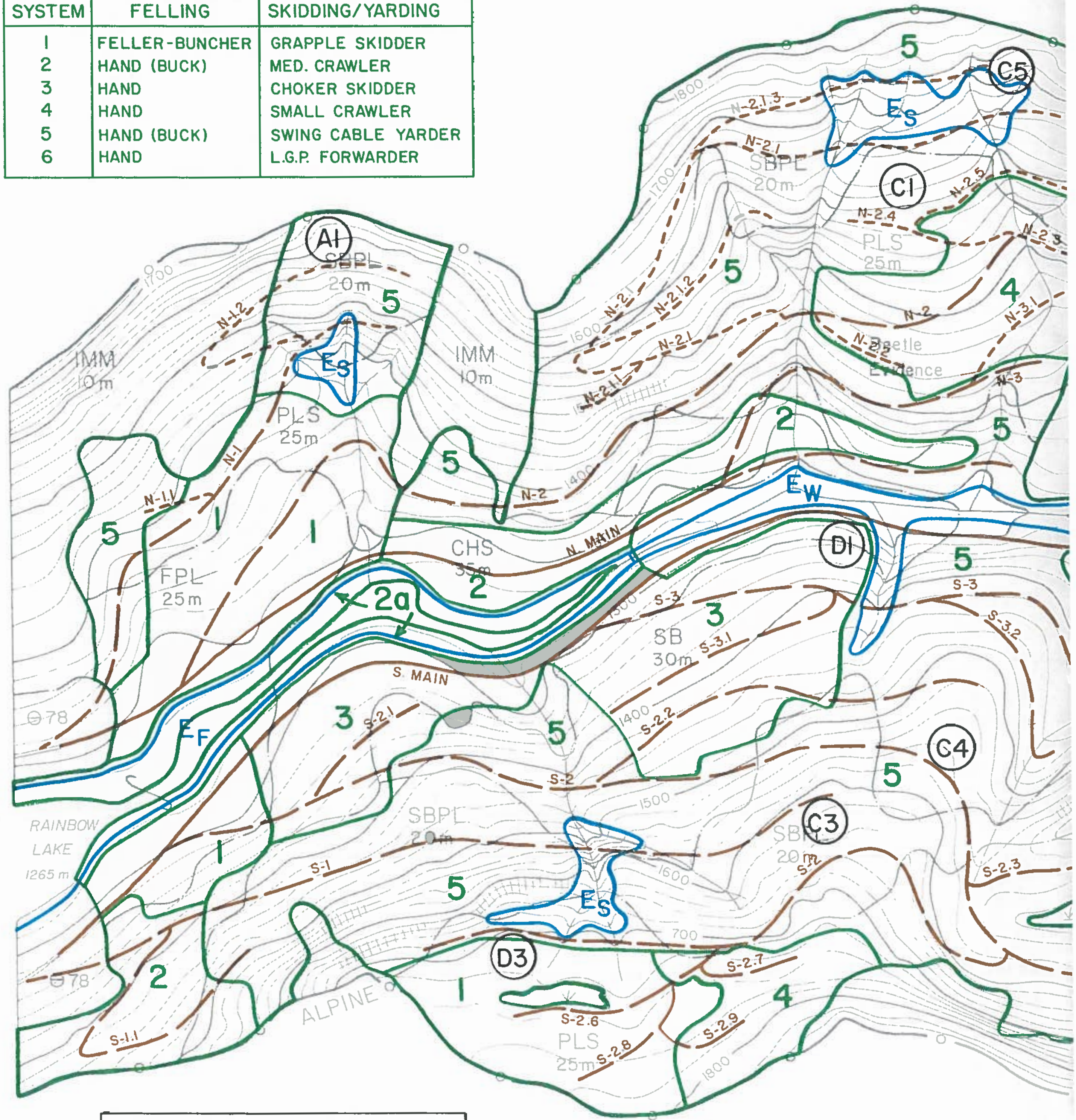
(Stand heights shown in metres)



MAP 2. ROADS AND LOGGING SYSTEMS
(PAPER PLAN, BEFORE FIELD CHECKS)

N SECTION

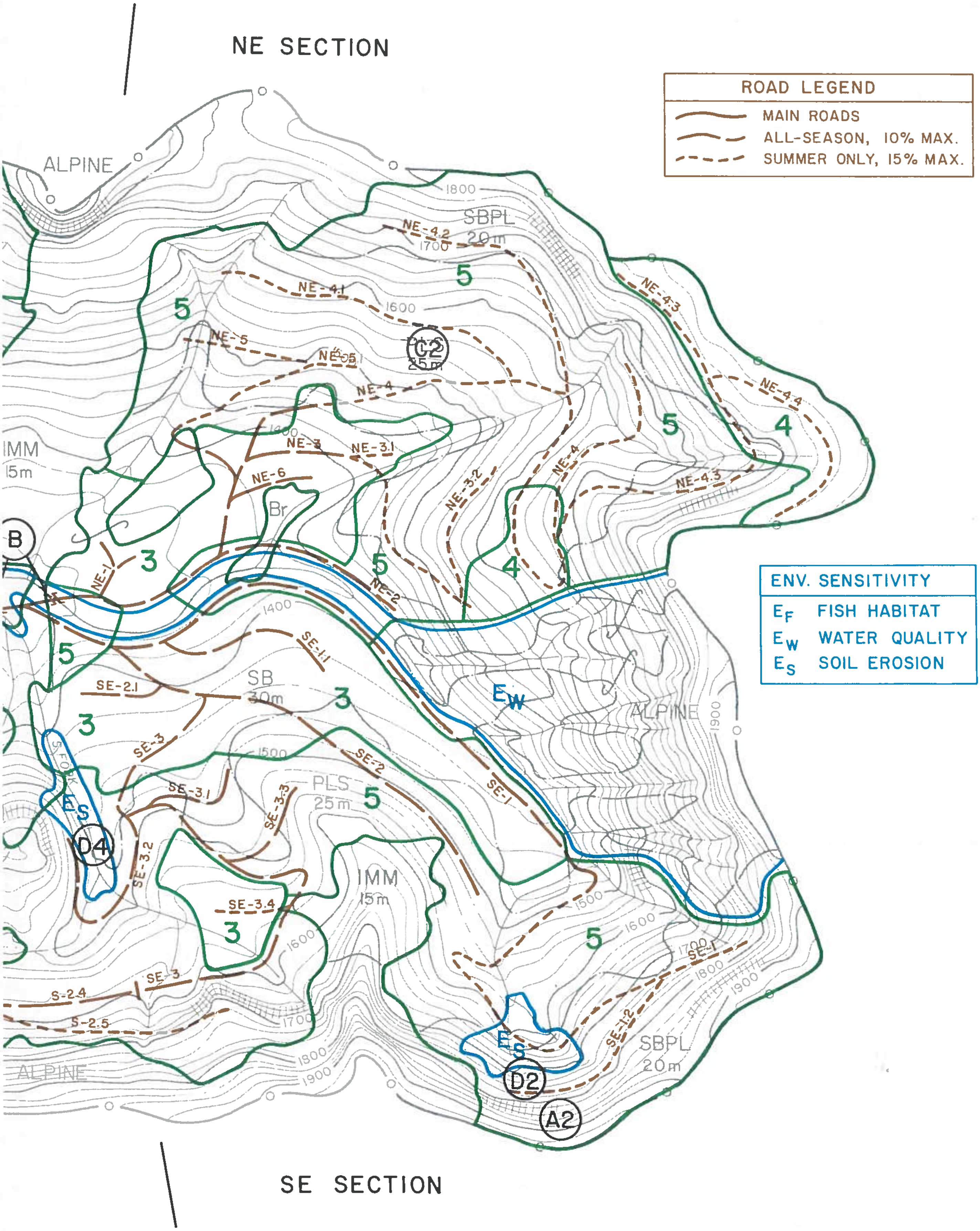
LOGGING SYSTEMS		
SYSTEM	FELLING	SKIDDING/YARDING
1	FELLER-BUNCHER	GRAPPLE SKIDDER
2	HAND (BUCK)	MED. CRAWLER
3	HAND	CHOKER SKIDDER
4	HAND	SMALL CRAWLER
5	HAND (BUCK)	SWING CABLE YARDER
6	HAND	L.G.P. FORWARDER



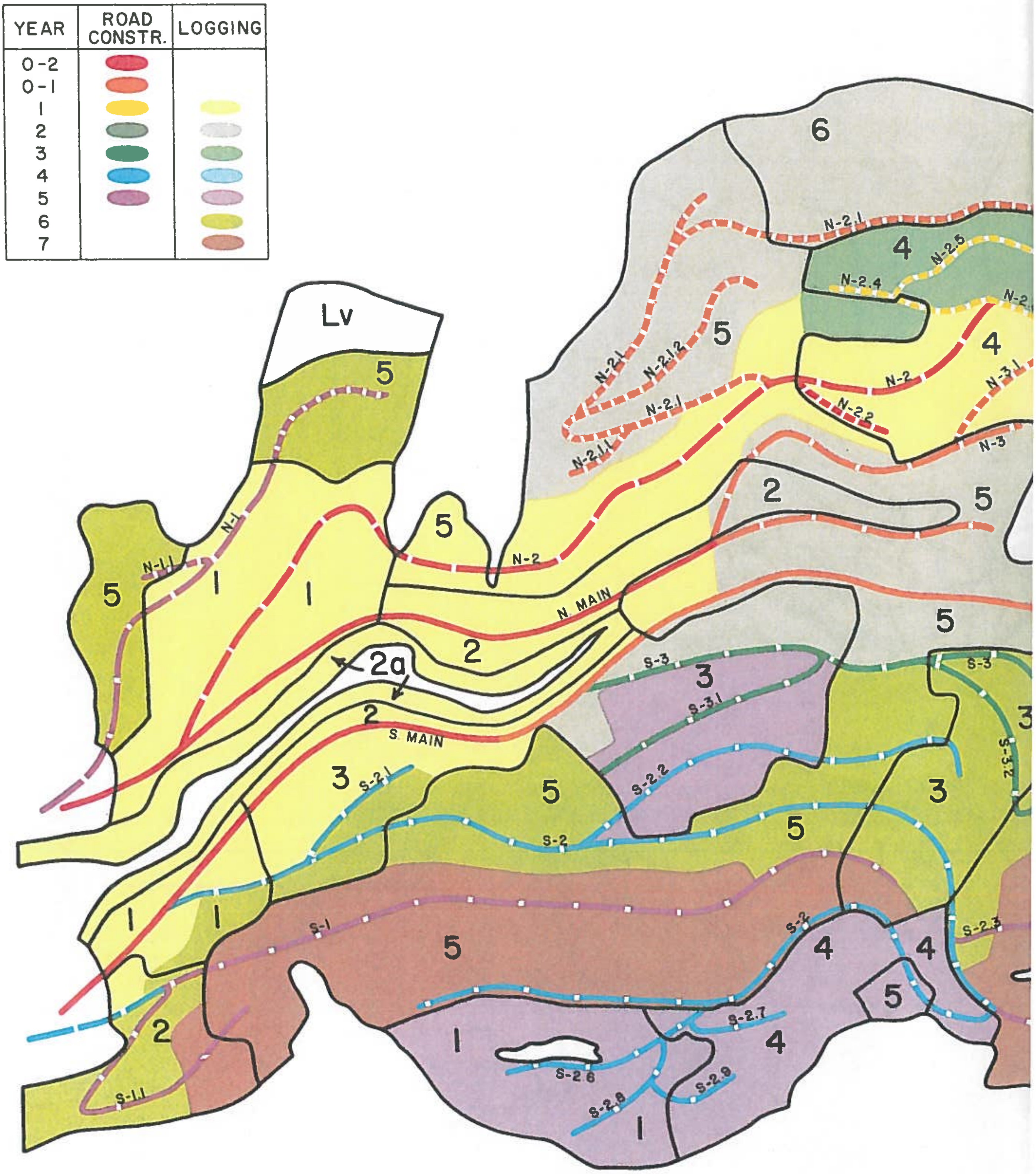
FIELD-CHECK POINTS (SEE TEXT)

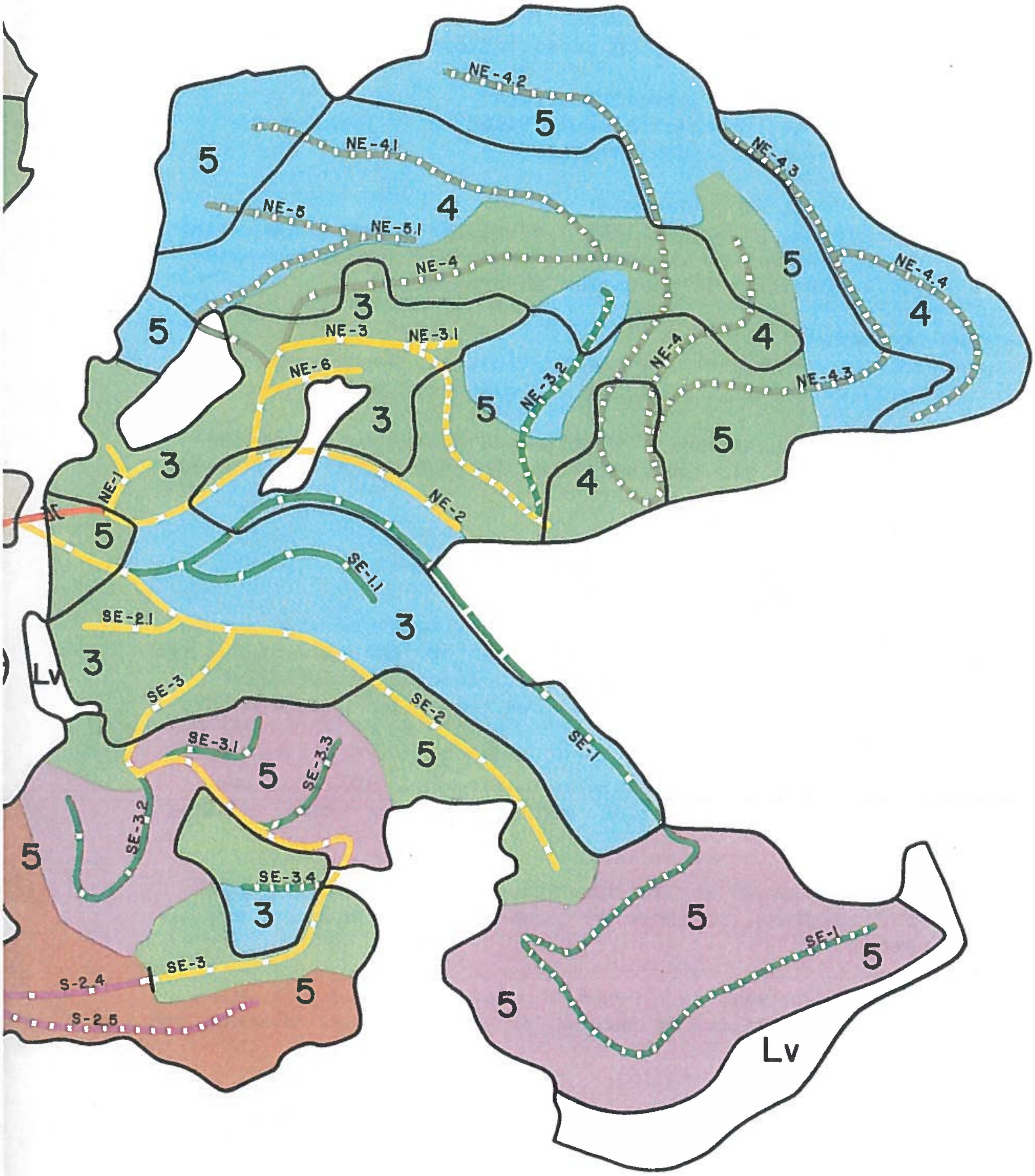
A, B, C1 ___ D4

S SECTION


NE SECTION
ROAD LEGEND
MAIN ROADS
ALL-SEASON, 10% MAX.
SUMMER ONLY, 15% MAX.
ENV. SENSITIVITY
E_F FISH HABITAT
E_W WATER QUALITY
E_S SOIL EROSION
ALPINE
SBPL
20 m
1800
1700
1600
1500
1400
1900
NE-4.2
NE-4.1
NE-4.3
NE-4.4
NE-4
NE-5
NE-3
NE-3.1
NE-3.2
NE-6
NE-1
NE-2
C2
25 m
IMM
15 m
Br
B
SB
30 m
SE-1.1
SE-2.1
SE-3
SE-2
SE-1
SE-3.1
SE-3.2
SE-3.3
SE-3.4
SE-1.2
PLS
25 m
D4
D2
A2
S-2.4
S-2.5
E_W
E_S
SE SECTION

MAP 3. SCHEDULE - ROAD CONSTRUCTION AND LOGGING
(FINAL PLAN, AFTER FIELD CHECKS)





NE-4.2
5
NE-4.1
5
4
NE-5
NE-5.1
NE-4.3
NE-4
5
NE-4.4
4
3
5
NE-3
NE-3.1
4
NE-6
NE-3.2
NE-4
NE-4.3
3
5
5
3
NE-1
4
NE-2
5
SE-1.1
SE-2.1
3
3
Lv
SE-3
SE-2
SE-3.1
5
SE-3.3
5
SE-1
SE-3.2
5
SE-3.4
3
5
SE-1
5
SE-3
S-2.4
5
5
S-2.5
Lv

When individual cut-block boundaries are eventually laid out, windfirmness along the stand edge will be one of the considerations. Walker (1982) suggests ways to recognize and treat vulnerable areas.

(c) Assess Silvicultural Requirements

The development plan must conform to MOF Region operating standards and to the company's commitments under its Licence, and must also recognize any special circumstances in the development area itself. For example, three main post-logging prescriptions might be planned:

- Lowland cedar-hemlock-spruce clearcuts:
  Prompt (1-year) mechanical scarification or burning and planting to avoid brush invasion.

- Upland spruce-balsam clearcuts:
  Slash-burning or scarification of winter-logged sites within 2 years. Selective treatment of summer-logged sites where needed. Planting if unstocked in 3rd year.

- Pine clearcuts:
  Selective burning or light scarification, 3-year wait for natural restocking. Planting if unstocked in 4th year.

Silviculture programs will influence the selection of harvesting systems and will also determine how long secondary roads should be kept open after harvesting.

(d) Propose Preliminary Road Network

Reconnaissance and the new topographic maps are used for this important planning phase. Major control points are the ends of the two existing roads at Rainbow Lake, and two field-located bridge sites leading to the headwaters of the creek. Two road-grade standards are selected:

i. Year-round: Branch roads limited to theoretical 10% sustained favourable grades and 4% adverse, suitable for year-round hauling at high speeds.

ii. Summer: Roads limited to 15% theoretical sustained favourable grade and 8% adverse, suitable for snow-free hauling only, and at lower speeds.

Logging roads must be located to connect landing points so that the maximum timber volume is reached by the least road mileage, so that timber above and below landings can be reached effectively by the mixture of logging systems, and so that both roadside and off-road damage to sensitive sites is minimized.

Based on the grade limits set, on the occurrence of good terrain for switchbacks and landings, and on the location of mature stands, a complete road network is located on paper (see Map 2, brown detail). For road segments where the grade limits are critical, grade points are stepped off with dividers. For example, to keep the grade under 10%, it must cross successive 20 m contours at horizontal distance intervals not less that 200 m (10 mm at map scale shown). For the 15% limit, the distance between contours must be not less than 133 m (6.67 mm at map scale). At road junctions, switchbacks and natural landing sites, the grade is customarily reduced below the theoretical maximum. Even so, experience shows that when paper plans are transferred to the ground, short pitches of road will exceed the theoretical maximum by a few percentage points.

Mature timber in the alpine slide area at the head of the main creek is to be left undisturbed for environmental and economic reasons. With this exception, virtually all of the timber is reached by the "paper" road system shown on Map 2, and road spacing is generally such that skidding or yarding distances are within practical limits.

At this stage, all roads should be named according to an overall scheme. Map 2 roads are named according to simple compass directions (N, NE, S and SE) with further subdivisions into branch and spur roads by decimals and numbers.

(e) Block Out Harvesting Systems

Map 2 (green detail) shows where 5 of the 6 harvesting systems can be used (System 6 is omitted so far). This is done in relationship to the planned road network. For example, System 5 (cable yarding) areas are placed for yarding above and below the road, while areas for the ground-skidding systems (1-4) are placed for downhill skidding or short, moderate adverse skids.

The best relationship between haul roads and skidding/yarding may not be reached in the first attempt. After the systems are blocked out initially, the results should be examined carefully and further paper improvements made if possible, by changing either road locations or system boundaries. The road/harvesting system pattern on Map 2 is the end result after several paper trials, and still further changes can be expected as a result of field checking.

5. Critical Field Checks

Paper planning identifies where we would like to put roads and system boundaries. Particularly for roads, the paper plan eliminates a large number of locations where roads are not wanted and allows us to look closely at a smaller number of remaining points. Ground checks will either confirm the original road pattern or show that some change is necessary. One change may lead to others nearby. A road change may lead to an adjustment in logging system boundaries. Conversely, a system change may lead to road changes.

Some specific checks which would be made before finalization of our paper plan are listed below (see Map 2, black detail, for locations).

Check A - Leave Areas

On-site checking may prove that some projected roads are not economically justifiable. For example, Road N-1.2 would be necessary to reach the uppermost 11 ha of low-value timber between two immature types (see Map 2, Check Point A-1). The volume available is 2 695 m^3. About 1 250 m of road would be required, much of it through the adjacent immature stand. The road cost estimate, including 800 m of drilling and blasting, comes to $105 000 or $39 per m^3 available. With logging costs added, these low-quality logs would cost over $70/$m^3$, or about $320 per MBM before milling and marketing. Projected lumber prices are not nearly high enough to offset production costs. Development of this 11-hectare portion of the drainage will be deferred several decades until the adjacent immature stand is also ready to cut.

Road SE-1.2 (Check Point A-2) is also field-checked. A similar calculation shows that this road and logging of about 21 ha of low-quality timber nearby are not economically justifiable. Other areas are similarly deleted after checking, for a total leave area of 73 ha.

Check B - Bridge Sites

Field checks confirm that two log bridges can be built economically to cross the South Fork and the main creek at the sites shown (Check Point B).

Check C - System Boundary Changes

The paper plan calls for System 5 (cable yarding) on 64% of the total harvested area. Along with high costs, this would create logistics problems, with too much summer cable yarding and too little ground skidding. Further ground checks confirm that some System 5 can be replaced by ground skidding, with minor changes in roads and with well-planned skid trail networks. Paper plan changes are then made:

<u>Check C-1</u> Enlarge System 4 area - no changes needed in Roads N-2.4 and N-2.5.

<u>Check C-2</u> Add System 4 on NE mid-slope, originally planned for System 5 because of steepness.

<u>Check C-3</u> Extend Road S-1 further than originally planned and use Systems 3 and 4 above road extension.

<u>Check C-4</u> Replace System 5 by System 3 at ends of Roads S-3, S-3.2, S-2.2 and S-2. Minor road changes needed.

<u>Check C-5</u> Replace System 5 by System 6 (long-distance forwarding with LGP skidders). This upper area served by Roads N-2.1 and N-2.1.3 runs up to 65% in ground slope, contains an E_s (soil erosion sensitivity) zone and has low-value timber. For off-road site protection, it was originally paper-planned for cable yarding.

After field-checking, the best possible locations for roads and cable settings looked like Figure 2(a). To keep yarding distances within about 250 m, much of the haul road and several landings would fall within the E_s zone. System 4 (small tractor skidding) would be no improvement since it would require similar or denser road and landing placement.

It is decided to try System 6 (L.G.P. forwarding) and keep most of the roads out of the E_s area. Figure 2(b) shows the resulting System 6 plan. A single road with fewer landings can put all parts of the 54-ha System 6 area within about 450 m forwarding distance. Road costs and roadside erosion hazard can be greatly reduced because 720 m less road is needed and because the road needed is on easier terrain.

Overall costing will be discussed later, but this case illustrates another important use for cost calculations, this time for comparing alternatives. Forwarding on this area will probably result in

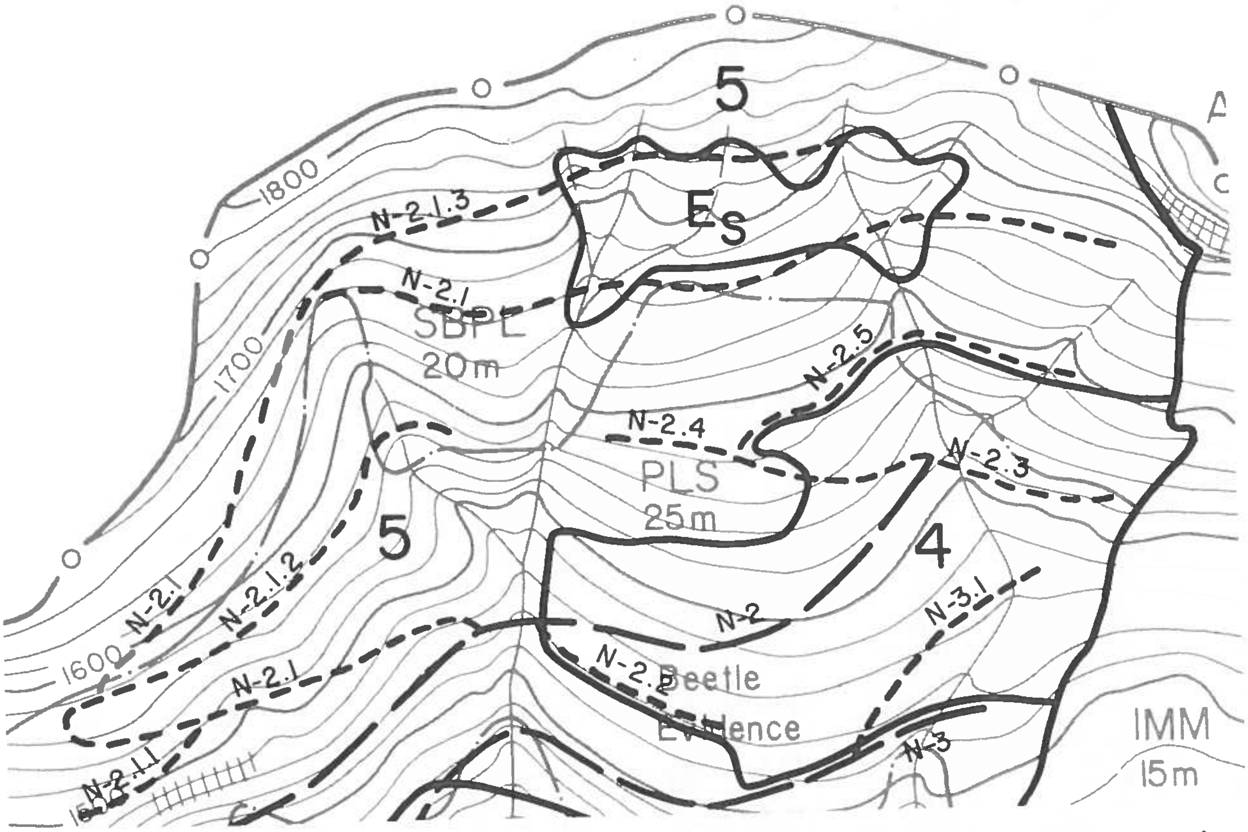


FIGURE 2(a). CHECK C-5. CABLE YARDING (APPROXIMATE SCALE 1:13 333).

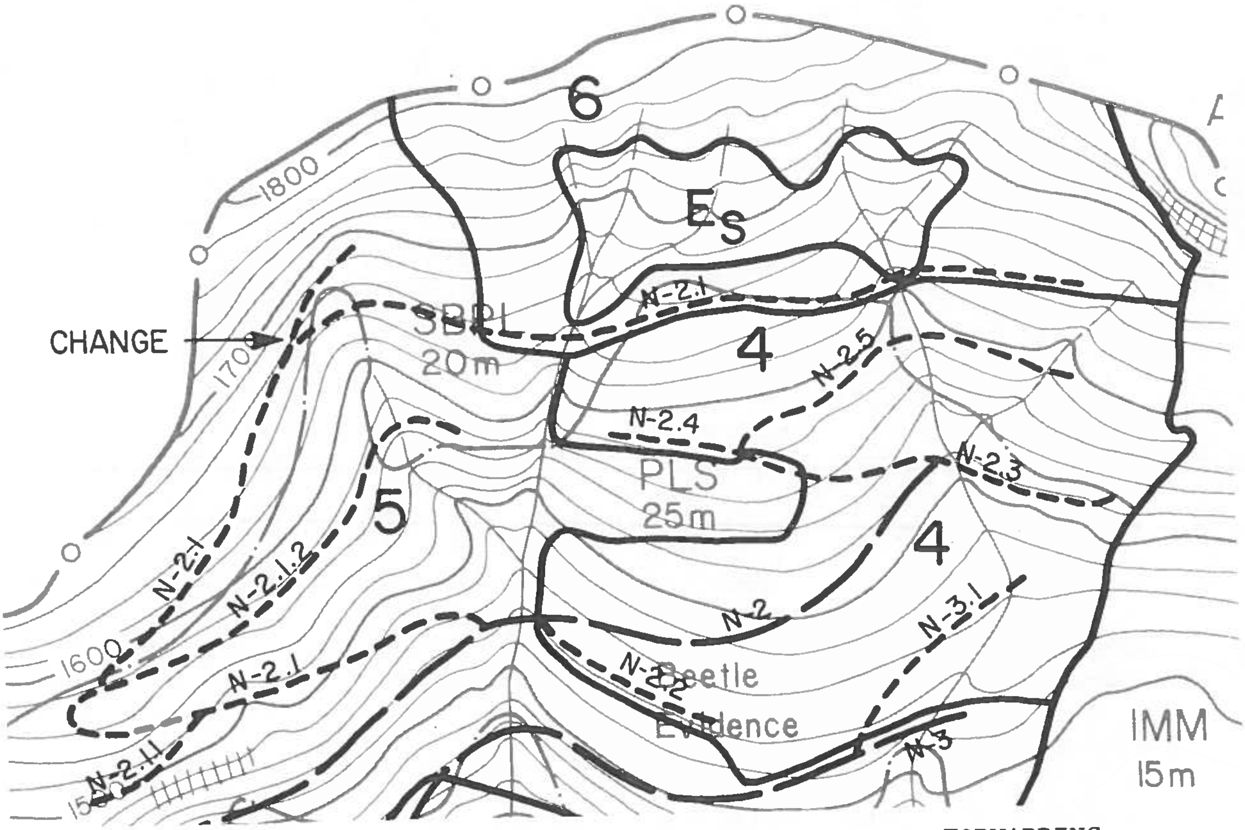


FIGURE 2(b). CHECK C-5. CABLE AND L.G.P. SKIDDER FORWARDING.

increased felling and forwarding costs and lower road costs. However, all relevant costs must be estimated and compared before the correct alternative is found. Table 4 shows how such a comparison could be made.

TABLE 4. COSTING OF CABLE VERSUS L.G.P. FORWARDER.

	SYSTEM 5 (ALL CABLE)			SYSTEM 5 & 6 (CABLE & L.G.P.)		
	BASIS	$	$/m^3	BASIS	$	$/m^3
AREA TO LOG (INCL. COMMON 20 HA OF CABLE)	74 ha			74 ha		
ROAD REQUIRED	2 560 m			1 840 m		
ROAD AND LANDING COSTS	($48.00/m)	122 880		($40.00/m)	73 600	
VOLUME CUT	18 130 m^3			18 130 m^3		
ROAD AND LANDING COST, $/m^3			6.78			4.06
FELLING COST (SAME BASIS EXCEPT FOR WALK-IN TIME)	18 130 m^3	45 320	2.50	18 130 m^3	54 390	3.00
SKID-ROAD CONSTRUCTION (L.G.P. ONLY)	-	-	-	13 230 m^3	23 810	1.80
YARDING COSTS	18 130 m^3	271 950	15.00	4 900 m^3	73 500	15.00
SKIDDER ASSIST AT YARDER LANDINGS	14 000 m^3	37 800	2.70	-	-	-
L.G.P. FORWARDING COSTS	-	-	-	13 230 m^3	238 140	18.00
TOTALS, COST TO LANDINGS, $/m^3	18 130 m^3	477 950	26.36	18 130 m^3	463 440	25.56

Neither system is particularly cheap, but System 5 & 6 results in costs to landing of $25.56 per m^3, cheaper than System 5 by $.80 per m^3. System 6 is justified for both economic and environmental reasons. If the cost estimates prove accurate on this area, System 6 can replace System 5 on other areas later.

Check D - Erosion Hazard Zones

Field checks of the E_s and E_w zones on Map 2 are made to determine:

- whether the mapping of the zones is accurate where roads are affected;
- whether special construction measures are needed;
- whether location changes would help avoid specific problems.

Some important check points shown on Map 2 are:

Check D-1	S. Main Road and Road S-3 must cross an important E_w zone. Ground checks confirm feasibility, with extra care and correct timing.
Check D-2	Road SE-1 - upper section must pass through E_s zone on 15% grade. Feasible. Road SE-1.2 is eliminated and upper fringe of timber left.
Check D-3	Road S-1 must cross lower part of E_s zone and Road S-2 should skirt upper edge. Both paper locations are feasible.
Check D-4	Road SE-3.2 is laid out to skirt E_s zone and yard uphill through it. Feasible if a 1-hectare wedge of mature timber below the E_s zone is left standing.

The final development plan, after adjustments for all changes, is shown on Map 3. Differences between Map 2 (paper) and Map 3 (final) are not obvious but are far-reaching. The net area and volume of timber for development is more realistic. Critical road and bridge sites have been checked. About 240 hectares have been transferred from cable to ground skidding systems with major improvements in costs and logistics. Ground checking has vastly increased confidence in the final plan and reduced the risk of costly mistakes later.

6. Final Development Plan

We now need to check the implications of the adjusted development plan with a series of detailed calculations.

(a) Determine Timber Areas and Volumes by System

Table 5 summarizes the areas and timber volumes to be harvested by each system. System areas by timber type are determined from

TABLE 5. AREA/VOLUME SUMMARY BY HARVESTING SYSTEM.

SYSTEM	TYPE	AREA (Ha)	NET VOLUME (m^3/Ha)							AREA X NET VOLUME - m^3(000)							NET m^3 /TREE	TREES /Ha
			F	C	H	B	S	Pl	TOTAL	F	C	H	B	S	Pl	TOTAL		
A. CLEARCUT:																		
1. Feller-buncher, Grapple Skidder	FPl 25 m	62	228					122	350	14.1					7.6	21.7	.80	438
	PlS 25 m	79				30	133	152	315				2.4	10.5	12.0	24.9	.65	485
		141							330	14.1			2.4	10.5	19.6	46.6	.72	458
2. Hand-fell, Medium Crawler	CHS 35 m	44		211	114		81		406		9.3	5.0		3.6		17.9	1.50	271
	SB 30 m	15				84	202	50	336				1.3	3.0	.7	5.0	1.20	280
	PlS 25 m	6				30	133	152	315				.2	.8	.9	1.9	.65	485
	SBPl 20 m	5				61	110	74	245				.3	.5	.4	1.2	.50	490
		70							371		9.3	5.0	1.8	7.9	2.0	26.0	1.33	278
3. Hand-fell, Choker Skidder	CHS 35 m	42		211	114		81		406		8.9	4.8		3.4		17.1	1.50	271
	SB 30 m	233				84	202	50	336				19.6	47.1	11.6	78.2	1.20	280
	PlS 25 m	30				30	133	152	315				.9	4.0	4.6	9.5	.65	485
	SBPl 20 m	11				61	110	74	245				.7	1.2	.8	2.7	.50	490
		316							340		8.9	4.8	21.1	55.7	17.0	107.5	1.18	288
4. Hand-fell, Small Crawler	SB 30 m	8				84	202	50	336				.7	1.6	.4	2.7	1.20	280
	PlS 25 m	146				30	133	152	315				4.4	19.4	22.2	46.0	.65	485
	SBPl 20 m	74				61	110	74	245				4.5	8.1	5.5	18.1	.50	490
		228							293				9.6	29.1	28.1	66.8	.63	464
5. Hand-fell, Swing Cable Yarder	CHS 35 m	41		211	114		81		406		8.7	4.7		3.3		16.7	1.50	271
	SB 30 m	148				84	202	50	336				12.4	29.9	7.4	49.7	1.20	280
	FPl 25 m	4	228					122	350	.9					.5	1.4	.80	438
	PlS 25 m	445				30	133	152	315				13.4	59.2	67.6	140.2	.65	485
	SBPl 20 m	242				61	110	74	245				14.8	26.6	17.9	59.3	.50	490
		880							304	.9	8.7	4.7	40.6	119.0	93.4	267.3	.77	395
6. Hand-fell, L.G.P. Skidder	SBPl 20 m	54				61	110	74	245				3.3	5.9	4.0	13.2	.50	490
		54							245				3.3	5.9	4.0	13.2	.50	490
SUBTOTAL, CLEARCUT		1 689							311	15.0	26.9	14.5	78.8	228.1	164.1	527.4	.85	367
B. SELECTIVE CUT (60%):																		
2a. Hand-fell, Medium Crawler	CHS 35 m	16		127	68		49		244		2.0	1.1		.8		3.9	2.00	122
	FPl 25 m	14	137					73	210	1.9					1.0	2.9	1.10	191
		30							227	1.9	2.0	1.1		.8	1.0	6.8	1.61	141
SUBTOTAL, ALL CUTTING		1 719							310	16.9	28.9	15.6	78.8	228.9	165.1	534.2	.86	362
PERCENT NET VOLUME BY SPECIES										3.1	5.4	2.9	14.8	42.9	30.9	100.0		
C. LEAVE:																		
	SB 30 m	9				84	202	50	336				.8	1.8	.5	3.0		
	PlS 25 m	12				30	133	152	315				.4	1.6	1.8	3.8		
	SBPl 20 m	52				61	110	74	245				3.2	5.7	3.8	12.7		
		73							278				4.3	9.1	6.1	19.5		
SUBTOTAL, CUT + LEAVE		1 792							309	16.9	28.9	15.6	83.1	238.0	171.2	553.7		
	IMMATURE	248																
	LOGGED '78	26																
SUBTOTAL, PRODUCTIVE		2 066																
	BRUSH	3																
	WATER, SWAMP	26																
	ALPINE	140																
TOTAL		2 235																

Map 3 using grid overlays or electronic digitizing equipment. Type volume averages by species are taken from the development cruise data, along with m^3/tree and trees/hectare averages. Individual type and species averages may be subject to high sampling errors at this stage, because of low sampling intensity. More accurate data will come later from cutting permit cruising.

Table 5 indicates that a total of 1 689 ha, with 527 400 m^3 of timber is designated for clearcutting. An additional 30 ha of stream-side timber with a volume of 6 800 m^3 is to be removed in partial cutting, for a total of 534 200 m^3. Overall cut volume is 310 m^3/ha, with an average of 0.86 m^3 per tree cut. About 73 ha of mature timber is to be left uncut, including Checks A-1 and A-2 and the slide area at the head of the drainage.

The total productive forest area is 2 066 ha. Table 5 also shows the non-forest areas of brush, water, swamps and alpine. Total drainage area is 2 235 ha and all individual map polygons are balanced to this total.

(b) Summarize and Schedule Road Construction

Road-building priorities are set by logging priorities. The first priority is to salvage beetle-infested stands in the north section, and the second is to extend mainline access so that choices for further development and logging are available. Table 6 outlines a complete road construction program which satisfies these first two priorities and then carries on to the completion of all roads shown on Map 3.

Table 6 also shows a chosen sequence by years. To keep logging sites away from construction sites and to allow time for new subgrade to firm up before use, there must be a time-lapse between construction and logging on any site. On soft or wet subgrades, this lapse should be about 2 years.

In Year 0-3 (three years before the first cut block is harvested), all necessary upgrading of existing roads outside the drainage is done. In each of the 6 years following (Year 0-2 to Year 4), 9-12 km of road is built. In Year 5, the final 8.9 km is completed, for a total of 69.7 km, and the construction program moves elsewhere.

Table 6 lists roughly estimated quantities and costs for subgrading, rock work, bridges (two must be built in Year 0-1), major culverts and ballasting. Subgrading costs include rough estimates for landings and for ditching and smaller culverts across streams which the map does not show. Much more accurate cost estimates for all items will be obtained later when on-site surveys are done. All costs are based on extensions of past experience and cost records obtained from similar terrain elsewhere. The purpose of preliminary estimates at this stage is to weigh the probable cost of one road plan against another, and thus to come close to the best.

Excluding minor reconstruction in Year 0-3, the estimated road construction cost begins at $256 900 in Year 0-2, rises to a peak of $428 000 in Year 2 and totals $2 479 400 altogether, or $35 570 per km of new grade. The average road cost per m^3 logged is $4.64/$m^3$ ($2 479 400 /534 200 m^3).

Map 3 shows, by colour codes, the extent of road building planned for each year as outlined in Table 6. As it happens, very little road passes through immature types, but future extensions of the planned road network can reach these when necessary.

For company projections of cash flow, road construction costs are split into main roads and branch or spur roads as follows:

COST ITEM	Km	$(000)	m^3(000)	$/$m^3$	$/km (000)
MAIN ROADS & BRIDGES	8.4	322.1	534.2	.60	38.3
BRANCH & SPUR ROADS	61.3	2 157.3	534.2	4.04	35.2
TOTAL	69.7	2 479.4	534.2	4.64	35.6

Main roads and bridges will become a permanent Crown asset and their cost, projected at $.60/$m^3$, will be recoverable by the company under Section 88 of the Forest Act, as a credit against stumpage payable by the company anywhere in the same TSA. The remaining roads, projected to average $4.04 per m^3, will be worked into stumpage appraisals for individual cutting permits in the drainage. The company will need preliminary and updated estimates like these from all its operations to predict road construction cash flows.

(c) Summarize and Schedule Logging

Table 7 is a complete schedule of the logging program, commencing with minor R/W timber removal in Years 0-2 and 0-1, jumping to

TABLE 6. ROAD CONSTRUCTION SCHEDULE.

YEAR	ROAD	FROM	TO	SUBGRADE			ROCK WORK			BRIDGES	CULVERTS (MAJOR)			BALLAST			TOTAL	
				m	$/m	$(000)	m	$/m	$(000)	$(000)	NO.	$/CULV.	$(000)	m	$/m	$(000)	$(000)	$/m
0-3	(OFF MAP)			COST TO UPGRADE MAIN ROAD AND REBUILD BRIDGE, LOWER DRAINAGE													80.0	
							NEW CONSTRUCTION											
0-2	N. MAIN	START	N-2	500	24	12.0											12.0	24.00
	N-2	START	END	3 850	18	69.3	200	80	16.0		4	3 000	12.0				97.3	25.30
	N-2.2	START	END	400	19	7.6											7.6	19.00
	N. MAIN	N-2	N-3	2 150	25	53.8					1	5 000	5.0	300	10.80	3.2	62.0	28.80
	S. MAIN	START	S-3	2 350	28	65.8					1	5 000	5.0	500	14.40	7.2	78.0	33.20
				9 250	22.54	208.5	200		16.0		6		22.0	800		10.4	256.9	27.80
0-1	S. MAIN	S-3	NE-1	2 350	30	70.5				58.0	1	6 000	6.0	600	14.40	8.6	143.1	60.90
	N-3	START	END	1 400	20	28.0	200	80	16.0		2	3 000	6.0				50.0	35.70
	N. MAIN	N-3	END	1 050	20	21.0				(2 spans,	2	3 000	6.0				27.0	25.70
	N-3.1	START	END	500	20	10.0				20 m each,	1	3 000	3.0				13.0	26.00
	N-2.1	START	END	3 250	24	78.0	400	80	32.0	log crib &	3	3 000	9.0				119.0	36.60
	N-2.1.1	START	END	300	25	7.5				stringers)							7.5	25.00
	N-2.1.2	START	END	850	25	21.2	100	80	8.0		1	3 000	3.0				32.2	37.90
				9 700	24.35	236.2	700		56.0	58.0	10		33.0	600		8.6	391.8	40.40
1	N-2.3	START	END	300	28	8.4					1	2 500	2.5	100	18.00	1.8	12.7	42.30
	N-2.4	START	END	600	28	16.8											16.8	28.00
	N-2.5	START	END	700	28	19.6	50	80	4.0		2	2 500	5.0				28.6	40.90
	NE-1	START	END	350	15	5.2											5.2	15.00
	NE-2	START	END	1 250	20	25.0					1	4 000	4.0				29.0	23.20
	NE-3	START	END	1 550	24	37.2					1	3 500	3.5				40.7	26.30
	NE-3.1	START	END	150	20	3.0											3.0	20.00
	NE-6	START	END	350	18	6.3								50	14.40	0.7	7.0	20.00
	SE-1	BRIDGE	SE-2	400	26	10.4								200	14.40	2.9	13.3	33.20
	SE-2	START	END	1 750	22	38.5	100	60	6.0					200	14.40	2.9	47.4	27.10
	SE-2.1	START	END	300	18	5.4											5.4	18.00
	SE-3	START	END	2 300	26	59.8	200	80	16.0		2	3 000	6.0	300	18.00	5.4	87.2	37.90
				10 000	23.56	235.6	350		26.0		7		21.0	850		13.7	296.3	29.63
2	NE-4	START	END	3 250	30	97.5	200	60	12.0		2	3 500	7.0				116.5	35.80
	NE-4.1	START	END	1 200	28	33.6	200	60	12.0		1	2 500	2.5				48.1	40.00
	NE-4.2	START	END	1 100	32	35.2	400	60	24.0								59.2	53.80
	NE-4.3	START	END	1 800	34	61.2	600	80	48.0		1	3 000	3.0				112.2	62.30
	NE-4.4	START	END	900	24	21.6											21.6	24.00
	NE-5	START	END	1 400	28	39.2	300	80	24.0		1	2 000	2.0				65.2	46.60
	NE-5.1	START	END	200	26	5.2											5.2	26.00
				9 850	29.80	293.5	1 700		120.0		5		14.5				428.0	43.45

TABLE 6. - cont.

3	NE-3.2	START	END	850	26	22.1											22.1	26.00
	SE-1	SE-2	END	4 400	28	123.2	1 000	80	80.0		3	3 500	10.5				213.7	48.60
	SE-1.1	START	END	700	18	12.6											12.6	18.00
	SE-3.1	START	END	400	18	7.2	50	80	4.0								11.2	28.00
	SE-3.2	START	END	800	22	17.6	100	80	8.0		2	3 000	6.0				31.6	39.50
	SE-3.3	START	END	400	20	8.0	50	80	4.0								12.0	30.00
	SE-3.4	START	END	300	18	5.4	50	80	4.0		2	4 000	8.0				17.4	58.00
	S-3	START	END	1 900	18	34.2	50	60	3.0		1	4 000	4.0	100	18.00	1.8	43.0	22.60
	S-3.1	START	END	900	18	16.2											16.2	18.00
	S-3.2	START	END	800	22	17.6	100	80	8.0		1	3 000	3.0				28.6	35.80
				11 450	23.07	264.1	1 400		111.0		9		31.5	100		1.8	408.4	35.67
4	S-2	START	END	5 900	28	165.2	800	80	64.0		4	3 000	12.0	1 000	18.00	18.0	259.2	43.90
	S-2.1	START	END	500	18	9.0											9.0	18.00
	S-2.2	START	END	1 500	26	39.0	100	60	6.0								45.0	30.00
	S-2.6	START	END	800	20	16.0											16.0	20.00
	S-2.7	START	END	400	20	8.0											8.0	20.00
	S-2.8	START	END	500	20	10.0											10.0	20.00
	S-2.9	START	END	400	22	8.8											8.8	22.00
	S-1	START	S-1.1	550	24	13.2											13.2	24.00
				10 550	25.52	269.2	900		70.0		4		12.0	1 000		18.0	369.2	35.00
5	S-1	S-1.1	END	2 750	24	66.0	200	60	12.0		2	5 000	10.0	400	18.00	7.2	95.2	34.60
	S-1.1	START	END	1 300	28	36.4	200	60	12.0								48.4	37.20
	N-1	START	END	2 150	28	60.2	200	80	16.0		4	2 500	10.0				86.2	40.10
	N-1.1	START	END	300	24	7.2											7.2	24.00
	S-2.3	START	END	500	20	10.0					1	2 000	2.0				12.0	24.00
	S-2.4	START	END	900	22	19.8											19.8	22.00
	S-2.5	START	END	1 000	28	28.0	400	80	32.0								60.0	60.00
				8 900	25.57	227.6	1 000		72.0		7		22.0	400		7.2	328.8	36.94
TOTALS (EXCL. YEAR 0-3)				69 700	24.89	1 734.7	6 250	75.36	471.0	58.0	48	3 250	156.0	3 750	15.92	59.7	2 479.4	35.57

TABLE 7. HARVESTING SCHEDULE.

YEAR	SYSTEM	SUMMER HAUL ONLY			SUMMER OR WINTER			TOTAL	
		Ha	m^3/Ha	m^3(000)	Ha	m^3/Ha	m^3(000)	Ha	m^3(000)
0 - 2	(New R/W)				22	354	7.8	22	7.8
0 - 1	(New R/W)				24	317	7.6	24	7.6
1	1. F/B, Grapple Skidder				79	330	26.1	79	26.1
	2. Medium, Crawler				29	371	10.8	29	10.8
	2a. Select., Med. Crawler				30	227	6.8	30	6.8
	3. Choker Skidder				23	340	7.8	23	7.8
	4. Small Crawler	34	293	10.0				34	10.0
	5. Swing Cable Yarder				56	300	16.8	56	16.8
SUBTOTAL		34	(293)	10.0	217	(315)	68.3	251	78.3
-Old R/W					-22	354	-7.8	-22	-7.8
+New R/W		+8	333	+2.6	+17	333	+5.7	+25	+8.3
TOTAL		42	(301)	12.6	212	(312)	66.2	254	78.8
2	2. Medium Crawler				11	371	4.1	11	4.1
	3. Choker Skidder				18	340	6.1	18	6.1
	5. Swing Cable Yarder	94	332	31.2	48	300	14.4	142	45.6
	6. L.G.P. Forwarder	54	245	13.2				54	13.2
SUBTOTAL		148	(300)	44.4	77	(319)	24.6	225	69.0
-Old R/W					-24	317	-7.6	-24	-7.6
+New R/W		+26	296	+7.7				+26	+7.7
TOTAL		174	(299)	52.1	53	(321)	17.0	227	69.1
3	3. Choker Skidder	12	340	4.1	79	340	26.9	91	31.0
	4. Small Crawler	57	293	16.7				57	16.7
	5. Swing Cable Yarder	79	300	23.7	37	300	11.1	116	34.8
SUBTOTAL		148	(301)	44.5	116	(327)	38.0	264	82.5
-Old R/W		-8	333	-2.7	-17	333	-5.7	-25	-8.4
+New R/W		+11	322	+3.5	+17	322	+5.5	+28	+9.0
TOTAL		151	(300)	45.3	116	(326)	37.8	267	83.1

TABLE 7. - cont.

4	3. Choker Skidder 4. Small Crawler 5. Swing Cable Yarder	8 85 114	340 293 300	2.7 24.9 34.2	81	340	27.5	89 85 114	30.2 24.9 34.2
SUBTOTAL -Old R/W +New R/W		207 -26	(299) 296	61.8 -7.7	81 +27	(340) 318	27.5 +8.6	288 -26 +27	89.3 -7.7 +8.6
TOTAL		181	(299)	54.1	108	(334)	36.1	289	90.2
5	1. F/B, Grapple Skidder 3. Choker Skidder 4. Small Crawler 5. Swing Cable Yarder	130	300	39.0	49 40 52 17	330 340 293 300	16.2 13.6 15.2 5.1	49 40 52 147	16.2 13.6 15.2 44.1
SUBTOTAL -Old R/W +New R/W		130 -11 +5	(300) 322 312	39.0 -3.5 +1.6	158 -17 +16	(320) 322 312	50.1 -5.5 +5.0	288 -28 +21	89.1 -9.0 +6.6
TOTAL		124	(299)	37.1	157	(316)	49.6	281	86.7
6	1. F/B, Grapple Skidder 2. Medium Crawler 3. Choker Skidder 5. Swing Cable Yarder	30	300	9.0	13 23 51 105	330 371 340 300	4.3 8.5 17.3 31.5	13 23 51 135	4.3 8.5 17.3 40.5
SUBTOTAL -Old R/W +New R/W		30	(300)	9.0	192 -27	(321) 318	61.6 -8.6	222 -27	70.6 -8.6
TOTAL		30	(300)	9.0	165	(322)	53.0	195	62.0
7	2. Medium Crawler 3. Choker Skidder 5. Swing Cable Yarder	23	300	6.9	7 5 146	371 340 300	2.6 1.7 43.8	7 5 169	2.6 1.7 50.7
SUBTOTAL -Old R/W +New R/W		23	(300)	6.9	158 -21	(304) 312	48.1 -6.6	181 -21	55.0 -6.6
TOTAL		23	(300)	6.9	137	(303)	41.5	160	48.4
ALL YEARS		725	(299)	217.1	994	(318)	316.6	1 719	533.7
% BY VOLUME				41%			59%		100%

70 000 - 90 000 m^3 per year in Years 1 to 5, and tailing off in Years 6 and 7. The schedule shows the distribution by logging systems and also separates "summer only" logging (road haul grades to 15%) from "summer or winter" (road grades to 10%). Forty-one percent of the timber volume must be hauled under snow-free conditions (roughly 7 months from June to December). The critical summer-logging years are Year 2 (75% summer) and Years 3, 4 and 5 (50-60% summer). The critical system is cable yarding, accounting for 50% of total logged volume. Year 7 calls for 96% cable yarding, but the volume is reduced and much is on moderate-grade roads, permitting all-season hauling.

Logging was intended to lag about 2 years behind road construction so that roads are firm for hauling. This objective is largely met by the scheduling shown in Table 7, but in a few cases there is a 1-year lag instead. These exceptions occur largely on upland, well-drained slopes.

(d) Determine Annual Log Mix

Table 7 showed the timber volumes scheduled for logging each year, without close analysis of species or sizes. Table 8 gives a breakdown. Fir, cedar and hemlock are minor species on the area. The plan calls for heavy cutting of these species in Year 1 and decreased volumes thereafter. Spruce and balsam account for 43% of the cut in Year 1, rising to 64% in Years 3 and 4 and falling gradually thereafter. Pine cut remains fairly constant at 28 to 34% throughout. This species pattern should be checked with mill people, along with similar data for timber from other sources.

Annual changes in average tree size (m^3/tree) are also shown in Table 8. Trees are large in the CHS and SB types and smaller in the others, averaging 0.86 m^3/tree overall. Because of the proportion of types cut in each year, tree size is highest in Year 1 (.92 m^3/tree) and gradually declines to 0.79 in Year 7. The mill people should again be consulted to see whether these fluctuations may be critical. If so, more sensitive analyses might be needed. For example, consulting firms have computer programs to break down cruise data into summaries by log-size groupings for a given set of bucking instructions.

(e) Estimate Equipment Needs

The road and logging programs will fluctuate from year to year and an estimate of varying equipment needs must be made. The equipment may be already owned by the division, brought in from other company operations, purchased new, or owned by contractors. Productivity will

TABLE 8. SPECIES AND SIZE MIX BY YEAR (EXCLUDING R/W).

YEAR	SYSTEM	Ha Cut	VOLUME BY SPECIES - m^3(000)							m^3/TREE
			F	C	H	B	S	Pl	TOTAL	
1	1	79	7.9			1.3	5.9	11.0	26.1	.72
	2	29		3.9	2.1	.7	3.3	.8	10.8	1.33
	2(a)	30	1.9	2.0	1.1		.8	1.0	6.8	1.61
	3	23		.6	.4	1.6	4.0	1.2	7.8	1.18
	4	34				1.4	4.4	4.2	10.0	.63
	5	56	.1	.5	.3	2.6	7.5	5.8	16.8	.76
TOTAL		251	9.9	7.0	3.9	7.6	25.9	24.0	78.3	.92
(%)			(12)	(9)	(5)	(10)	(33)	(31)	(100)	
2	2	11		1.5	.8	.3	1.2	.3	4.1	1.33
	3	18		.5	.2	1.2	3.2	1.0	6.1	1.18
	5	142	.2	1.8	1.0	5.9	20.3	16.4	45.6	.83
	6	54				3.3	5.9	4.0	13.2	.50
TOTAL		225	.2	3.8	2.0	10.7	30.6	21.7	69.0	.83
(%)			(-)	(6)	(3)	(16)	(44)	(31)	(100)	
3	3	91		2.6	1.3	6.1	16.1	4.9	31.0	1.18
	4	57				2.4	7.3	7.0	16.7	.63
	5	116	.1	1.1	.6	5.4	15.5	12.1	34.8	.76
TOTAL		264	.1	3.7	1.9	13.9	38.9	24.0	82.5	.89
(%)			(-)	(5)	(2)	(17)	(47)	(29)	(100)	
4	3	89		2.5	1.4	5.9	15.6	4.8	30.2	1.18
	4	85				3.6	10.8	10.5	24.9	.63
	5	114	.1	1.1	.5	5.4	15.3	11.8	34.2	.76
TOTAL		288	.1	3.6	1.9	14.9	41.7	27.1	89.3	.87
(%)			(-)	(4)	(2)	(17)	(47)	(30)	(100)	
5	1	49	4.9			.8	3.7	6.8	16.2	.72
	3	40		1.1	.6	2.7	7.0	2.2	13.6	1.18
	4	52				2.3	6.6	6.3	15.2	.63
	5	147	.1	1.4	.7	6.9	19.7	15.3	44.1	.76
TOTAL		288	5.0	2.5	1.3	12.7	37.0	30.6	89.1	.80
(%)			(6)	(3)	(2)	(14)	(41)	(34)	(100)	
6	1	13	1.3			.2	1.0	1.8	4.3	.72
	2	23		3.0	1.6	.6	2.6	.7	8.5	1.33
	3	51		1.4	.8	3.4	9.0	2.7	17.3	1.18
	5	135	.1	1.3	.7	6.3	18.0	14.1	40.5	.76
TOTAL		222	1.4	5.7	3.1	10.5	30.6	19.3	70.6	.93
(%)			(2)	(8)	(4)	(15)	(43)	(28)	(100)	
7	2	7		.9	.5	.2	.8	.2	2.6	1.33
	3	5		.1	.1	.3	.9	.3	1.7	1.18
	5	169	.2	1.6	.8	7.9	22.6	17.6	50.7	.76
TOTAL		181	.2	2.6	1.4	8.4	24.3	18.1	55.0	.79
(%)			(-)	(5)	(2)	(15)	(44)	(34)	(100)	
1-7	ALL	1 749	16.9	28.9	15.5	78.6	229.0	164.9	533.8	.86
(%)			(3)	(5)	(3)	(15)	(43)	(31)	(100)	

vary widely and the planner is predicting over a 10-year period. The objective is a reasonable forecast of the ebbs and flows of equipment and manpower on the operation.

Table 9 is an estimate of the heavy equipment needed, by years, to build the roads and log the timber in our example. Support equipment such as crew and supervisory transport, repair and maintenance facilities, etc. are excluded for simplicity but will also be needed. Table 9 is based on quantities of new road or logging required, appropriate production rates, a standardized 180-shift year and a selected machine utilization rate. For example, Year 1 calls for 10.0 km of new road. It is decided that 7.0 km of this is suitable for a large dozer and the remaining 3.0 km for a hydraulic excavator. The number of machine-years needed for each is calculated by the formula:

$$MY = \frac{Q}{qsu}$$

where
- MY = machine-years
- Q = quantity of work needed
- q = quantity per shift
- s = shifts per year (set at 180)
- u = machine utilization factor (set at .80, or 80% of the available 180 shifts per year)

For the large dozer, the calculation is:

$$MY = \frac{7.0 \text{ km}}{(.090 \text{ km/sh})(180 \text{ sh/year})(.80)} = 0.5 \text{ machine-years}$$

For the excavator, the calculation is:

$$MY = \frac{3.0 \text{ km}}{(.080 \text{ km/sh})(180 \text{ sh/year})(.80)} = 0.3 \text{ machine-years}$$

Similar machine-year calculations for all machines and years are shown in Table 9. Although not done in this example, production rates and machine utilization factors could be arbitrarily moved up or down in relation to the operating difficulties.

In our small development area, many individual machines are scheduled for part-time use. The subgrading work just illustrated for Year 1 requires a large dozer for about 6 months and an excavator for about 3 months. During Year 1, it will be decided whether to move these machines elsewhere for the rest of the year or to start early on Year 2 work. The company might also be forced to use only one of the two machines for Year 1, with some sacrifice in road-building efficiency. Logging companies seldom have the ideal machine for every occasion.

Year 1 also calls for 16 800 m^3 to be cable-yarded, requiring 1.0 yarder-year under "summer or winter" hauling conditions. A single yarder working for 9 months can produce this volume, supported partly by a boom loader and partly by a swing skidder and front-end loader. In Year 2, on the other hand, 45 600 m^3 must be cable-yarded, requiring 2.6 years of yarder time, and 31 200 m^3 of this must be hauled in "summer only" conditions (see Table 7). Three yarders will be needed in Years 2, 5, 6 and 7, the peak cable-yarding years. Before the paper plan (Map 2) was checked and altered, a fourth yarder would have been necessary at times.

System 3 (wheeled choker skidder behind hand fallers) is needed in Year 1 to log only 7 800 m^3 (summer or winter). This calls for only 0.5 skidder-years. For efficient operating, this might translate into two skidders working together for 2 months, assisted by a medium dozer for trail building and by a two-month portion of the 1.2 machine-years allocated for front-end loaders. The two skidders will require alternate work elsewhere for a large part of Year 1. In our example, there is scope for this on other company operations.

Year 4 is the peak year for small crawler skidding, calling for 24 900 m^3 of "summer only" logging at the head of the drainage. About 4.3 machine years are estimated for this on the 180-shift basis. This may mean seven small crawlers each working for 120 days, behind hand fallers and in front of two front-end loaders.

The logging manager needs advance estimates like those in Table 9 so that he can arrange for movements of men and equipment to and from the operation at the right times. To make the estimates realistic, the planner must consult with operating people and use all cross-checks available.

(f) Estimate Annual Operating Costs

The main elements for a rough costing by years and for the whole operation are now assembled. The company may choose to proceed with rough overall costing immediately, or to avoid this step and wait for more detailed information. Road construction costs are already roughly estimated (Table 6). Logging costs can be added if necessary. Parts of the operation may be company, contractor, or a combination.

Company Operations

- Multiply heavy equipment requirements (Table 7) by annual all-found equipment costs.
- Add costs not based on heavy equipment, such as:
  hand falling, delimbing, bucking

TABLE 9. HEAVY EQUIPMENT REQUIREMENTS BY YEAR.

PHASES	MACHINES	ESTIMATED "q" (PROD./SHIFT/MACH.)	YEAR 0 - 2		YEAR 0 - 1		YEAR 1		YEAR 2	
			QUANTITIES AND MACHINE-YEARS							
			Q	MY	Q	MY	Q	MY	Q	MY
A. ROAD CONSTRUCTION:										
1. SUBGRADE	LARGE DOZER	.09 km	6.0	.5	6.4	.5	7.0	.5	8.0	.6
	EXCAVATOR	.08 km	3.2	.3	3.3	.3	3.0	.3	1.9	.2
	DRILL	.02 km	.2	.1	.7	.2	.4	.1	1.7	.6
2. SURFACE	FRONT-END LOADER		.6	.1	.6	.1	.9	.1	-	-
	GRAVEL TRUCKS		.6	.2	.6	.1	.9	.2	-	-
	MEDIUM DOZER		.6	.1	.6	.1	.9	.1	-	-
	GRADER		.6	.1	.6	.1	.9	.1	MAINT.	.1
3. BRIDGES	LARGE DOZER		-	-	2 BR.	.2	-	-	-	-
	EXCAVATOR		-	-	2 BR.	.2	-	-	-	-
TOTAL, ROAD CONSTRUCTION			(9.2)	1.4	(9.7)	1.9	(10.0)	1.4	(9.9)	1.5
B. LOGGING: TO LANDING										
SYSTEM 1 TRAILS	MEDIUM CRAWLER	(600 m^3)	-	-	-	-	26.1	.3	-	-
FALL	FELLER-BUNCHER	300 m^3	-	-	-	-	"	.6	-	-
SKID	GRAPPLE SKIDDERS	120 m^3	-	-	-	-	"	1.5	-	-
SYSTEM 2 2(a) TR. & SKID (+R/W)	MEDIUM CRAWLER	90 m^3	7.8	.6	7.6	.6	18.1	1.4	4.2	.3
SYSTEM 3 TRAILS	MEDIUM CRAWLER	(440 m^3)	-	-	-	-	7.8	.1	6.1	.1
SKID (+R/W)	CHOKER SKIDDERS	100 m^3	-	-	-	-	"	.5	"	.4
SYSTEM 4 TRAILS + SKID	SMALL CRAWLERS	40 m^3	-	-	-	-	10.0	1.7	-	-
SYSTEM 5 YARD	CABLE YARDER	120 m^3	-	-	-	-	16.8	1.0	45.6	2.6
SWING (PART)	CHOKER SKIDDER	300 m^3	-	-	-	-	"	.4	"	1.1
SYSTEM 6 TRAILS	MEDIUM CRAWLER	150 m^3	-	-	-	-	-	-	13.2	.6
SKID, FORWARD	L.G.P. TRACK SKIDDER	(70 m^3)	-	-	-	-	-	-	"	1.3
TOTAL, LOGGING			(7.8)	.6	(7.6)	.6	(78.8)	7.5	(69.1)	6.4
C. LOADING:										
SYSTEM 1-6 LOAD	FRONT-END LOADER	350 m^3	-	-	-	-	62.0	1.2	23.5	.5
SYSTEM 5 LOAD	BOOM LOADER	240 m^3	7.8	.2	7.6	.2	16.8	.5	45.6	1.3
TOTAL, LOADING			(7.8)	.2	(7.6)	.2	(78.8)	1.7	(69.1)	1.8
D. HAULING, TOTAL	ON-OFF-HIGHWAY TRUCKS	90 m^3	(7.8)	.6	(7.6)	.6	(78.8)	6.1	(69.1)	5.3
TOTAL, LOG, LOAD, HAUL			-	1.4	-	1.4	-	15.3	-	13.5
TOTAL, ALL MACHINES			-	2.8	-	3.3	-	16.7	-	15.0

TABLE 9. - cont.

YEAR													
3		4		5		6		7		ALL		AVERAGE
(Q = km OR THOUSANDS m³)												
Q	MY	Q	MY	Q	MY	Q	MY	Q	MY	Q	MY	(Q/MY)
8.0	.6	6.6	.5	5.9	.5	MAINT.	.1	MAINT.	.1	47.9	3.9	12.31
3.4	.3	4.0	.3	3.0	.3	-	-	-	-	21.8	2.0	10.54
1.4	.5	.9	.3	1.0	.3	-	-	-	-	6.3	2.1	3.00
-	-	1.0	.1	.4	.1	-	-	-	-	3.5	.5	7.00
-	-	1.0	.2	.4	.2	-	-	-	-	3.5	1.0	3.50
-	-	1.0	.1	.4	.1	-	-	-	-	3.5	.5	7.00
MAINT.	.1	1.0	.2	.4	.2	MAINT.	.2	MAINT.	.1	3.5	1.2	2.92
-	-	-	-	-	-	-	-	-	-	2 BR.	.2	-
-	-	-	-	-	-	-	-	-	-	2 BR.	.2	-
(11.4)	1.5	(10.6)	1.7	(8.9)	1.7	(-)	.3	(-)	.2	(69.7)	11.6	6.01
-	-	-	-	16.2	.2	4.3	.1	-	-	46.6	.6	-
-	-	-	-	"	.4	"	.1	-	-	"	1.1	42.36
-	-			"	.9	"	.2	-	-	"	2.6	17.92
-	-	-	-	-	-	8.3	.6	2.6	.2	48.8	3.7	13.19
31.6	.5	31.1	.5	11.2	.2	8.7	.1	1.7	-	98.2	1.5	-
"	2.2	"	2.2	"	.8	"	.6	"	.1	"	6.8	14.44
16.7	2.9	24.9	4.3	15.2	2.7	-	-	-	-	66.8	11.6	5.76
34.8	2.0	34.2	2.0	44.1	2.6	40.5	2.3	44.1	2.6	260.1	15.1	17.23
"	.8	"	.8	"	1.0	"	.9	"	.8	"	5.8	-
-	-	-	-	-	-	-	-	-	-	13.2	.6	-
-	-	-	-	-	-	-	-	-	-	"	1.3	10.15
(83.1)	8.4	(90.2)	9.8	(86.7)	8.8	(62.0)	4.9	(48.4)	3.7	(533.7)	50.7	10.53
48.3	1.0	56.0	1.1	42.6	.9	21.5	.4	4.3	.1	258.2	5.2	49.65
34.8	1.0	34.2	1.0	44.1	1.3	40.5	1.2	44.1	1.3	275.5	8.0	34.44
(83.1)	2.0	(90.2)	2.1	(86.7)	2.2	(62.0)	1.6	(48.4)	1.4	(533.7)	13.2	40.43
(83.1)	6.4	(90.2)	7.0	(86.7)	6.8	(62.0)	4.8	(48.4)	3.7	(533.7)	41.3	12.92
-	16.8	-	18.9	-	17.8	-	11.3	-	8.8	(533.7)	105.2	5.07
-	18.3	-	20.6	-	19.5	-	11.6	-	9.0	(533.7)	116.8	4.57

TABLE 10. PRELIMINARY HARVESTING COST ESTIMATE AND SAWMILL

YEAR	CONSTRUCTION, ROADS AND LANDINGS			LOGGING			
	ROAD BUILT (km)	ANNUAL COST		LOCATION	SYSTEM	HA LOGGED	VOLUME m^3 (000)
		$/km	TOTAL $(000)				

ESTIMATES FROM THE ABOVE TABLE WOULD BE FOR DIRECT COSTS ONLY. IF THEY COME OUT TO, SAY $22.00/m^3$ FOR YEAR 1, AND OVERHEAD AND STUMPAGE ARE ESTIMATED AT $6.00/m^3$, THEN TOTAL HARVESTING COSTS ARE $28.00. IF FURTHER PROJECTIONS OF MILL COSTS AND REVENUES ARE THEN OBTAINED AS SHOWN, THE FINANCIAL CONTRIBUTION OF THE RAINBOW CREEK OPERATION IN YEAR 1 COULD BE CALCULATED ROUGHLY AS SHOWN IN THE TABLE TO THE RIGHT.

BASED ON MANY ASSUMPTIONS, THE HARVESTING OPERATIONS WILL ALLOW THE COMPANY TO REALIZE NET REVENUES OF ABOUT $408 000 BEFORE TAXES IN YEAR 1 OR ABOUT $5.21/m^3$ HARVESTED.

COST-REVENUE PROJECTION.

LOGGING COSTS				CONSTRUCTION & LOGGING	
ON TRUCK $/m³	HAULING $/m³	TOTAL $/m³	ANNUAL COST $(000)	ANNUAL COST $(000)	UNIT COST $/m³ LOGGED

PROJECTED COSTS AND REVENUES	LARGE-LOG MILL: PRODUCTION FACTORS	LARGE-LOG MILL: $(000)	SMALL-LOG MILL: PRODUCTION FACTORS	SMALL-LOG MILL: $(000)	COMBINED MILLS: PRODUCTION FACTORS	COMBINED MILLS: $(000)
LOG COSTS:						
VOLUME, m³ (000)	14.0		64.3		78.3	
HARVESTING COSTS, $/m³	$28.00		$28.00		$28.00	
$(000)		392		1 800		2 192
MILL COSTS (LUMBER & CHIPS):						
LUMBER RECOVERY FACTOR, MBM/m³	.210		.220		.218	
VOLUME SAWN, MBM	2 940		14 146		17 086	
MILL COSTS, $/MBM	$140		$120		$123.50	
$(000)		412		1 698		2 110
TOTAL HARVESTING & MILL COSTS		804		3 498		4 302
LUMBER REVENUES:						
AV. MKT. VALUE, $/MBM	$300		$250		$259	
$(000)		882		3 536		4 418
CHIP REVENUES:						
RECOVERY, B.D.U./m³	.120		.140		.136	
B.D.U.	1 680		9 002		10 682	
VALUE, F.O.B. MILL, $/B.D.U.	$24.00		$28.00		$27.30	
$(000)		40		252		292
TOTAL REVENUE BEFORE TAXES		922		3 788		4 710
REVENUES LESS COSTS:						
$(000)		118		290		408
$/MBM	$40.00		$20.50		$23.88	
$/m³	$8.43		$4.51		$5.21	

- scaling
- camp and/or shop
- crew transport
- engineering
- supervision
- road maintenance
- slash disposal, cleanup

Contract Operations

- Predict phase contract rates and apply to correct volumes.
- Add applicable company costs as in above list.

Combined Costs

- Combine company and contract operations for the total. It is important not to overlook cost items or to let them escape between the company and contractor categories. Small omissions have a way of accumulating into serious underestimates of total cost.

Table 10 illustrates a simple format for summarizing these preliminary cost estimates by year. For our hypothetical example, we will assume that the company can wait for more accurate overall costing based on intensified cruising, ground location surveys and stumpage appraisals to be done later on cutting permits. This portion of Table 10 is therefore not filled in. The remaining portion of Table 10 illustrates how the cost estimates for Year 1 could be combined with revenue projections to predict whether the woods and mill operations in Year 1 will be economically sound.

The timber development plan for the Rainbow Creek area is now complete and ready for implementation.

7. Reassess the Whole Plan

Now it is wise for the planner and others to review the whole development plan. This step may seem obvious, but must not be neglected in the rush to start operations.

One useful way to review a development plan is to work out ratios for comparison against previous experience. If ratios are unusually high or low, possible reasons should be looked for. If reasons are not found or not valid, further plan changes will be necessary. The MOF Appraisal Manual is a source of many cost and productivity ratios. Some simple operating and production ratios which can also be used to check a plan for gross discrepancies are shown in Appendix I. Ratios are derived from Tables 5, 6 and 9 for our hypothetical plan.

8. Planning Schedule

From our hypothetical illustration it can be seen that a "plan for the planning itself" is needed to control the many steps involved. The time for this is of course at the beginning, but discussion of this subject was delayed until now, when all the planning steps have been discussed.

The simplest form of planning schedule is the Gantt Chart, first popularized by Gantt in the 1930s. Figure 3 is an illustration based on Rainbow Creek. Twenty-three major planning phases are listed chronologically, commencing at the company decision to start development planning, moving to July of Year 0-2 with MOF approval of the development plan, and then moving to March of Year 0-1 with the start of operations on the first cutting permit. The time needed for each phase and the degree of overlap between phases are estimated and charted. The earliest feasible starting times for road construction and felling are shown near the bottom of Figure 3. Time allotted for MOF review and approvals is limited, to speed up the beetle salvage program.

The chart shows key dates dictated by circumstances or seasonal weather. The most important, of course, are the date when the company decides to start development planning and the date when cutting is expected to start. All other steps must be fitted between these two dates. The phases marked (*) are especially important, including:

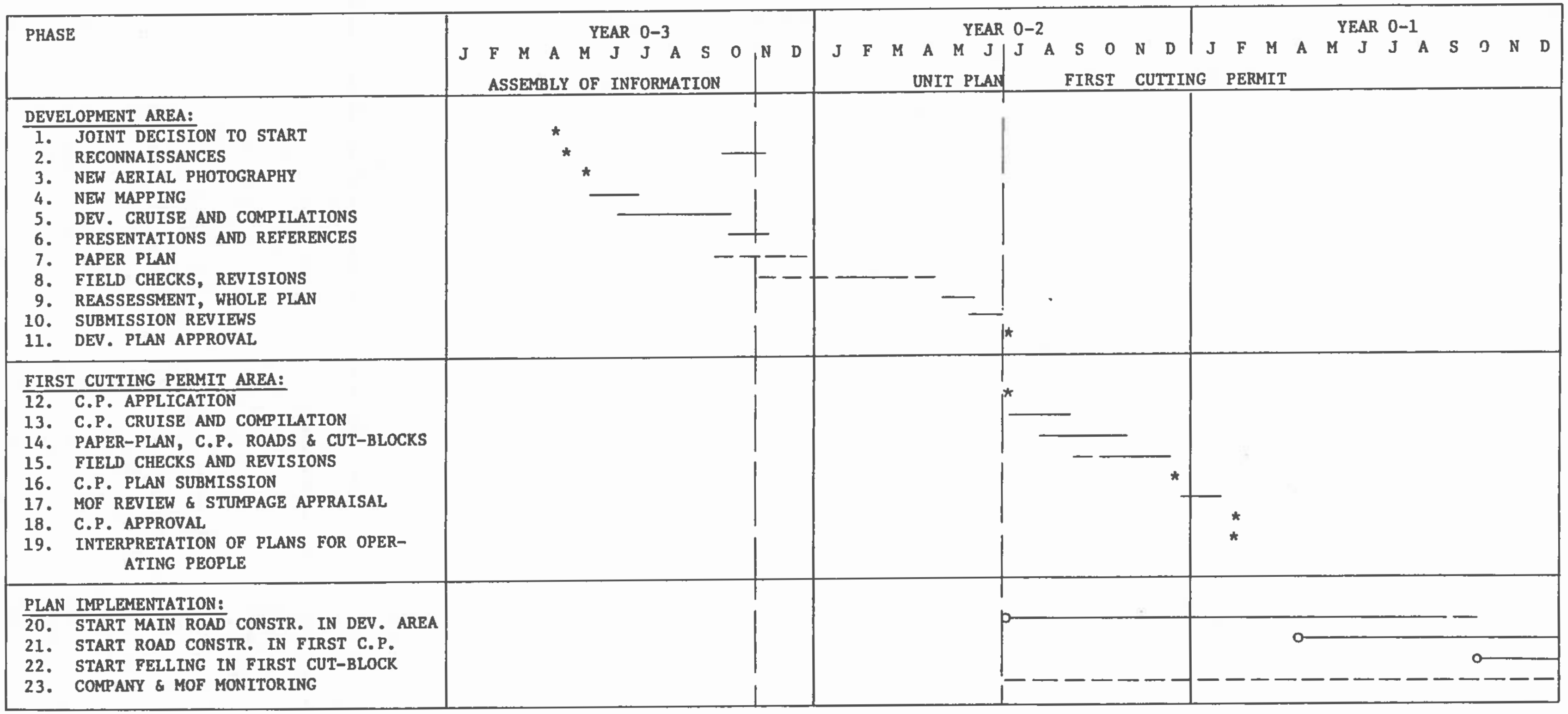
Phase 3 - New Photography - must be delayed until May to avoid long shadows and snow. Satisfactory existing photography would remove this limitation.

Phase 6 - Presentation and Referrals - further planning must not start until all potential problems are fully discussed and resolved between parties.

Phase 11 - Development Plan Approval - this marks the end of development planning and the start of cutting-permit planning.

Phase 18 - C.P. Approval - end of cutting permit planning and start of operational implementation and monitoring phases.

FIGURE 3. PLANNING SCHEDULE FOR ENTIRE DEVELOPMENT AREA AND FIRST CUTTING PERMIT.



*KEY EVENTS AT START AND END OF PLANNING.
oSTART OF OPERATIONS FOLLOWING MOF APPROVALS.

B. FOLLOW-THROUGH

We have just concluded a theoretical planning exercise. Despite efforts to keep our example simple, many complexities entered into the process. A real-life planning sequence would likely be even more complex.

What is gained by total-chance development planning? An extremely important gap has been filled, the gap between the strategic and operational planning levels. The whole drainage has been systematically mapped. Timber and terrain groupings have been identified accurately. Ways to reach and harvest all loggable stands have been found and an operating sequence has been worked out. Alternatives have been compared and trade-offs calculated to arrive at the best compromises. Critical points on the paper plan have been identified and field-checked systematically. The mill people know what species and size mixes to expect. Annual requirements for equipment and personnel have been roughed out. We have removed many uncertainties about the development area and are in a position to do further location and layout work with a confidence that we would not otherwise have. We know that we have looked at the total chance in the area.

What does a unit plan cost? If the area is extremely simple, much less mapping and paper planning would suffice. This was not the case in our example and a considerable planning investment has been made. Whatever was invested, however, would be less than the cost of a few kilometers of road in the wrong place or a misapplication of one of the harvesting systems.

What follows the development plan? Preparation and acceptance of a development plan is a major milestone. It is not intended to extend this handbook much further, except to note the subsequent steps which need to be understood to avoid duplication of effort. Normally the drainage would be broken into cutting permits for intensified cruising, road location and logging layout surveys and stumpage appraisal. A cutting permit normally covers about 3 years of cutting or about half of the drainage in our example. Perhaps C.P. 1 should cover the areas to be roaded up to Year 2 and C.P. 2 the remainder, in order that cruising and location crews can have road access within reasonable walking distance of their work. The development plan maps should already be suitable for C.P. work and ideally should require only minor alterations to correct discrepancies in timber types or topography found in the field. More detailed and accurate cruise summaries will be compiled and may call for changes in scheduling. Individual roads will be field-located and the survey results will provide more refined construction cost estimates. Individual cutting blocks will be laid out around these. Landings must be ground-located and in the case of cable settings, checked by the running of critical deflection lines. The silvicultural implications of the planned cutting block patterns must be reviewed and any necessary changes made.

When planning is done, the physical implementation of the plans can commence. This transfer from planning to operations is critical. If the doers have not participated until now, they will not accept the plan as theirs. It will remain a paper plan and will not materialize on the ground.

Throughout planning and reconnaissances the planner will notice specific sensitive or critical parts of the planning area. On one road section it may be important to maintain precise grade levels to clear an obstruction further on. A generally good logging area may include a wet patch requiring special care or winter skidding. It is essential that the planner pass on this sort of information to the foremen, contractors and operators. It will also be essential to walk critical areas together in the field.

Likewise, the Ministry people concerned should be briefed on the overall plan, and asked to look at specific problems when they arise. Ministry participation from the start will provide a proper context for future monitoring. Company participation will assure that future company planning anticipates Ministry concerns.

In our example, the time lapse between the start of planning and completion of all harvesting is about 10 years. If weather, insects, harvesting and milling methods, labour relations and government policies remain stable over this time, the unit plan could be executed exactly. This would be unusual, however. Unforeseen changes would almost undoubtedly cause the inheritors of the plan to change the harvesting pattern or schedule. The MOF Forest Planning Handbook is correct in stating (p. 11) that "There is no FINAL plan. Each plan charts a course of action only until the situation is reassessed". The planner should not be discouraged by this, since his development plan remains the basic structure around which orderly adjustments can be made.

CONCLUSIONS

Some degree of planning occurs before any cutting operation begins. The only question is how much and how elaborate. It is time consuming and confusing to overplan and attempt to leave no decisions to the operating people. It can also be a costly mistake to underplan. In this handbook we have tried to describe an appropriate level of total-chance planning for a relatively steep Interior drainage requiring co-ordination of road development with several harvesting systems. For simple areas the level of detail is too much; for complex areas, too little. The basic objective of all planning is to minimize uncertainties. Success in this will depend on:

- reliable maps and information for the drainage
- well-defined operating objectives
- group reconnaissance trips
- careful system choices
- thorough paper-planning and field-checking
- thoughtful review of all implications of the plan
- a readiness to change the plan for good reasons
- good communications between the planners, the doers and the government people
- the extent to which weather, markets and many other factors co-operate while the plan is being executed.

We hope this handbook will help you and your company to eliminate those uncertainties which can be eliminated and to deal wisely with the ones which remain.

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APPENDIX I. COMPARISON RATIOS DERIVED FROM RAINBOW CREEK DEVELOPMENT PLAN.*

QUANTITY OR RATIO	Unit	LOGGING SYSTEM			NET PER-SHIFT PRODUCTION RATES (180 SHIFTS/YEAR)
		GROUND SKIDDING	CABLE YARDING	COMBINED	
A. ROAD CONSTRUCTION:					
km Road By System	- km	41.7	28.0	69.7	
Area Logged per km Road	- ha/km	20	31	24	
Average Road Spacing	- m	200	310	240	
Volume per km Road	- m^3/km	1 280	9 560	7 660	
Machine Production, Subgrade only	- km/MY			11.8	65 m/shift/machine
Machine Production, Completed Road & Bridges	- km/MY			6.0	34 m/shift/machine
Man-Years (Excl. Superv., Support)	- myr			14	
Man-Yr. Prod., Completed Roads & Bridges	- km/myr			5.0	28 m/shift/man
B. LOGGING TO LANDING:					
Total Volume Logged	- m^3(000)	273.6	260.1	533.7	
Volume Logged per Hectare	- m^3/ha	318	304	310	
Volume Logged per Machine-Year	- m^3/MY	9 180	12 480	10 530	59 m^3/shift/machine
Man-Years	- myr			244	
Volume Logged per Man-Year	- m^3/myr			2 190	12 m^3/shift/man
C. LOADING:					
Volume Loaded per Loader-Year	- m^3/LY			40 430	225 m^3/shift/loader
Man-Years	- myr			13	225 m^3/shift/man
D. HAULING:					
Volume Hauled per Truck-Year	- m^3/TY			12 920	72 m^3/shift/truck
Man-Years	- myr			42	72 m^3/shift/driver
TOTAL ROADS AND HARVESTING:					
Volume per Machine-Year	- m^3/MY			4 570	25 m^3/shift/machine
Man-Years	- myr			313	
Volume per Man-Year	- m^3/myr			1 705	9.5 m^3/shift/man

*This table is intended only to illustrate the kinds of ratios which should be calculated to check a plan. Numerical values are peculiar to the example, and are not necessarily valid elsewhere.

APPENDIX II. DEFINITIONS OF TERMS AS APPLIED IN THIS HANDBOOK

A.A.C. - Annual allowable cut volume determined for a forest management unit.

Bucking - Cutting logs to specified lengths.

C.P. (Cutting Permit) - Specific portion of a unit, planned and appraised for approximately 2-3 years of harvesting.

C.R.M.P. (Coordinated Resource Management Plan) - A local plan for development of a forest area for mutual benefit of all public and private users, coordinated at the MOF District level.

Cruising - Determining stand timber volumes from field sampling.

Delimbing - Removal of limbs from cut trees or logs.

Development Area - Portion of TSA or TFL designated for timber development over several years.

Forest Region - Major subdivision of B.C. for forest administration. Interior regions are Kamloops, Nelson, Cariboo, Prince George and part of Prince Rupert.

FL (Forest Licence) - Fifteen-year replaceable cutting rights for a specified annual volume of Crown timber in a TSA. Licensee implements MOF forest management programs on licensee development areas.

Harvesting - General term for all work to develop, cut and transport wood to processing plants.

Leave stand - Mature timber to be left uncut under any plan, usually for site protection or economic reasons.

Licence - General term including TFL, FL or TSL tenure under Crown jurisdiction.

Licensee - Holder of a licence granting timber rights and requiring forest management.

Method (harvesting) - Way of accomplishing a harvesting phase. Usually named for the equipment chosen.

APPENDIX II - cont.

MOF (Ministry of Forests, or Forest Service) - B.C. Government ministry responsible for Crown forests. Offices at Victoria headquarters, Regions and Districts.

Operating Chance - Location, timber and terrain conditions which combine to make harvesting difficult or easy.

Phase (harvesting) - Separate segment of the work in developing, cutting and transporting timber.

Scaling - Determining log volumes by direct measurement or a combination of measurement and weighing.

Skidding (ground-skidding) - Moving trees or logs from felling site to roadside with wheeled or tracked vehicles.

System (harvesting) - Combination of harvesting methods used for a series of related phases. Eg. Feller-buncher/grapple skidder/ manual bucking/front-end loader.

TFL (Tree Farm Licence) - Twenty-five-year replaceable cutting rights for a specified area of Crown and/or private forest. Licensee has responsibility for forest management.

TFL M & WP (TFL Management and Working Plan) - Long-term licensee timber-supply and forest management strategy for a TFL. Similar to TSA plans for non-TFL lands. Updated every 5 years by TFL licensee.

T.S.A. (Timber Supply Area) - Major portion of a Forest Region with a concentration of timber-processing plants and a major transportation network for a flow of timber to them.

T.S.A. Plan - Long-term MOF timber-supply and forest management strategy for a T.S.A.

T.S.L. (Timber Sale Licence) - Short-term cutting rights on a fixed timber area. Forest Service has responsibility for forest management.

Yarding - Moving trees or logs from felling site to roadside with cable winch or helicopter.

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