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FOREST HARVESTING AND RENEWAL PLANNING FOR THE BRITISH COLUMBIA INTERIOR: AN EXTENSION OF THE TOTAL-CHANCE CONCEPT

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Abstract

Handbook No. 9 is a sequel to Handbook No. 4, *Timber Development Planning for the British Columbia Interior: The Total-Chance Concept*, which was published by the Forest Engineering Research Institute of Canada (FERIC) in 1983. Handbook No. 4 described the steps required at that time to prepare a total-chance harvesting development plan, using the fictitious Rainbow Creek (in British Columbia) as a model. Handbook No. 9 describes how timber-development operations might have progressed since 1983, and what new factors must be incorporated into onward planning in response to new technologies, attitudes, guidelines, and policies affecting forest management.

A new plan and operating schedule illustrates how the Rainbow Creek road-construction and harvesting programs should continue under new constraints. To this is added a detailed plan and schedule for forest-renewal operations, now the direct responsibility of the forest company. Examples show how all operations can be integrated for best field results and profitability.

The remarkable capabilities of recent geographic information system (GIS) technology are demonstrated, as planning progresses through the stages of initial preparation, optimization, review, modification, presentation, and approval.

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- Selected harvesting and silvicultural specialists in the forest industry and government, throughout the forest regions of British Columbia, for outlining their local experience in planning and conducting integrated harvesting and silvicultural operations. FERIC contacted these people through personal visits and/or by telephone. Their names appear in Appendix IV.
- Andrew Mitchell of the British Columbia Ministry of Forests, for demonstrating that the right geographic information system can be of immense value for creating and refining total-chance plans.
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Author

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Disclaimer

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Summary

In 1983, the Forest Engineering Research Institute of Canada (FERIC) published Handbook No. 4, *Timber Development Planning for the British Columbia Interior: The Total-Chance Concept.* It described the efforts of an imaginary forest company to create a timber-development plan for the fictitious Rainbow Creek drainage in British Columbia. The handbook was well received as a checklist of the many steps needed "to eliminate all the uncertainties which can be eliminated, and to deal wisely with the ones which remain" (Breadon 1983).

Momentous changes have since occurred in British Columbia's Crown forest policies, in industrial forest-management objectives and responsibilities, in public attitudes toward forests, and, of course, in the forests themselves. This new Rainbow Creek report extends the total-chance concept to include silviculture and all other resource programs affecting a forest. Applied computer technology, i.e. a geographic information system (GIS), is used to help make integrated resource management decisions.

Integrated planning is complex and subject to revision, and integrated resource management decisions are often difficult to make. The Rainbow Creek model demonstrates some of this complexity and changeability. For Rainbow Creek, this report traces the complex process of forest harvesting and renewal planning:

- Planning for completion of the PASS 1 roads and harvesting operations.
- Planning forest-renewal operations on the openings created during PASS 1.
- Predicting the economic implications of these plans.
- Finding the alternatives which best integrate harvesting and renewal operations, to achieve the best possible results on the ground at the lowest aggregate costs.
- Confirming that PASS 2 operations will be viable.
- Putting the perfected plan through the steps leading to official approval.

There will never be a final plan for Rainbow Creek. There can only be a series of plans, each updated from the last, and all serving the current needs of the company, the Crown, and all other users of Rainbow Creek's timber and non-timber resources. The total-chance concept, applied systematically with the best available tools, can assist forest managers in making wise integrated resource management decisions.

MAP 1. TOPOGRAPHY AND TIMBER TYPES

SCALE 1:20 000

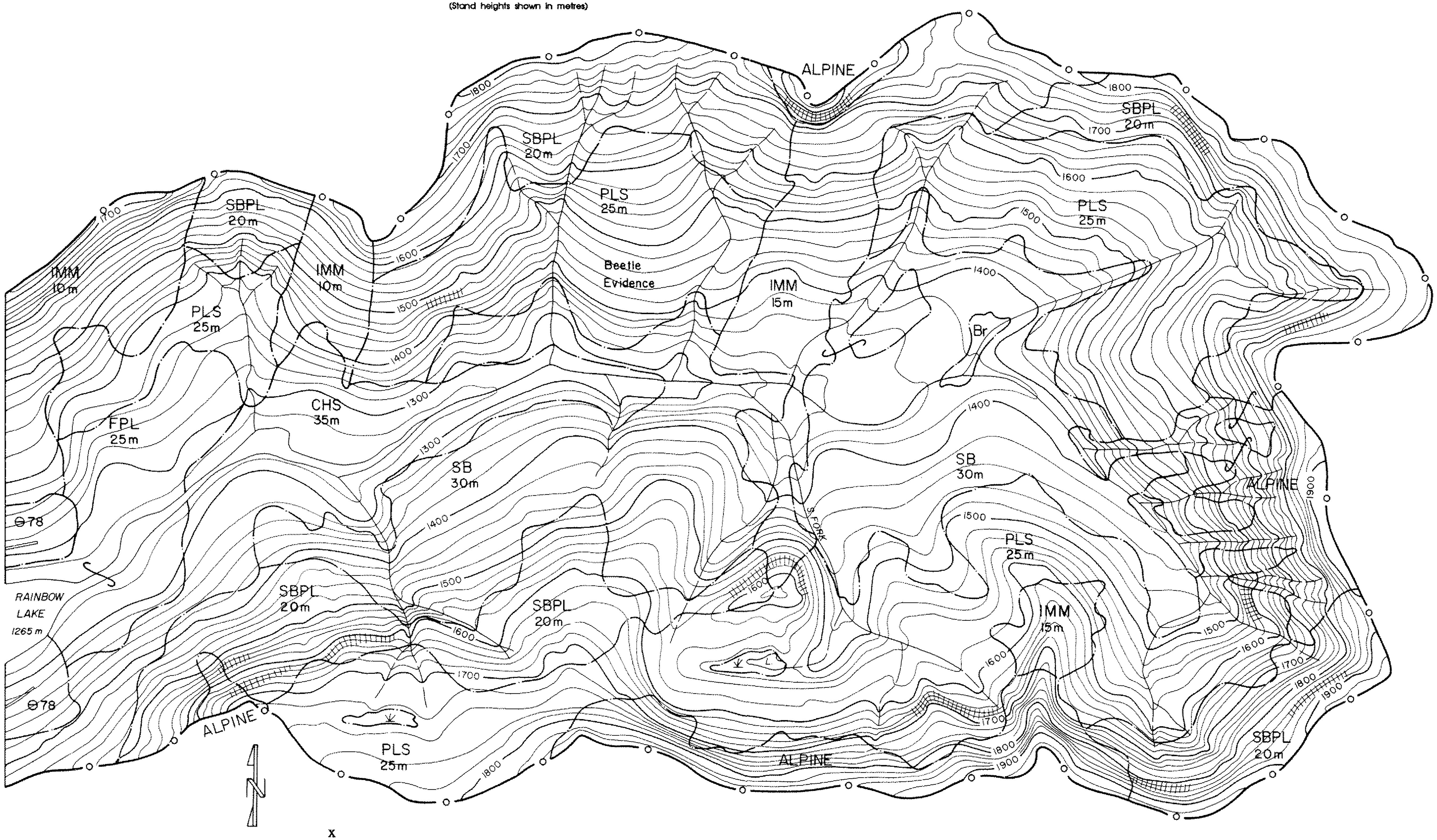
0 200 400 600 800 1000
Metres

CONTOUR INTERVAL: 20 m

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 HARVESTING OPERATIONS

SCHEDULE: ROADS AND HARVESTING

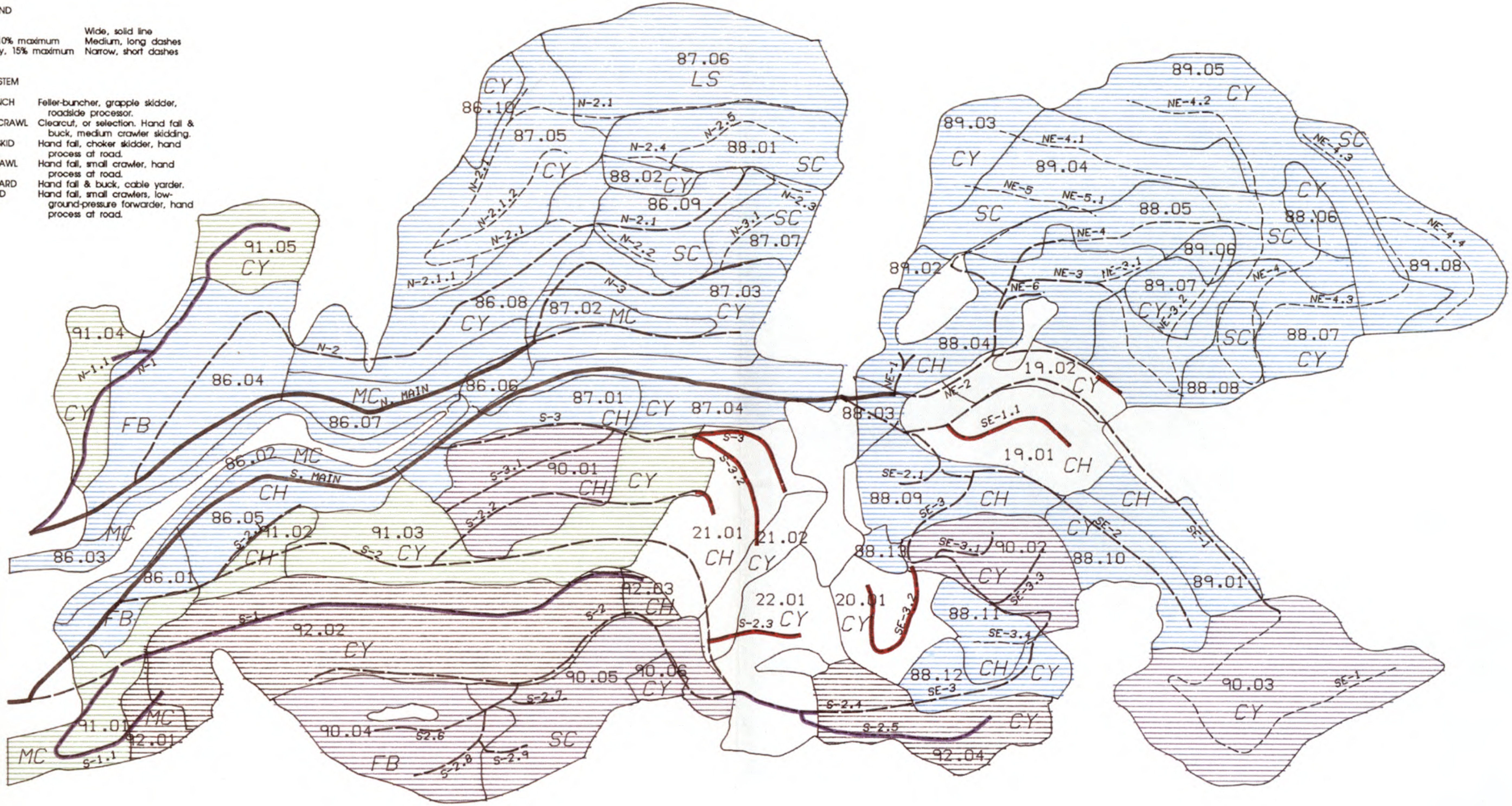
YEAR	ROAD CONSTRUCTION	HARVEST
PASS 1: 1984-1989	black	light blue
PASS 1: 1990	purple	purple
PASS 1: 1991	none	green
PASS 1: 1992	none	brown
PASS 2: 2017-2022	red	uncoloured

ROAD LEGEND

Main	Wide, solid line
All-season, 10% maximum	Medium, long dashes
Summer only, 15% maximum	Narrow, short dashes

HARVEST SYSTEM

FB = FELBUNCH	Feller-buncher, grapple skidder, roadside processor.
MC = MEDCRAWL	Clearcut, or selection. Hand fall & buck, medium crawler skidding.
CH = CHOSKID	Hand fall, choker skidder, hand process at road.
SC = SMCRAWL	Hand fall, small crawler, hand process at road.
CY = CABYARD	Hand fall & buck, cable yarder.
LS = LGPSKID	Hand fall, small crawlers, low-ground-pressure forwarder, hand process at road.

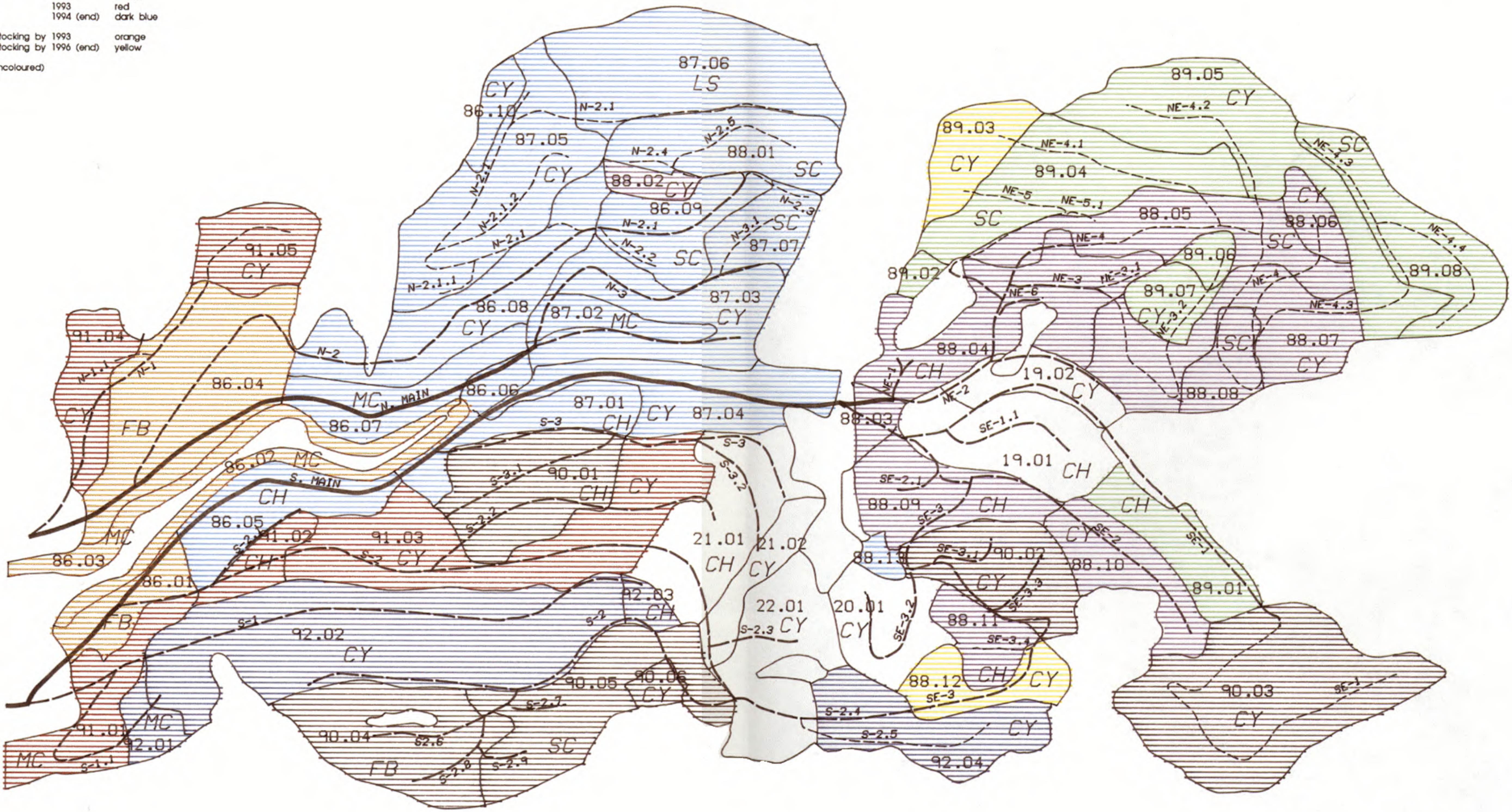


MAP 3. REFORESTATION OPERATIONS

PASS 1: PLANTING & NATURAL RESTOCKING SCHEDULE

Planting completed	1988-89	light blue
Plant by	1990	purple
Plant by	1991	green
Plant by	1992	brown
Plant by	1993	red
Plant by	1994 (end)	dark blue
Natural restocking by	1993	orange
Natural restocking by	1996 (end)	yellow

(PASS 2: Uncoloured)



INTRODUCTION

In 1983, the Forest Engineering Research Institute of Canada (FERIC) published Handbook No. 4, *Timber Development Planning for the British Columbia Interior: The Total-Chance Concept* (Breadon 1983). It illustrated the orderly planning of timber-harvesting operations for a fictitious drainage called Rainbow Creek, somewhere in British Columbia. The total-chance planning concept was demonstrated, both as a way to avoid the dangers of piecemeal development and to ensure that harvesting operations over the entire drainage would satisfy all recognized objectives.

Since 1983, significant changes in forest management have occurred. New government forest policies and regulations require intensified planning and integration of road development, harvesting, and forest-renewal operations. Silvicultural programs and expenditures have mushroomed. Integrated resource management programs have placed greater emphasis on land uses other than timber extraction. The total-chance concept, originally focused on timber harvesting, obviously should now extend into silviculture and all other resource programs affecting a forest.

The objectives of this 1989 project were to:

- Develop a framework for broadening the total-chance concept to include planning for the other programs which must now complement the timber-development and harvesting plans, within the context of integrated resource management for the 1990s.
- Accomplish this by revisiting Rainbow Creek, observing what has occurred since 1983, and preparing a new, more comprehensive plan for both timber development and forest-renewal operations.
- Prepare a sequel to FERIC Handbook No. 4, illustrating the extended total-chance planning process.

This project complements a 1989-90 series of integrated resource planning seminars conducted throughout British Columbia by FERIC (1990).

More than ever, people in British Columbia want to know what is happening in their forests. Integrated planning is complex and subject to revision, and integrated resource management decisions are often difficult to make. The Rainbow Creek model will demonstrate some of this complexity and changeability, even though it was deliberately kept simple for illustration purposes.

The total-chance concept, applied systematically with the best available tools, can assist forest managers in making wise planning decisions, and in explaining these decisions to others.

RAINBOW CREEK REVISITED

Map 1, reproduced from FERIC Handbook No. 4, shows Rainbow Creek's topography and original forest cover at a scale of 1:20 000. Additional maps in Handbook No. 4 (not reproduced here) outlined areas to be harvested by different harvesting systems, and the required road network; the road-building and harvesting programs originally planned for each year were colour coded. The road-building program was to span seven years, between Year 0-2 and Year 0+5. The harvesting program was planned to lag approximately two years behind the roads, commencing in Year 0+1 and ending in Year 0+7.

If we assume that the total-chance plan in Handbook No. 4 was approved late in 1983, then road-building would have commenced in 1984, corresponding to Year 0-2. Harvesting would then have started in 1986 (Year 0+1). Harvesting operations would continue through 1992, and then move elsewhere.

Prevention of unnecessary soil disturbance in Rainbow Creek operating areas is a continuing concern. Further road construction, harvesting, and forest-renewal operations will be governed by the new *Interim Harvesting Guidelines for the Interior of British Columbia* (British Columbia Ministry of Forests 1989). The *Interim Harvesting Guidelines* were developed by the Interior Forest Harvesting Council, which consists of representatives from the forest industry, British Columbia Ministry of Forests, Forestry Canada, and FERIC. Following a two-year trial period and subsequent modifications, the *Guidelines* will become Ministry policy.

Although a detailed discussion was not presented in Handbook No. 4, forest-renewal and standimprovement operations would have followed harvesting, on schedules appropriate for the treatments prescribed. Under the company's Forest Licence tenure, the company has been undertaking forest-renewal operations, chiefly site preparation and planting, subject to Ministry approval and reimbursement under Section 88 of the Forest Act.

In 1987, the Forest Act (British Columbia Ministry of Forests 1989) was amended to make silvicultural prescriptions, treatments, and costs a licensee responsibility, not a Ministry responsibility, on areas harvested after October 1987. This licensee responsibility would be discharged only after establishment, according to Ministry standards, of a free-growing new crop.

Obviously, an updated total-chance plan for Rainbow Creek is now needed, to integrate forest-renewal with the harvesting operations, and also to satisfy non-forestry requirements which are becoming more sharply defined.

Let us revisit Rainbow Creek, and review what has "happened" since timber-development operations started in 1984. Then let us "plan" what should happen to complete the current cycle of development, harvesting, and forest renewal.

EVENTS SINCE 1984

It is now late in 1989. In an imaginary drainage, it is tempting to relate a story about spectacular wildfires, insect rampages, economic catastrophes, or anti-logging campaigns occurring since the 1983 total-chance plan went into effect. However, this revisitation is intended to illustrate how road-development, harvesting, forest-renewal, and other programs would unfold under more normal circumstances—not exactly according to the original plans, but not so different as to dictate entirely new plans.

Road Construction

Road development and harvesting followed the original planning and scheduling closely. Road construction from 1984 through 1987 proceeded on schedule. In 1988 and 1989, for reasons which will be explained, portions of several branch and spur roads were not built. The complete set of roads built by the end of 1989 is shown on Map 2 (Roads and Harvesting Operations).

Unit costs for road construction gradually increased with inflation. However economies of scale and improvements in the productivity of construction machines partially offset normal inflation rates, resulting in a net increase in road costs of 2% annually. Appendix I lists the roads and bridges built from 1984 to 1989 and shows construction costs as experienced. Roads not yet built (1990+) are also shown, with 1989 estimates of their construction costs.

Harvesting

Harvesting commenced in 1986, and for the most part followed the original total-chance plan through 1989. Prompt 1986 and 1987 salvage harvesting stopped an incipient mountain pine beetle infestation on Blocks 86.09 and 87.03 (Map 2).

Inevitably there were departures from the original plan, and some of these are noteworthy. For example, a 1985 lightning fire burned 6.9 ha of timber on the north slope, which became accessible when road N-2.1 was built, also in 1985. The fire-killed timber was salvaged in 1986 (see Block 86.10 on Map 2), rather than cut normally in 1987 as scheduled. To offset this, a 16.8-ha stand scheduled for cutting in 1986 was left uncut until 1987 (see Block 87.07 on Map 2).

Also, the original plan called for removal of all economically accessible mature timber. Since then, downstream settlement has brought on the need to manage Rainbow Creek as a part of a permanent domestic water supply. Although the selection system prescribed for Blocks 86.02 and 86.03 has successfully protected the integrity and water quality of the main creek, concerns about the extent of further clearcutting upstream were expressed in 1987. In 1988, the company agreed to defer scheduled cutting on selected areas originally scheduled for harvesting between 1989 and 1992.

The areas deferred for domestic water supply consideration are openings with 19, 20, 21, and 22 prefixes (i.e. Blocks 19.01 to 22.01) on Map 2. The new numbering signifies that the blocks will now be left uncut until the years 2019 to 2022, some 30 years beyond the dates originally scheduled. At that time they will become part of a PASS 2 harvest. PASS 2 may also include a second cut in Blocks 86.02 and 86.03, which were selectively cut in 1986, and harvesting of presently immature stands which will have matured by then.

Except where needed to reach PASS 1 blocks, roads to the PASS 2 blocks will not be built until about two years before harvesting occurs. Construction of Roads SE-1.1, SE-3.2, S-3.2, and part of S-3 will be deferred until the year 2017.

Although there is an economic cost associated with this lengthy pause in harvesting, the company accepts it. The timber on the PASS 2 blocks is mature, but not decadent, and is not expected to deteriorate. Fortunately, harvesting rights held elsewhere by the company can substitute for the 1989-92 reduction in the Rainbow Creek cut. Other land users and managers are impressed with the company's cooperative attitude and will in turn tend to be cooperative during future dealings.

Changing Players

The original total-chance development plan was compiled by "Planning" Peter. Peter has now become "Super" Peter, Area Supervisor responsible for all development, harvesting, and silvicultural operations in Rainbow Creek and several other nearby drainages. Peter relies on "Books" Bill to keep him well informed on the current and projected finances of all parts of the operation. Bill also understands the capabilities of computers.

"Roads" Robbie and "Logs" Louie supervise the road-development and harvesting operations in the field. With their help, "Trees" Tom now does the onward timber-development planning for the area, as well as the planning, prescribing, and field supervision of the growing silvicultural program.

Roads Robbie and Logs Louie depend entirely on contractors for road development and logging in Rainbow Creek. "Cutbank" Charlie and "Hotlogs" Harry were among the original contractors in the drainage. They were successful, grew in size, and joined forces to form C & H Contracting Ltd. C & H now does all road construction and all harvesting, with the exception of cable yarding and small crawler blocks which are handled by "Cables" Chris and "Smallcat" Sam, respectively. "Trucks" Tony handles all log hauling at present. All of these contractors move between Rainbow Creek and other nearby operations, as needed.

Similarly, Super Peter and Trees Tom have developed a network of silvicultural contractors who have local experience in prescribed burning, mechanical site preparation, tree planting, brush control, or juvenile spacing. These include:

- Two local helicopter services, Upland Helicopters Ltd. and Silvicopter Services Ltd., which have slashburning and aerial herbicide spraying expertise.
- C & H Contracting, which often uses its construction and harvesting machines to do slashburning and mechanical site preparation projects on the same blocks that the machines have logged.
- MSP Contracting, which specializes in mechanical site-preparation projects.
- Greenwood Silviculture Contracting, Newforest Silviculture Services, and several other silvicultural contractors which compete for planting, ground herbicide application, brushing, and juvenile spacing contracts.

Trees Tom hopes that his support of local contractors will result in the emergence of longer-term, multi-function, "stewardship" arrangements to ensure balance and continuity of the company's forest-renewal programs. Under such an arrangement, a single contractor might undertake, on a specified area, all the surveys, site preparation, reforestation, and juvenile tending operations needed to progress from harvesting of the old crop to the free-growing stage of the new crop.

Integrated Resource Management

In the early 1980s, Rainbow Creek was included in a Coordinated Resource Management Plan (CRMP), developed cooperatively by forestry, mining, recreation, and range users within a larger area. This plan brought together the interested parties, identified broad use patterns, and served its purpose well; but, it needs to be modernized. Many more people—users of a wide range of resources for livelihood or recreation—are drawn to the Rainbow Creek area by the new road access.

The federal, provincial, and municipal agencies with jurisdiction over resources have changed. The Ministry of Forests now expects the company to deal directly with those government agencies that might be affected by company activities. Agency personnel have been changing jobs and relocating. Those Peter and his staff deal with most frequently are:

- Timber, engineering, appraisals, silviculture, protection, recreation, range, and other Ministry of Forests people at the Forest Region and Forest District levels.
- Water management, recreational fisheries, wildlife, and other people at the Ministry of Environment Region and District offices.

Peter and his staff realize that no list of interested parties stays the same for long, and that other government, industry, or private agencies are likely to become interested in Rainbow Creek at future developmental stages. They know that demands for detailed information about the company's plans and activities can only increase. They are seeking a planning vehicle which will help them respond promptly to these demands. More importantly, this planning vehicle must be ready when the company itself needs reliable data as a basis for good forest-management decisions.

Forest-Renewal Operations

When the first total-chance plan was prepared, the classification of Interior forest ecosystems was at an early stage of development. Since then, major advances have been made throughout British Columbia, including work in the Southern Interior (Utzig et al 1986, Lloyd et al 1990). Proper identification and interpretation of the ecosystem has become a basis for prescribing silvicultural treatments. Before a cutting permit is issued, a Preharvest Silviculture Prescription (PHSP) must be prepared by the company and approved by the Forest District manager, for each proposed cutblock or treatment unit therein.

The PHSP is a site-specific detailed document that commits the company to specified silvicultural treatments and results. Licensees are reluctant to prepare highly detailed PHSPs much more than a year or two in advance of harvesting, and thus the silvicultural component of a total-chance plan that spans several years cannot be based entirely on PHSPs. As an alternative, Trees Tom has divided the area into generalized ecological units and planned a series of treatments for each. At the same time, he has developed a set of approximate treatment costs, upon which to base future silviculture budgeting. In the meantime, post-harvest site preparation has started on blocks harvested in 1986, 1987, and 1988, followed by reforestation on some of them.

The entire forest-renewal component of the total-chance plan is described later.

GIS Breakthrough

The maps and calculations in FERIC Handbook No. 4 were prepared by conventional drafting and compilation methods, even though it was obvious that computer technology would be indispensable on large-scale complex applications. Since that time, geographic information system (GIS) packages for forestry applications have been developed for use with relatively inexpensive microcomputers. For example, an investment of about $100 000 might pay for a consultant to select the appropriate GIS system, assemble the necessary data in digital form, and complete a pilot planning project. A further $60 000 might pay to install in-house software and hardware. Finally a team of data collectors, hardware operators, and users within the system—often the same people, changing roles as needed—must become adept at exploiting the new system. The time and money necessary to achieve this will vary widely in relation to the scale and complexity of the GIS application.

Once the system is operating, essential planning can be done with major savings in time and cost. Previously impractical "what-if" trials can now be simulated easily on the computer, and will help in making the best management decisions.

Let us suppose that the company is considering the purchase of the necessary hardware and software for one of these GIS packages. One option of particular interest, developed by the Integrated Resources Branch of the British Columbia Ministry of Forests, is called *Harvest Management System (HMS)*.[1] It is described in detail by Mitchell (1989). *HMS* is an application of the widely used *Terrasoft* system, developed and

[1]FERIC currently provides a training course for prospective *HMS* users, under a British Columbia Ministry of Forests contract.

supported by Digital Resources Systems (Canada) Ltd. of Nanaimo, British Columbia.

As Books Bill understands it, the steps needed to make an *HMS* model of Rainbow Creek are as follows. Using a digitizer, technicians "trace" all map detail (boundaries, topography, environmentally sensitive areas, forest cover, roads, system boundaries, separations by year of harvest) from the original maps into the computer's memory and onto the colour monitor screen.

In this application, a "cutblock" or "block" is defined as a polygon to be harvested by one harvesting system, in one year. It is surrounded by polygons of differing systems or years, or by areas not to be harvested within the planning period.[2] Each block is given a sequential number. Numerical or text information for each block is supplied by keyboard entries or from tables stored in memory. This information is also linked automatically to the map cells contained within the polygon for the block. The information includes:

- Block number
- Year of harvest
- System name (FELBUNCH, MEDCRAWL, CHOSKID, SMCRAWL, CABYARD, or LGPSKID, as defined later)
- Clearcut or partial cut
- Hauling times, load sizes, and hourly costs
- Share of branch or spur road costs borne by block
- Falling and processing—expected production and direct costs per shift
- Skidding or yarding—expected production and direct costs per shift
- Loading—expected production and direct costs per shift
- Block rehabilitation costs (omitted in this case for simplicity)
- Fixed costs borne by block (omitted in this case for simplicity).

In addition, tables containing net m^3/ha and species breakdown for each timber type are stored and used internally to calculate species and total volumes by block. Block area, in hectares, is automatically computed and stored by *HMS*. As an option, *HMS* can store customized tables specifying, for each species, estimated percentages by log grade, and corresponding per-m^3 values, delivered to mills. From these, timber values are computed for comparison with extraction costs. Summaries of areas, volumes, and costs can be produced for single blocks, and for combinations defined by attributes such as main road, year of cutting, harvest system, or subrange within the entire range of per-m^3 cost.

Maps 2 and 3 are examples of *HMS* plotter output. Appendix II shows a sample of printer output for the 15 blocks remaining for PASS 1 harvesting.

NEW RAINBOW CREEK PLAN, 1990+

Map 2 shows the blocks already harvested up to the end of 1989, in pale blue. Some of these are in early stages of forest renewal; others were harvested recently, and have yet to enter the forest-renewal cycle. The remaining coloured blocks are mature stands still available for cutting (purple for 1990, green for 1991, and brown for 1992).[3] Some of these blocks still require road construction (see roads coloured purple).

Completion of PASS 1 Road Construction

The Rainbow Creek construction program has proceeded largely as originally planned, and should be completed at the end of 1990. Figure 1 illustrates the construction phases and machines employed.

Since 1984, the role of the tracked excavator in road work has expanded, and that of the crawler tractor diminished. However, some of the roads planned for 1990 will be on steep thin-soiled terrain, favouring teamwork by the rock drill and medium crawler. The numbers of shifts required for all machine types, for both construction and road maintenance, are shown later (Table 4a).

---

[2]When the "block" has been harvested, it becomes an "opening," awaiting forest renewal.

[3]The colour codes in Map 2 are the same as those used in FERIC Handbook No. 4 for the years 1990-92, so that the original and revised scheduling can be compared.

The expected cost of each road was originally estimated in 1983. Cutbank Charlie built the 1984 and 1985 roads and bridges under contract, for which the company paid $256 900 and $396 234 respectively. Charlie (now C & H Contracting) continued this construction program on schedule, and for the costs shown in Appendix I, until the end of 1989. Total expenditures to the end of 1989 were $2 155 219, or $37.51/m (i.e. $37 510/km).

In 1988 the company decided to reserve certain watershed buffer areas for PASS 2 harvesting (Map 2, uncoloured blocks). This meant that C & H would finish the 65.85 km of PASS 1 road development in 1990, at an estimated total cost of $2 504 992 or $38.04/m.

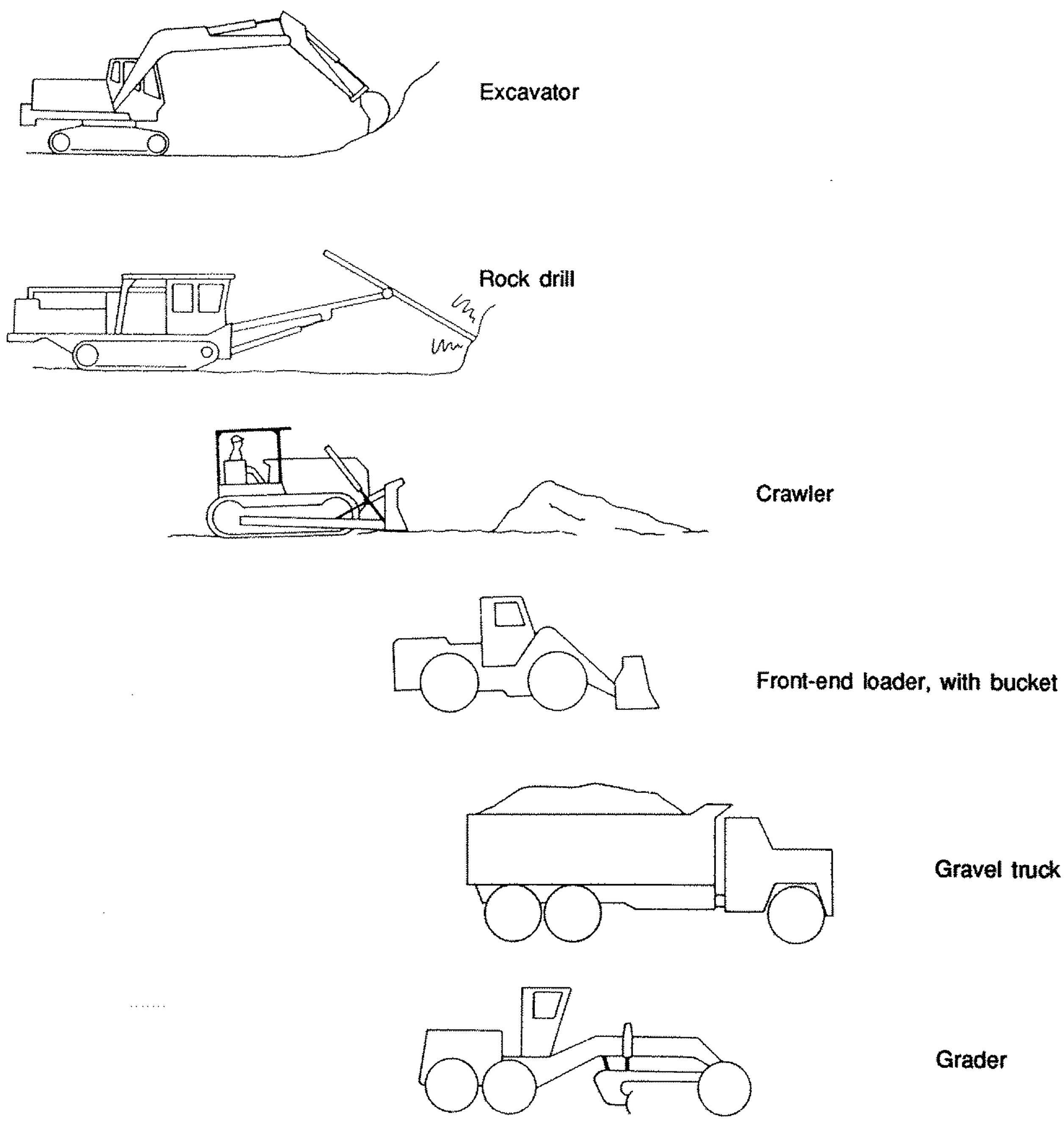


Figure 1. Machines required for constructing and maintaining log-hauling roads.

Appendix I is a complete listing of all Rainbow Creek roads already built or proposed, showing:

- Year built
- Road name
- Length in metres
- Cost as built (from 1984 to 1989), or estimated future cost (in 1989 dollars)
- Equivalent cost in \$/m of length.

From the start of construction, PASS 1 road costs have been written off as follows.

The capital cost of \$322 100 for the north main road, the south main road, and the bridges was charged against the total volume harvested during PASS 1. The cost per m^3 cut is

$$\frac{\$322\ 100}{470\ 054\ m^3} = \$0.69/m^3.$$

The cost of the main road system will thus be written off by 1992, and not carried on to the conclusion of PASS 2 harvesting.

The cost of branch and spur roads was distributed over the blocks each road developed, on the basis of proportional length needed to access each block. Roads Robbie's rather lengthy *Lotus* spreadsheet for these calculations is not shown.

Table 1 is a schedule and budget for the completion of all roads. Using 1989 rates for costing, the remainder of PASS 1 roads will be completed in 1990 and will cost \$349 773, or \$41.64/m. Because they will be built in 1990, however, the discounted cost in 1989 is slightly lower, i.e. \$328 425, or \$39.10/m.[4] Roads S-2.5 and N-1 are expected to cost more than average because they will traverse steep terrain and will require extensive rock drilling and blasting.

Table 1 also shows cost estimates for PASS 2 roads, although these roads will not be built until the years 2018-2019. At 1989 rates, their cost is estimated at \$118 779, or \$31.67/m. All PASS 2 roads will traverse moderate terrain, and will cost less per metre than the average for PASS 1 roads. Since they will not be built for 29-30 years, their discounted present cost is much less, at only \$18 488, or \$4.93/m.

Completion of PASS 1 Harvesting

Harvesting Systems. Six harvesting systems were defined for Rainbow Creek in 1983. These were numbered from 1 to 6 at that time, but renamed for *HMS* purposes as follows:

- FELBUNCH (FB on Map 2)—Feller-buncher; wheeled grapple skidder to road; manual delimb and buck at roadside (now mechanized with a roadside processor); boom-type loader.
- MEDCRAWL (MC on Map 2)—Clearcut or selection system. Hand fall, buck and delimb partly at stump and partly at roadside; medium crawler skid to road; wheeled front-end loader.
- CHOSKID (CH on Map 2)—Hand fall; wheeled choker (i.e. line) skidder to landing; manual delimb and buck at landing; wheeled front-end loader.
- SMCRAWL (SC on Map 2)—Hand fall; small crawler skid to landing; manual delimb and buck at landing; wheeled front-end loader, heel-boom loader, or self-loading trucks (depending on landing).
- CABYARD (CY on Map 2)—Hand fall, delimb and buck partly at stump and partly at roadside; small mobile cable yarder; wheeled front-end loader, heel-boom loader, or self-loading trucks, depending on landing space.
- LGPSKID (LS on Map 2)—Hand fall; small crawler primary skid to concentration points; low-ground-pressure tracked skidder swing to landing; manual delimb and buck at landing; wheeled front-end loader. (This system was used with moderate success in 1986, and discontinued thereafter.)

Figures 2 to 7 illustrate the types of equipment used in each system.

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[4]Discounting of future expenditures was recommended by Forestry Canada as a device for costing, on an equitable basis, projects to be paid for at differing times in the future. The discounted cost can be regarded as the estimated amount which must be set aside now, in order to pay for a future project. The discount rate, 6.50% real compound interest, was also suggested by Forestry Canada, to reflect expected lending rates, less inflation.

Table 1. Road-Completion Schedule and Budget (1989 Dollars, Discounted to 1989 from Year of Construction)

Year and road	Length (m)	Estimated cost of construction: Original estimate	Estimated cost of construction: 1989 estimate	Estimated cost of construction: $/m	Discounted cost: 1989 $	Discounted cost: 1989 $/m
Remainder of PASS 1 roads						
1990 S-2.5	1 000	$60 000	$66 245	$66.24	$62 202	$62.20
1990 S-1 (B)	2 750	$95 200	$105 108	$38.22	$98 693	$35.89
1990 N-1.1	300	$7 200	$7 949	$26.50	$7 464	$24.88
1990 S-1.1	1 300	$48 400	$53 438	$41.11	$50 176	$38.60
1990 S-2.4	900	$19 800	$21 861	$24.29	$20 527	$22.81
1990 N-1	2 150	$86 200	$95 172	$44.27	$89 363	$41.56
Total remainder PASS 1	8 400	$316 800	$349 773	$41.64	$328 425	$39.10
PASS 2 roads						
2018 SE-3.2	800	$31 600	$34 889	$43.61	$5 618	$7.02
2018 NE-2	200	$4 640	$5 123	$25.61	$825	$4.12
2018 SE-1.1	700	$12 600	$13 911	$19.87	$2 240	$3.20
Subtotal 2018 roads	1 700	$48 840	$53 923	$31.72	$8 682	$5.11
2019 S-3.2	600	$22 629	$24 984	$41.64	$3 777	$6.30
2019 S-3	700	$15 842	$17 491	$24.99	$2 644	$3.78
2019 S-2.2	150	$4 500	$4 968	$33.12	$751	$5.01
2019 S-2.3	350	$8 400	$9 274	$26.50	$1 402	$4.01
2019 S-3.2	100	$3 771	$4 164	$41.64	$630	$6.30
2019 S-2.3	150	$3 600	$3 975	$26.50	$601	$4.01
Subtotal 2019 roads	2 050	$58 742	$64 856	$31.64	$9 805	$4.78
Total PASS 2 roads	3 750	$107 582	$118 779	$31.67	$18 488	$4.93

***Harvest Management System (HMS)* Analyses.** Trees Tom has been updating the maps and data from the original 1983 total-chance plan, to give Super Peter, Roads Robbie, Logs Louie, and himself a basis for operational decisions, and to comply with Ministry of Forests' planning requirements. Updating has been tedious work. Time has not been available to examine all the development, cutting, and silvicultural options for each new year. After many discussions within the company of this common problem, Tom and Bill were authorized to use and test the *Harvest Management System (HMS)* in preparing a comprehensive new plan for Rainbow Creek.

Tom and Bill selected Fred's Forest Consulting Ltd. to install *HMS*, set up the project, and show both Tom and Bill how to continue operating the system. Fred's people digitized topographic, forest cover, harvesting, and other detail from the current maps, and set up new timber-cruise, road-cost, harvest-cost, and other input in the form required by *HMS*. They then produced a series of initial map overlays, similar to those which make up Map 2, to examine on the computer monitor screen. At this stage, proposed blocks were given temporary numbers until a cutting schedule could be established by trial. After this, the final numbers which appear on Map 2 (90.01-22.01) were substituted, matching the permanent numbers assigned to blocks already harvested.

HMS reports, based on area values derived from these map overlays and on parameters input to *HMS*, were then printed. The first reports were for individual blocks, the next for tentative groupings representing individual years, and the next for several years combined. Appendix II is a copy of the *HMS* output for the 15 blocks remaining to be harvested during PASS 1 in 1990, 1991, and 1992.

In order of appearance, the main things Appendix II shows are:

- **Title, dates, parameter tables used, and cost limits:** Blocks with per-m^3 costs outside the specified limits can be excluded, if a cost stratification is desired.
- **Attributes:** These are characteristics identified for each block, by which *HMS* has sorted. In this case the first attribute is year of harvest, and 1990, 1991, and 1992 have been selected. No sorting within the other attributes took place.
- **Logging systems selected:** The six Rainbow Creek systems are identified. Other systems stored for other *HMS* projects are excluded.
- **Cutblocks from map TCHANCE:** *HMS* has stored the Rainbow Creek map under the name TCHANCE. Data compiled for each of the 15 blocks analyzed are shown by block number, system, area in hectares, volume to cut in m^3, production in m^3/shift (falling, yarding or skidding, and loading), and shifts required to harvest the volume, again by the three phases. *HMS* calculates the volume in each block by determining the area of each forest type within a block, and then multiplying by per-hectare volumes supplied for each type. The production rates are fed to *HMS*, and the shifts required are calculated by dividing the volume to log by the volume produced per shift, by system and phase.
- **Logging totals:** The same information, by individual cutblocks, is condensed, summarized, and totalled by system (five of the six possible systems are being used in this example).
- **Volumes by species:** *HMS* is supplied with percentage breakdowns by species for each forest type, from which species volumes are compiled for the 15 blocks analyzed. The species occurring in this case are: Bl—*Abies lasiocarpa* (subalpine fir), Cw—*Thuja plicata* (western red cedar), Fd—*Pseudotsuga menziesii* (Douglas-fir), Hw—*Tsuga heterophylla* (western hemlock), Pl—*Pinus contorta*, (lodgepole pine), and S—*Picea* spp. (Interior spruce).

  As the summary shows, the remaining fifteen PASS 1 blocks have about 72 000 m^3 of spruce, 51 000 m^3 of lodgepole pine, 26 000 m^3 of subalpine fir, and lesser volumes of the other species, for a total of 163 054 m^3.

  HMS will provide a further breakdown by log grades, if percentages are supplied. For simplicity in this case, all species were restricted to a single grade—SAWLOG—meaning logs suitable for lumber and byproduct chips.

  At the right of the table is an artificially inserted column labelled "Value/m^3." This contains per-m^3 dollar values, as defined and supplied by the user, for each species and grade. Based on these, the final column was printed by *HMS*, and shows values by species, totalling about $7 529 000.
- **Total logging summary:** This block of results is self-explanatory, with some exceptions.

  "Total spur road cost" is that for branch and spur roads accessing the 15 blocks, both built and unbuilt. This category excludes main road costs, which appear below.

  Most of Appendix II is direct *HMS* printout. However some cost items are not integrally linked to *HMS*, and may change from time to time. In Appendix II, for example, the item marked "Direct costs (above)" is $26.35/$m^3$, and was derived by *HMS*. The cost items below this ("Share of main roads," $0.69/$m^3$; "Road maintenance," $1.00/$m^3$; "Area administration," $3.50/$m^3$; "Stumpage," $10.00/$m^3$; and "Discounted silv. cost,"[5] $2.33/$m^3$) were calculated "off line," converted to $/$m^3$ cut, and appended. *HMS* reports tend to be voluminous. These "off line" values can be changed without reactivating *HMS* and printing a new set of reports.

  "Share of main roads" is the $/$m^3$ amount applied to all PASS 1 blocks to write off the capital cost of the main roads. "Road maintenance" is based on calculations which will appear later (Table 4a). "Administration" and "Stumpage" are not calculated, but based on company records for similar operations.

  The sum of all costs included is $43.87/$m^3$. Total value is $7 529 249, or $46.18 per m^3 cut. For woods operations in Rainbow Creek during the remainder of PASS 1, a modest profit of $2.31/$m^3$ is predicted.

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[5]The derivation of "Discounted Silviculture Cost" is shown at the end of Appendix II. A full discussion of forest-renewal costing appears later in this report.

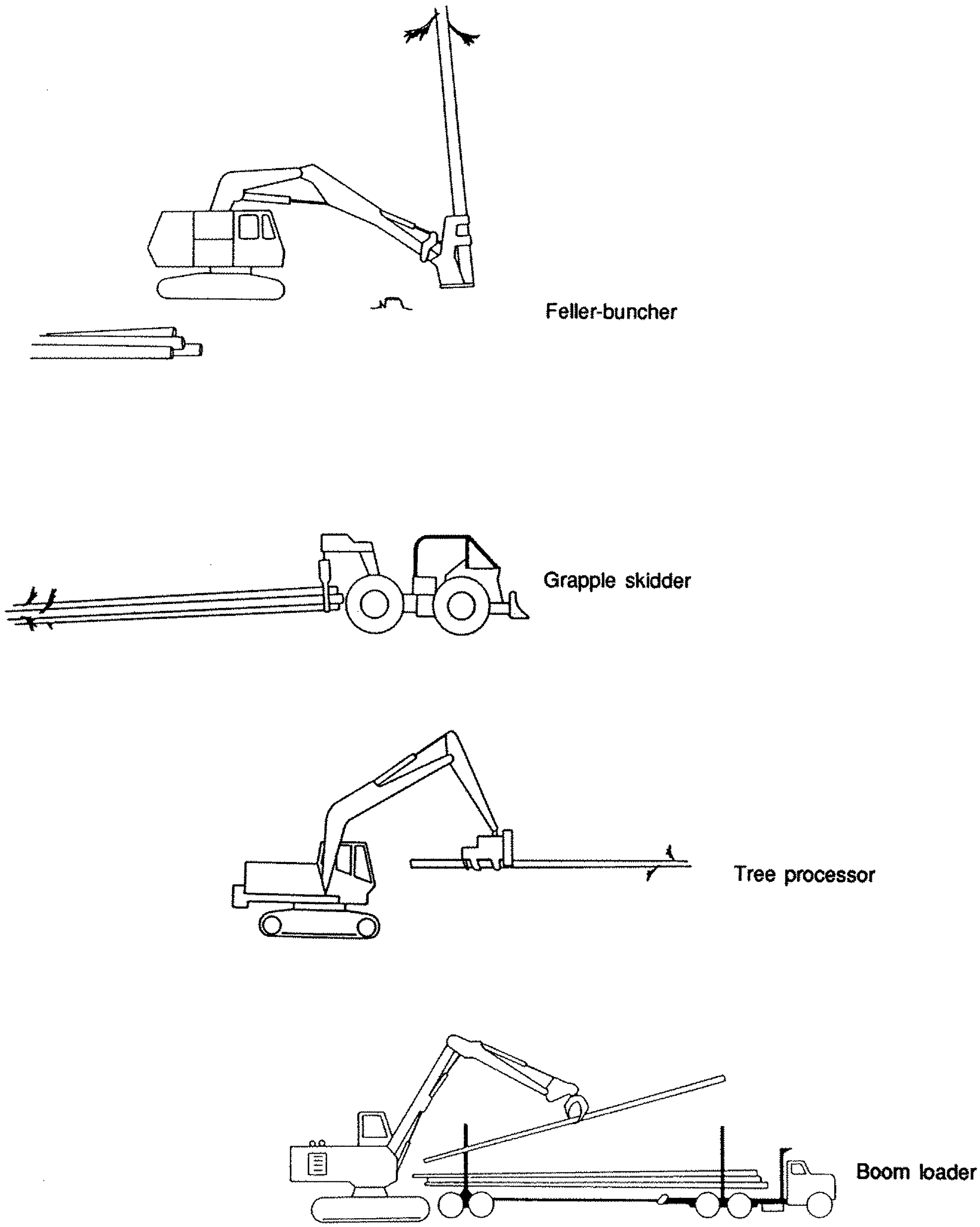

Figure 2. FELBUNCH system, suitable for harvesting small timber on moderate terrain.

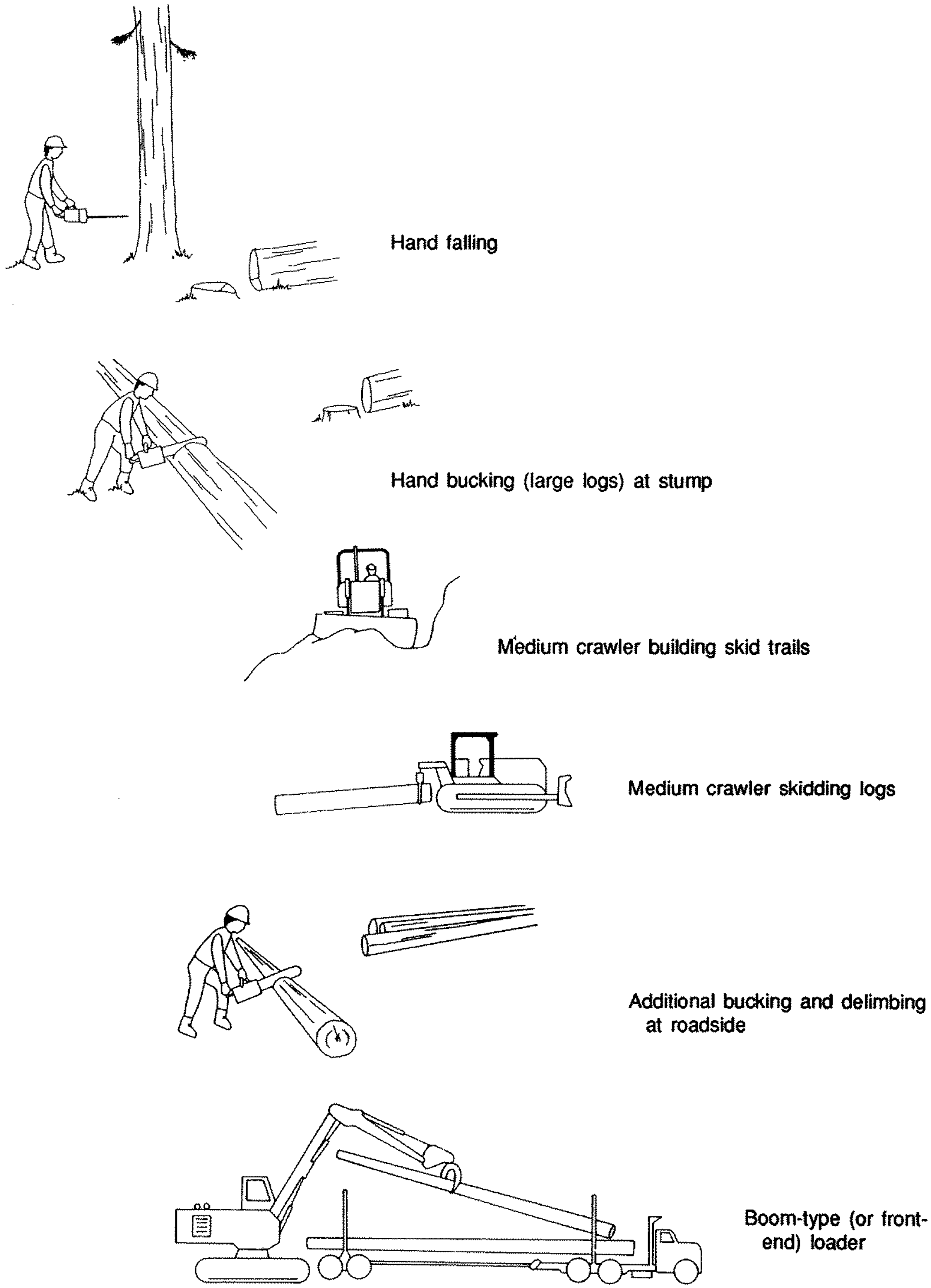

Figure 3. MEDCRAWL system, suitable for harvesting large timber on broken terrain with adverse skidding.

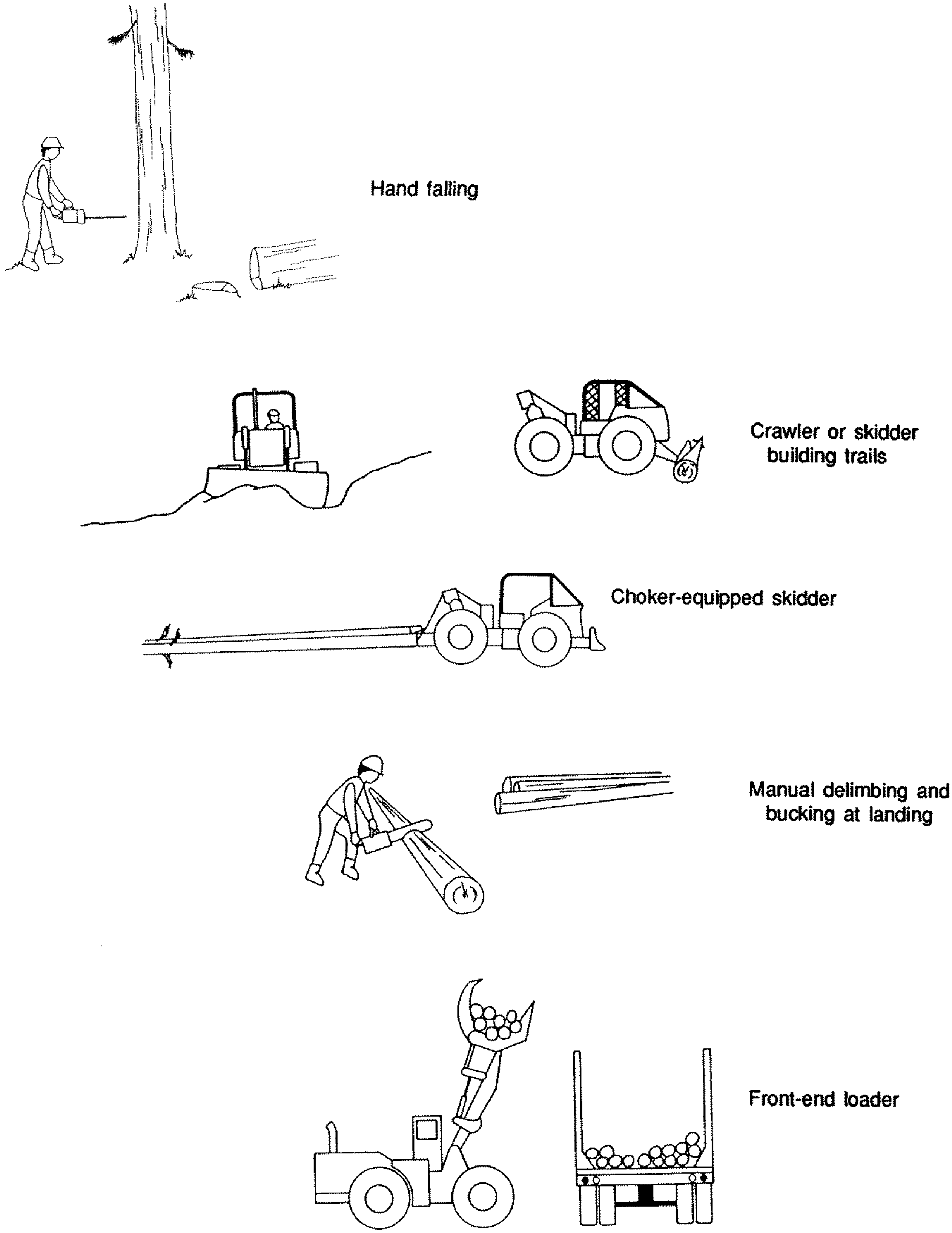

Figure 4. CHOSKID *system, suitable for harvesting a range of timber sizes on moderate terrain with firm or frozen ground.*

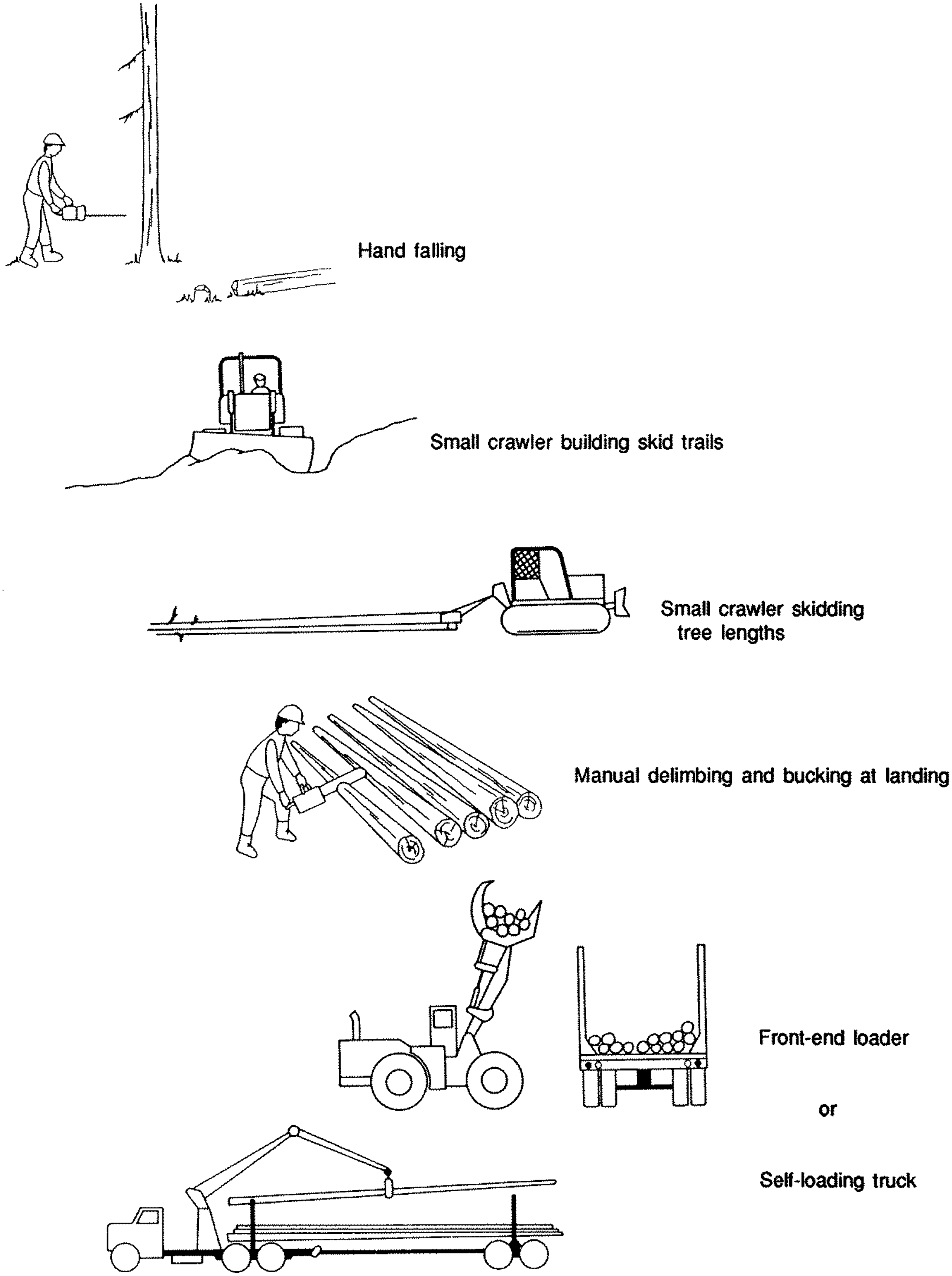

Figure 5. *SMCRAWL system, suitable for harvesting small timber on steep slopes with short skids and small landings.*

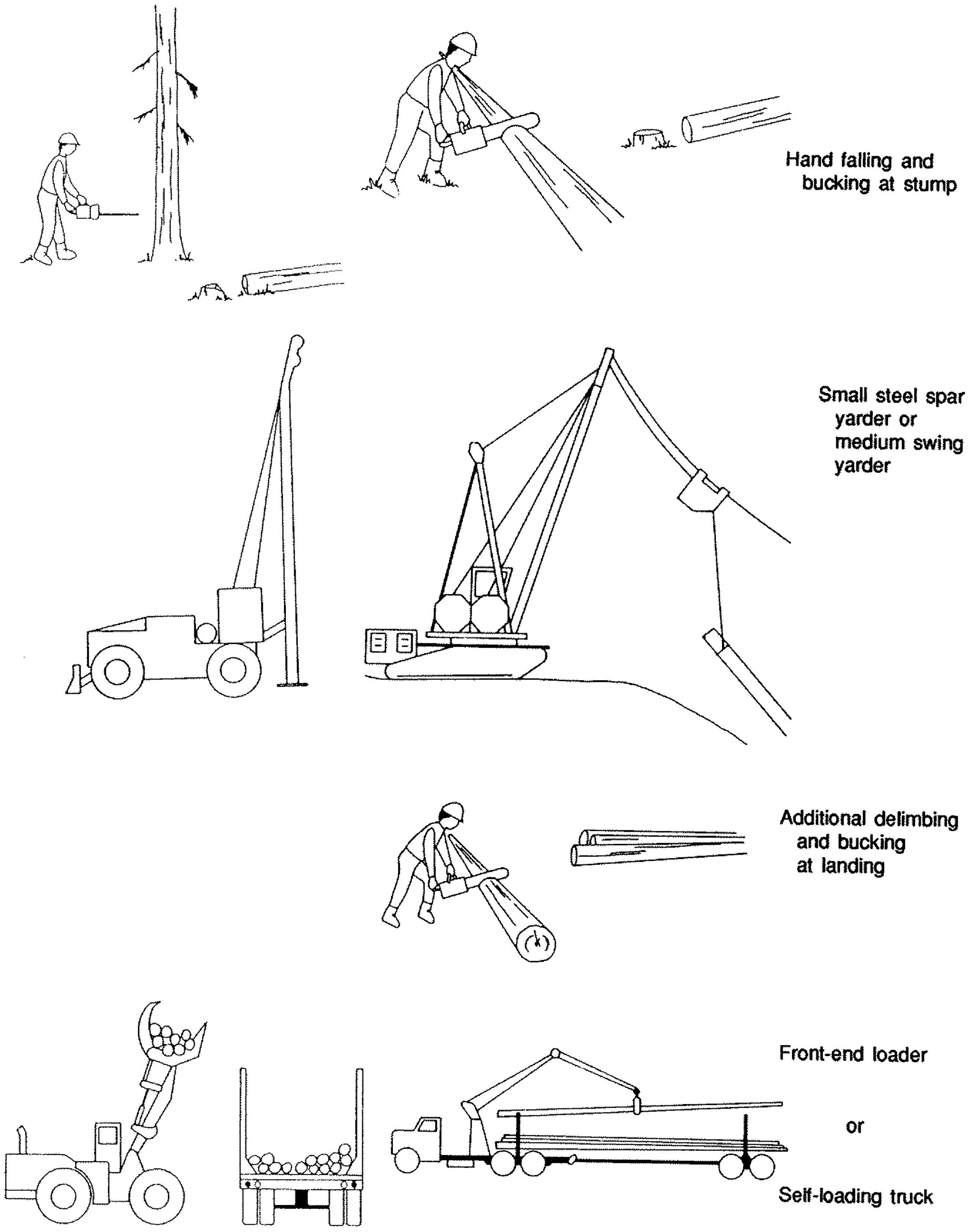

Figure 6. CABYARD system, best suited for harvesting large timber on steep terrain, but can also be used with small timber.

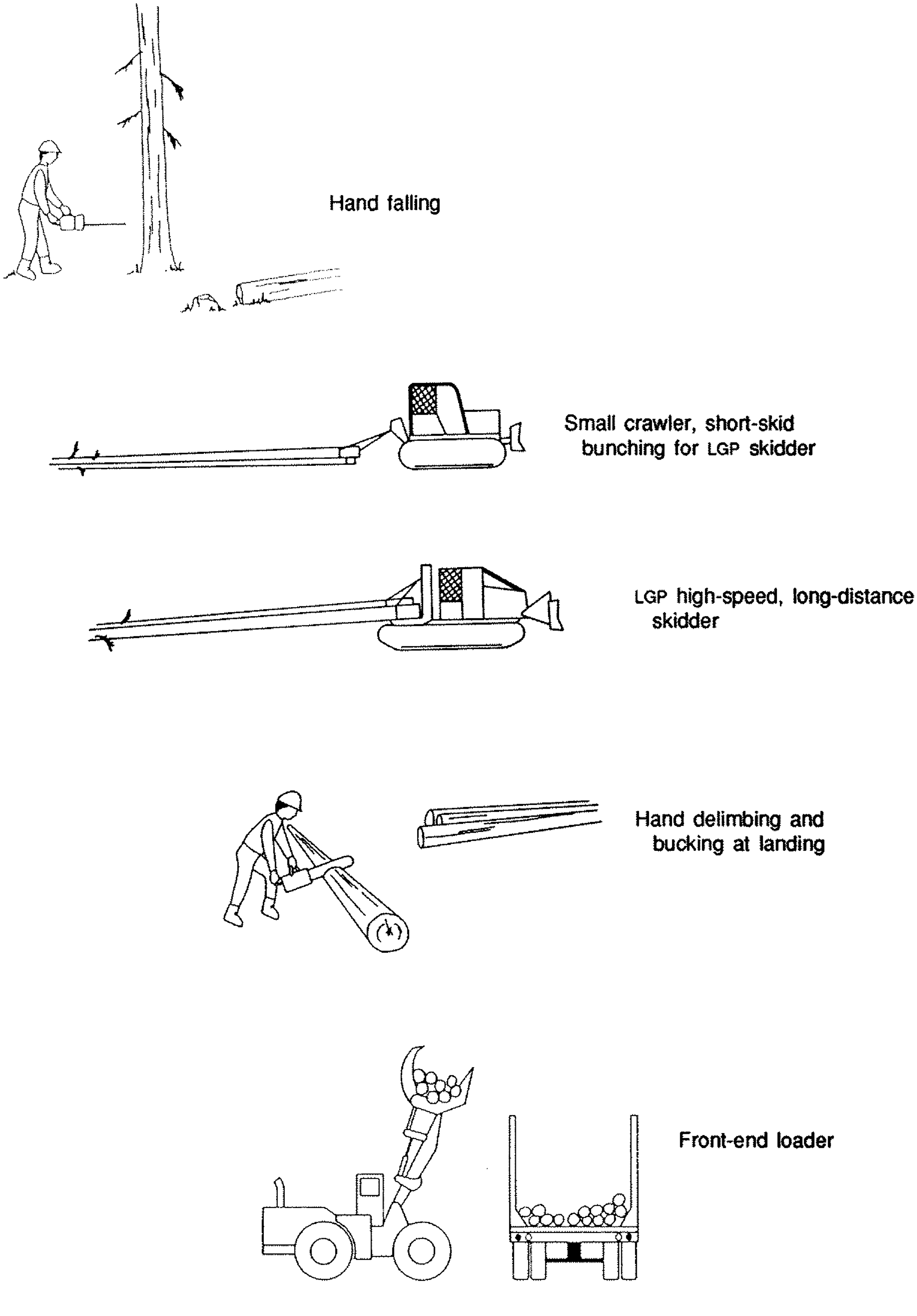

Figure 7. LGPSKID system, suitable for harvesting small timber on steep and regular terrain.

Harvesting Areas and Volumes. Appendix II represents only a small sample of the information available from *HMS*.

For Rainbow Creek, similar printed reports by individual blocks, years, systems, and combinations thereof, amounted to about 240 pages. Many of the reports were of the "what-if" variety, printed to check the merits of a particular combination, and then rejected. Still others were merely viewed on the computer monitor, and not printed.

Table 2 is derived from *HMS* output and shows cutover areas and timber volumes cut or planned, by time interval, harvesting system, and species. Using *HMS* made it easy to select the following time intervals:

- All past harvesting (1986-89)
- Harvesting planned for the individual years 1990, 1991, and 1992
- Harvesting planned for the remainder of PASS 1 (1990-92 combined)
- Harvesting planned for PASS 2 (2019-2022).

Table 2 indicates that a reasonably constant species profile can be maintained during future harvesting. Subalpine fir, spruce, and lodgepole pine, making up the Interior spruce-pine-fir (S-P-F) lumber grades and pulp chips, constitute 89% of the total volume to be cut; Douglas-fir, cedar, and hemlock make up the remaining 11%. The proportion of S-P-F rises over time, from 84% for all past harvesting, to 91% for the remainder of PASS 1, and finally to 100% for PASS 2. All of the remaining 13 675 m^3 of cedar, hemlock, and Douglas-fir (over half of this volume is cedar) will be delivered to mills during 1991 and 1992, unless poor demand at that time strongly dictates otherwise. Because only three years of harvesting remain, not much scope remains for altering cutting plans at Rainbow Creek.

Table 2 also shows the distribution of volumes cut by each harvesting system. For example, the cable yarding (CABYARD) system removed 40% of the volume in all past cutting. The CABYARD proportion is expected to leap to 64% during the remainder of PASS 1, as steep terrain physically curtails the other systems. During PASS 2, the proportion of CABYARD will revert to 52%, with a return to more work being done on terrain where ground skidding (CHOSKID) is feasible.

Table 2 indicates totals of 1711.5 timbered hectares and 524 320 m^3 harvested or planned for harvesting. The corresponding figures in Handbook No. 4 were 1719 ha and 534 200 m^3. The difference in the respective area estimates is negligible, at 0.4%. The difference in volume estimates is 2%, resulting from the discovery that volumes harvested in 1986-89 netted 98% of cruise volumes, because of underestimated defect. Estimates of harvesting volume for the remainder of PASS 1 were correspondingly revised downward to 98% of the original cruise estimates.

Harvesting Schedule. Table 3 is a detailed schedule showing areas and volumes to be harvested during the remainder of PASS 1. The information is presented by year, system, block number, and season (summer haul only, versus summer or winter haul, as determined chiefly by road standard and deep-snow limitations on cable yarding).

Blocks 90.03, 90.06, 91.04, 91.05, and 92.04 are clearly summer harvesting operations, and are so marked.

Blocks 90.04 and 90.05 are at high elevation, but are on moderate terrain and served by all-season roads. Hence they are designated all-season, with roads to be plowed if hauling in snow is necessary. The remaining blocks are also served by all-season roads. Logs Louie wants relatively snow-free yarding conditions for CABYARD blocks, but the FELBUNCH, MEDCRAWL, CHOSKID, or SMCRAWL systems operate efficiently on frozen ground or snow without causing much site damage.

The proportion of annual volume hauled in summer is 32% in 1990, 26% in 1991, 24% in 1992, and 28% for all three years combined. Because even the upper timbered slopes of the Rainbow Creek drainage are snow-free for at least 40% of each year, no extraordinary acceleration of harvesting during the summer months will be necessary. The implications of Table 3, in terms of shifts and machines required, are examined in the next section.

Table 2. Harvesting Areas and Volumes

Period	System	Area cut (ha)	Net volume cut[a] Fd (m³)	Cw (m³)	Hw (m³)	Bl (m³)	S (m³)	Pl (m³)	Total (m³)	Volume by system (%)
1986-89 (All past harvesting)	FELBUNCH	82.4							28 076	9
	MEDCRAWL[b]	68.6							19 837	6
	CHOSKID	164.1							55 408	18
	SMCRAWL	217.7							66 177	21
	CABYARD	400.6							123 488	40
	LOSKID	60.8							15 013	5
	All	994.2	14 937	21 135	11 379	41 119	123 165	95 266	307 000	100
	% by species		5%	7%	4%	13%	40%	31%	100%	
1990	FELBUNCH	43.6							13 395	18
	CHOSKID	40.7							13 659	18
	SMCRAWL	45.5							13 389	18
	CABYARD	117.8							34 332	46
	All	247.6				11 868	35 093	27 814	74 775	100
	% by species					16%	47%	37%	100%	
1991	MEDCRAWL	27.3							10 383	22
	CHOSKID	10.1							3 601	8
	CABYARD	108.4							33 226	70
	All	145.8	1 595	6 741	3 630	6 779	18 967	9 498	47 210	100
	% by species		3%	14%	8%	14%	40%	20%	100%	
1992	MEDCRAWL	8.0							2 421	6
	CHOSKID	4.7							1 200	3
	CABYARD	139.2							37 448	91
	All	151.9		1 111	598	7 678	17 939	13 743	41 069	100
	% by species			3%	1%	19%	44%	33%	100%	
1990-92 combined (remainder of PASS 1 cut)	FELBUNCH	43.6				1 487	5 656	6 252	13 395	8
	MEDCRAWL	35.3	309	5 343	2 877	513	2 980	782	12 804	8
	CHOSKID	55.5		1 111	598	4 062	9 978	2 711	18 460	11
	SMCRAWL	45.5				1 600	5 675	6 114	13 389	8
	CABYARD	365.4	1 286	1 398	753	18 663	47 710	35 196	105 006	64
	All	545.3	1 595	7852	4 228	26 325	71 999	51 055	163 054	100
	% by species		1%	5%	3%	16%	44%	31%	100%	
2019-2022 combined (PASS 2, mature timber deferred)	CHOSKID	78.6							26 049	48
	CABYARD	93.4							28 217	52
	All	172.0				10 797	28 762	14 707	54 266	100
	% by species					20%	53%	27%	100%	
Total area and volume		1 711.5	16 532	28 987	15 607	78 241	223 926	161 028	524 320	
	% by species		3%	6%	3%	15%	43%	31%	100%	

[a] *HMS* could report species volumes for each system, if desired.
[b] MEDCRAWL includes selection system.

Table 3. Harvesting Schedule, Remainder of PASS 1 (1990-92)

Year of harvest	System	Opening no.	Summer haul only (ha)	Summer haul only (m³)	Summer or winter haul (ha)	Summer or winter haul (m³)	Total (ha)	Total (m³)	Remarks
1990	CHOSKID	90.01			40.7	13 659	40.7	13 659	
	CABYARD	90.02			31.4	10 075	31.4	10 075	
	CABYARD	90.03	81.9	22 909			81.9	22 909	Summer operation.
	FELBUNCH	90.04			43.6	13 395	43.6	13 395	Snow-plow roads
	SMCRAWL	90.05			45.5	13 389	45.5	13 389	if winter hauling.
	CABYARD	90.06	4.5	1 348			4.5	1 348	Summer operation.
	All systems		86.4	24 257	161.2	50 518	247.6	74 775	
	% volume by season			32%		68%		100%	
1991	MEDCRAWL	91.01			27.3	10 383	27.3	10 383	
	CHOSKID	91.02			10.1	3 601	10.1	3 601	
	CABYARD	91.03			66.9	20 925	66.9	20 925	
	CABYARD	91.04	20.1	6 335			20.1	6 335	Summer operation.
	CABYARD	91.05	21.4	5 966			21.4	5 966	Summer operation.
	All systems		41.5	12 301	104.3	34 909	145.8	47 210	
	% volume by season			26%		74%		100%	
1992	MEDCRAWL	92.01			8.0	2 421	8.0	2 421	
	CABYARD	92.02			105.4	27 550	105.4	27 550	
	CHOSKID	92.03			4.7	1 200	4.7	1 200	
	CABYARD	92.04	33.8	9 898			33.8	9 898	Summer operation.
	All systems		33.8	9 898	118.1	31 171	151.9	41 069	
	% volume by season			24%		76%		100%	
1990-92 combined	FELBUNCH				43.6	13 395	43.6	13 395	
	MEDCRAWL				35.3	12 804	35.3	12 804	
	CHOSKID				55.5	18 460	55.5	18 460	
	SMCRAWL				45.5	13 389	45.5	13 389	
	CABYARD		161.7	46 456	203.7	58 550	365.4	105 006	
	All systems		161.7	46 456	383.6	116 598	545.3	163 054	
	% volume by season			28%		72%		100%	

Harvesting Equipment Requirements and Cost Reconciliation. *HMS* reports (see Appendix II) display users' estimates of productivity in terms of m³/shift for each system, by falling (includes delimbing and bucking), yarding (includes skidding), and loading phases. These are followed by the calculated numbers of shifts required to complete each phase for the volume shown. For truck hauling, *HMS* makes analogous calculations based on estimated production rates. For any given set of blocks, *HMS* then computes total direct costs for each phase, by multiplying calculated numbers of shifts by assumed all-found costs per shift. The "Total logging summary," near the end of Appendix II (page 45), shows phase cost estimates derived in this way for the 15 blocks to be harvested in 1990-92.

Table 4 is an independent *Lotus* extension of the same data, used to analyze equipment needs. The table is based on the same productivity and cost estimates as in Appendix II. For the same 1990-92 period, Table 4 shows numbers of shifts required for each year, each harvesting system, and each machine within that system. The information in Table 4 can be used to calculate the number of machines required; Table 5 is an example.

If the estimates and assumptions are correct, CABYARD operations for 1990 will require:

- Two full-time fallers and one part-time faller to fell, partially delimb, and buck at the stump.
- Two full-time Interior-type cable yarders, and one part-time cable yarder.
- Two full-time loaders, one for each of the two full-time yarders, with occasional moves to service the part-time yarder. Front-end loaders were selected because the timber is relatively small, but it may be necessary to replace one of these with a boom-type loader for use on steep landings. In 1990, CABYARD operations will be separated three ways, i.e. on branch roads SE-1, SE-3, and S-2. Long-distance loader movements between settings must be minimized, or limited to the more mobile loaders.
- Three full-time highway logging trucks, and one part-time truck. A self-loading truck might be desirable at times, to reduce both the necessity for loader moves and the potential damage to sensitive sites which the other loading machines could cause.

A portion of Trucks Tony's fleet will handle the 1990 hauling in Rainbow Creek. Cables Chris can field two yarders, crews, and support equipment; additional part-time yarding capacity will be needed in 1990, but not thereafter.

To complete Table 4 and confirm the *HMS* cost estimates, machine costs were calculated, based on the numbers of shifts and all-found per-shift cost estimates shown. These are based on current (1989) equipment owning and operating costs and labour rates, and are the same as those used by *HMS*. Costs exclude main, branch, or spur-road construction costs, and also exclude indirect costs such as those listed under "Cost, $\$/m^3$" at the end of Appendix II.

In Table 4, the total direct harvesting cost for the 15 blocks logged in 1990-92 is calculated at $3 235 846. This differs from the *HMS* total in Appendix II by $624, a negligible amount. As was done for road costs (Table 1), the year-by-year harvesting costs in Table 4 are discounted to 1989 present values, at 6.5% interest. The sum of these discounted values is $2 887 616.

The FELBUNCH system (feasible only on moderate, uniform slopes with small timber) emerges as the least costly, at $\$14.97/m^3$ delivered. CABYARD (used where steep terrain precludes use of other systems) is the most costly, at $\$21.12/m^3$. The average cost, weighted by volume, for all systems during 1990-92 is $\$19.85/m^3$ (discounted at 6.5% to a 1989 present value of $\$17.71/m^3$).

Road Construction and Maintenance: Equipment Requirements and Costs. Appendix I includes a cost estimate for 1990 road construction to complete all roads needed in PASS 1. These roads, totalling 8400 m in length, are also marked in purple on Map 2. Appendix I shows Roads Robbie's updated 1989 cost estimate, totalling $349 773.

Roads Robbie now needs an estimate of the equipment requirements and corresponding costs for this construction program, and also for a 1990-92 road-maintenance program. For this information, Table 4a is the "road" equivalent to Table 4, showing equipment needs and costs for road construction and road maintenance until the end of PASS 1 logging operations.[6] Based on a more detailed assessment of the final locations, the 1990 shifts and costs by machine types are as shown in Table 4a. The new construction cost is higher than earlier estimates, at $373 400 (discounted at 6.5% to a 1989 present value of $350 610).

Road-maintenance estimates for 1990-92, in 1989 dollars, total $157 200 (discounted at 6.5% to a 1989 value of $140 452). The undiscounted total averages $\$0.96/m^3$ cut. This average, rounded up to $\$1.00/m^3$, appears as one item in the calculation of total harvesting costs in Appendix II.

Of the three years included, machine requirements are heaviest in 1990 (Table 4a), while both construction and maintenance are in progress. The calculation of 1990 equipment needs, combined for both construction and maintenance programs, is shown in Table 6.

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[6]At the end of PASS 1 logging, a basic road-access maintenance program will be assumed under the silvicultural program (see Table 8).

Table 4. Harvesting Equipment: Direct Costs, 1990-92

System	Productivity/ shift/ machine (m^3)	All-found cost $/shift (1989 $)	Year 1990 Production required (m^3)	Year 1990 Shifts required (no.)	Year 1990 Cost (1989 $)	Year 1991 Production required (m^3)	Year 1991 Shifts required (no.)	Year 1991 Cost (1989 $)
FELBUNCH								
Feller-buncher +								
Processor	400	$1 734	13 395	33	$58 067			
Grapple skidder	300	$571	13 395	45	$25 495			
Boom loader	400	$826	13 395	33	$27 661			
Haul truck	90	$600	13 395	149	$89 300			
				260	$200 523			
MEDCRAWL								
Chain saws	90	$388				10 383	115	$44 762
Medium crawler	120	$663				10 383	87	$57 366
Boom loader	200	$612				10 383	52	$31 772
Haul truck	90	$600					115	$69 220
							369	$203 120
CHOSKID								
Chain saws	100	$347	13 659	137	$47 397	3 601	36	$12 495
Line skidders (trails)	150	$714	13 659	91	$65 017	3 601	24	$17 141
Front-end loader	260	$495	13 659	53	$26 005	3 601	14	$6 856
Haul truck	90	$600	13 659	152	$91 060	3 601	40	$24 007
				432	$229 478		114	$60 499
SMCRAWL								
Chain saws	70	$265	13 389	191	$50 687			
Small crawler	60	$408	13 389	223	$91 045			
Front-end loader	260	$495	13 389	51	$25 491			
Haul truck	90	$600	13 389	149	$89 260			
				615	$256 483			
CABYARD								
Chain saws	140	$367	34 332	245	$89 999	33 226	237	$87 100
Cable yarder	140	$1 224	34 332	245	$300 160	33 226	237	$290 490
Front-end loader	160	$495	34 332	215	$106 215	33 226	208	$102 793
Haul truck	90	$600	34 332	381	$228 880	33 226	369	$221 507
				1 086	$725 253		1 051	$701 889
Totals, all systems			74 775		$1 411 737	47 210		$965 508
1989 present value, discounted @ 6.5% compound interest					$1 325 575			$851 249

Table 4a. Road-Construction and Road-Maintenance Equipment: Direct Costs, 1990-92

System	Productivity/ shift/ machine (km)	All-found cost $/shift (1989 $)	Year 1990 Production required (km)	Year 1990 Shifts required (no.)	Year 1990 Cost (1989 $)	Year 1991[a] Production required (km)	Year 1991[a] Shifts required (no.)	Year 1991[a] Cost (1989 $)
Road construction								
Excavator	0.04	$1 280	6.00	150	$192 000			
Large crawler	0.03	$1 200	0.60	20	$24 000			
Medium crawler	0.03	$960	2.40	80	$76 800			
Rock drill	0.01	$800	0.70	70	$56 000			
Front-end loader		$520		15	$7 800			
Gravel truck		$560		30	$16 800			
Totals, construction			9.70	365	$373 400			
1989 present value, discounted @ 6.5% compound interest					$350 610			
Road maintenance								
Medium crawler		$960		15	$14 400		10	$9 600
Front-end loader		$520		15	$7 800		10	$5 200
Gravel truck		$560		15	$8 400		10	$5 600
Gravel		$640		60	$38 400		45	$28 800
Totals, maintenance				105	$69 000		75	$49 200
1989 $/$m^3$ harvested					$0.92			$1.04
1989 present value, discounted @ 6.5% compound interest					$64 789			$43 378

[a] Road construction is finished.

Year 1992			Years 1990-92 combined			
Production required (m^3)	Shifts required (no.)	Cost (1989 $)	Production required (m^3)	Shifts required (no.)	Cost (1989 $)	Equivalent ($/$m^3$)
			13 395	33	$58 067	$4.34
			13 395	45	$25 495	$1.90
			13 395	33	$27 661	$2.07
			13 395	149	$89 300	$6.67
			13 395	260	$200 523	$14.97
2 421	27	$10 437	12 804	142	$55 199	$4.31
2 421	20	$13 376	12 804	107	$70 742	$5.53
2 421	12	$7 408	12 804	64	$39 180	$3.06
2 421	27	$16 140	12 804	142	$85 360	$6.67
	86	$47 361	12 804	455	$250 482	$19.56
1 200	12	$4 164	18 460	185	$64 056	$3.47
1 200	8	$5 712	18 460	123	$87 870	$4.76
1 200	5	$2 285	18 460	71	$35 145	$1.90
1 200	13	$8 000	18 460	205	$123 067	$6.67
	38	$20 161	18 460	584	$310 137	$16.80
			13 389	191	$50 687	$3.79
			13 389	223	$91 045	$6.80
			13 389	51	$25 491	$1.90
			13 389	149	$89 260	$6.67
			13 389	615	$256 483	$19.16
37 448	267	$98 167	105 006	750	$275 266	$2.62
37 448	267	$327 403	105 006	750	$918 052	$8.74
37 448	234	$115 855	105 006	656	$324 862	$3.09
37 448	416	$249 653	105 006	1 167	$700 040	$6.67
	1 185	$791 078	105 006	3 323	$2 218 220	$21.12
41 069		$858 600	163 054		$3 235 846	$19.85
		$710 791			$2 887 616	$17.71

Year 1992 [a]			Years 1990-92 combined			
Production required (km)	Shifts required (no.)	Cost (1989 $)	Production required (km)	Shifts required (no.)	Cost (1989 $)	Equivalent ($/km)
			6.00	150	$192 000	
			0.60	20	$24 000	
			2.40	80	$76 800	
			0.70	70	$56 000	
				15	$7 800	
				30	$16 800	
			9.70	365	$373 400	
					$350 610	
	5	$4 800		30	$28 800	
	5	$2 600		30	$15 600	
	5	$2 800		30	$16 800	
	45	$28 800		150	$96 000	
	60	$39 000		240	$157 200	
		$0.95			$0.96	
		$32 286			$140 452	

Table 5. Calculation of Machine Requirements, CABYARD SYSTEM 1990

Machine	Shifts required (no.)	Shifts available per machine [a] (no.)	Machines required (no.)
Chain saws	245	113	2.2
Cable yarders	245	113	2.2
Front-end loaders	215	113	1.9
Haul trucks	381	113	3.4

[a] Based on an average operating year for cable yarding of 7 months, 19 single shifts per month, and 85% machine availability.

Table 6. Calculation of Equipment Needs for Road-Construction and Road-Maintenance Programs 1990

Machine	Shifts required (no.)	Shifts available per machine [a] (no.)	Machines required (no.)
Excavator	150	170	0.9
Large crawler	20	170	0.1
Medium crawler	95	170	0.5
Rock drill	70	170	0.4
Front-end loader	30	170	0.2
Gravel truck	45	170	0.3
Grader	60	170	0.4

[a] Based on an average operating year for construction or maintenance of 200 shifts, and on 85% machine availability.

Only one machine, an excavator, will be required nearly full time (0.9 machine-years). A medium-sized crawler will be required for 0.5 machine-years, chiefly to work on summer-only roads on steep terrain (S-2.5 and N-1). The remaining machines will work from 0.1 to 0.4 machine-years each in Rainbow Creek, and will work elsewhere for the rest of 1990.

Additional *HMS* Capabilities. Map 2 is a planimetric map, produced by *HMS* on a plotter, using pens of various colours. It shows the development and harvesting detail necessary for purposes of this report. *HMS* can also display a wide variety of other visual information, on a colour monitor or on paper.

Map 1 was manually drafted in 1982 and shows topographic detail, including 20-m contours, needed for planning on steep terrain. If the contours from Map 1 or any other source were digitized for *HMS*, Rainbow Creek could be studied from an infinite number of hypothetical aerial or ground viewing points, at any stage during the harvesting cycle, using the graphic capabilities of *HMS*. Mitchell (1989) describes and illustrates some of the graphic capabilities of *HMS* in more detail.

Peter and his staff incorporated contours into the *HMS* model, and were able to illustrate various features of their plan during discussions, by displaying the appropriate images on the colour monitor. Images that were particularly useful were saved and plotted, for inclusion in written reports.

Forest-Renewal Program (PASS 1 Openings)

The foregoing discussion has been concerned with the planned removal of mature timber from the Rainbow Creek drainage. Good forest management demands an equally well-planned process of forest renewal. Harvesting is costly, but provides immediate revenues for the company (and government). Forest renewal is less costly on a per-hectare basis, but consumes revenues (in the short run) rather than providing them.

As an exercise in scheduling, forest renewal is more complex than harvesting. Whereas clearcut harvesting of an opening usually requires one entry lasting 1-5 months, forest renewal on the same opening may require five or more entries, at carefully timed intervals spanning 10-20 years.

Forest-Renewal Objectives. "Forest renewal" means all steps leading to establishment of a free-growing[7] commercial timber crop to replace or improve upon the previous crop (Breadon 1988a). This includes the various forms of post-harvesting site preparation, restocking, and tending, up to the free-growing stage. It excludes the more discretionary or later-stage treatments like fertilizing, pruning, or commercial thinning.

Forest-Renewal Methods for Rainbow Creek. Breadon (1988a, 1988b) describes the main forest-renewal alternatives currently employed in the British Columbia Interior. Highly productive sites on moderate terrain warrant prompt and specialized mechanical site preparation, prompt planting with extra-large stock, timely herbicide applications, and juvenile spacing, to fulfill their promise of future yields. However, on steeper and rougher sites, or on those with poorer growth capacity, only the simpler forest-renewal methods may be possible. Map 1 leaves no doubt that most of the Rainbow Creek drainage is on steep and rough ground, and is classified as a medium or poor site. The choice of forest-renewal methods is governed by these factors.

Figure 8 illustrates the main forest-renewal treatments Trees Tom will employ on Rainbow Creek, together with the equipment types used for each. These are:

Site Preparation.

Broadcast burning.

Advantages—Feasible on steep terrain; reduces slash for planters; provides sanitation against insect pests, mistletoe, and some pathogens; inhibits competing plants; reduces duff for better seedling growth.

Disadvantages—Must be done in dry conditions, with consequent risk of escape or expense of fireguarding; may cause site degradation (hot burn on shallow soils); generally kills seed or seedlings on ground, necessitating subsequent planting.

Methods—Helitorch; ground lighting.

Followed by—Planting or seeding from timber edges (rarely by artificial seeding).

Machine scarification and debris piling (with or without subsequent burning of piles).

Advantages—Concentrates slash, exposes soil for natural seeding or planting, no wildfire risk; can selectively work the site.

Disadvantages—Limited by steep or wet terrain; may cause site degradation; may be costly.

Methods—Medium crawler with brush blade; helitorch or manual lighting (usually during non-hazardous burning conditions).

Followed by—Planting or natural seeding.

No site preparation.

Advantages—No direct cost; no fire damage or site degradation; seeds or natural seedlings are unhurt.

Disadvantages—No reduction in fire hazard; no insect or disease sanitation; danger of inadequate natural regeneration or brush encroachment, especially on good sites; expensive planting; reduced survival.

Comments—Site preparation may be unnecessary or undesirable on steep debris-free slopes, on sites where harvesting techniques or timing have already provided suitable ground disturbance, or on sites where adequate natural stocking is already present or assured.

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[7]A stand is considered free-growing where growth and development are not threatened by understocking, competing noncommercial vegetation, or overstocking.

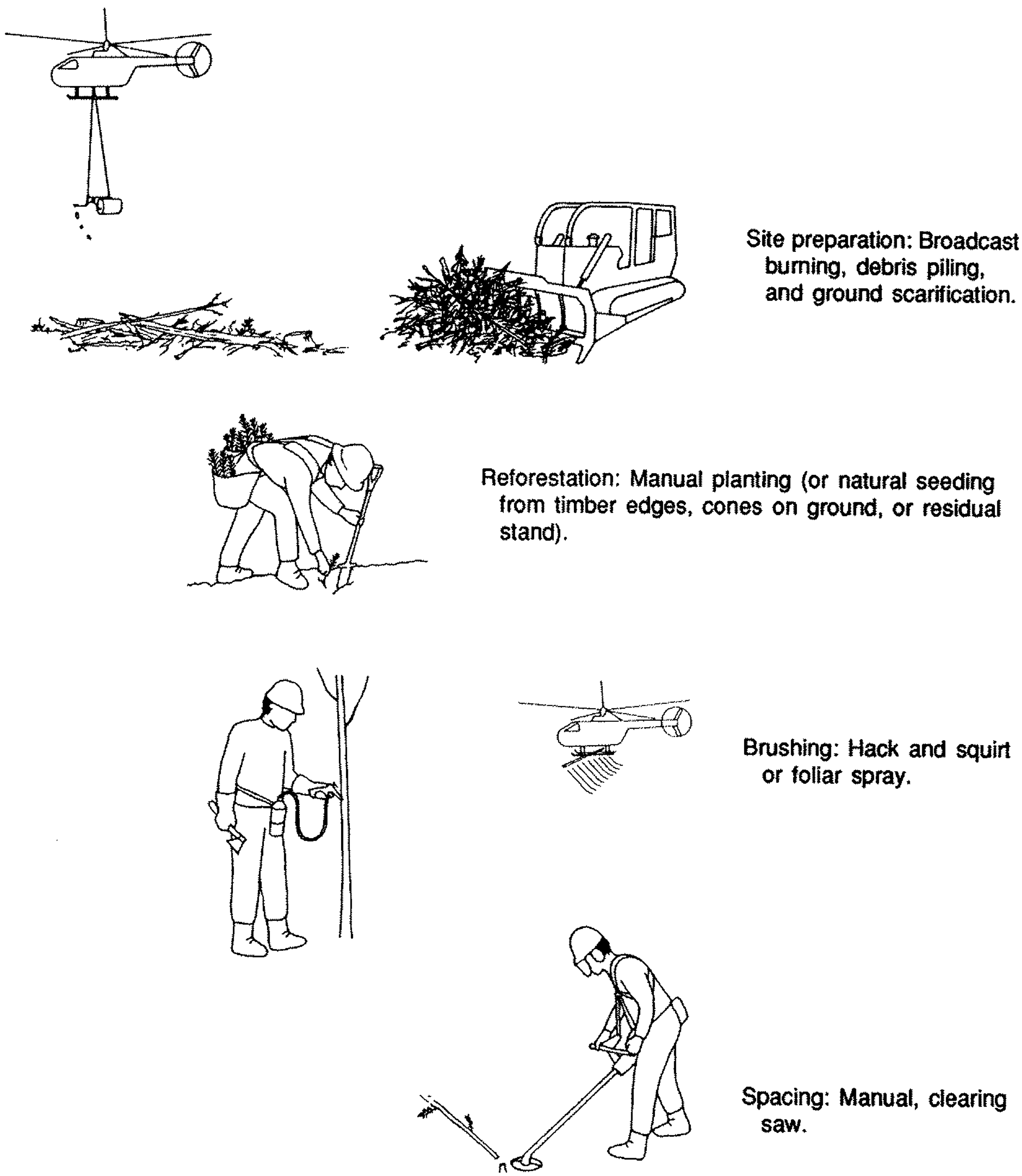

Figure 8. Main forest-renewal treatments prescribed for Rainbow Creek.

Reforestation.

Planting.

Advantages—Prompt restocking; establishes in advance of competing vegetation; controlled species and stock; controlled spacing.

Disadvantages—Expense and problems associated with nursery and planting operations.

Methods—Manual planting, usually container stock, with shovel.

Natural seeding.

Advantages—None of the expense and problems associated with nursery and planting operations.

Disadvantages—Probable regeneration delay of several years; limited control over species composition; increased risk of suppression by brush; lack of control over spacing.

Methods—Clearcut lodgepole pine blocks are particularly well adapted for natural seeding, with or without mechanical scarification. The essence of the selection system is natural seeding from residual trees, followed if necessary by fill-planting.

Advanced regeneration released after harvesting.

Advantages—New crop already established, before harvesting; no direct expense.

Disadvantages—Probability of unwanted species; poor-quality crop from prolonged suppression; poor response to release; uncontrolled spacing; gaps or damaged trees after harvesting.

Methods—After partial cutting or clearcutting, with follow-up fill-planting and spacing as needed.

Fill-Planting.

Where regeneration surveys identify unstocked areas within plantations or naturally restocked areas, it may be feasible to fill-plant. Fill-planting tends to be costly, because planters must walk further per seedling planted, must search for established seedlings before planting new ones, and often must hand-clear planting spots.

Brushing.

Young conifers may be overtaken and choked out by competing herbs, shrubs, and noncommercial tree species. Particularly on richer sites, one or more brushing operations may be necessary to bring the coniferous stand to the free-growing state.

Methods—Unwanted vegetation may be cut manually, motor-manually, or with mobile equipment. Herbicides may be applied to cut surfaces to prevent sprouting, or herbicides may be sprayed on foliage or applied to the ground under target vegetation. Foliar herbicide sprays may be applied aerially, with special precautions to prevent drift, especially into adjacent waterways.

Juvenile Spacing.

Natural or planted conifer stands may need spacing as the crown canopy closes, to prevent stagnation or delay in attaining merchantable trees.

Methods—Young stands may be spaced with clearing saws. Chain saws are used on older immature stands. On a few grossly overstocked areas on moderate terrain, mobile equipment may clear alternate parallel strips, leaving residual strips for follow-up manual spacing.

Forest-Renewal Planning. Site-preparation operations began in Rainbow Creek in 1987, on openings harvested the previous year. Planting began on some of the same openings in 1988. Also in 1988 and 1989, the company conducted Preharvest Silviculture Prescription (PHSP) surveys on all unharvested PASS 1 openings, under new Ministry of Forests regulations. In general, it was found that the original forest types coincided with recognized biogeoclimatic subzones (Table 7).

Figure 9 is a chart showing typical scheduling of post-harvest surveys and treatments for each subzone and variant. It shows the elapsed time since harvesting, and the time at which a survey or treatment should be scheduled. Naturally, if the survey or treatment is not needed on a particular opening, it is not carried out. For example, the recommended timing of brushing and spacing operations is indicated in Figure 9 in every case, but these treatments would not necessarily be desirable on every opening, nor on every hectare within an opening.

Appendix III is the forest-renewal program and budget for all PASS 1 cutovers; it was prepared by Trees Tom in 1989. It is based on field inspections of the openings already harvested, and 1988-89 PHSPs for those not yet harvested.

Throughout Appendix III, costs are Tom's 1989 estimates, at prevailing 1989 rates. They include direct costs, usually in the form of payments to contractors, plus field supervision. They exclude company or departmental overhead charges.

Appendix III is a formidable spreadsheet, spanning 19 years of forest-renewal operations, of which 16 years lie ahead, and only three behind. The shaded area indicates what work has been completed (as of December 1989), while the unshaded area is work that is planned and budgeted; it is evident that much remains to be done. Further discussion of the spreadsheet, part by part, follows.

Table 7. Forest Types and Biogeoclimatic Subzones [a]

Forest type [b]	Biogeoclimatic subzone	Variants
CHS 35m	ICH aw2	
FPl 25m	IDF aw1	
SB 30m	ESSF wc2	Moister, richer
PlS 25m	ESSF wc2	Drier, less rich
SBPl 20m	ESSF wc2	High elevation, short growing season

[a] D. Lloyd et al 1990.
[b] See Map 1.

YR/BLOCK, HA, HARV SYSTEM. This information was copied from the *HMS* analysis (Appendix II) for all PASS 1 openings.

MAIN BGC SUBZ., MAIN TBR TYPE. The biogeoclimatic subzones are those outlined in Table 7. Timber types are the same as shown on Map 1. Where the boundaries of a cutblock enclose more than one subzone or timber type, the one making up the most area within the block is listed.

PREHARVEST SILVICULTURE PRESCRIPTIONS (PHSPs) and POST-HARVEST SURVEYS. PHSPs became a licensee requirement late in 1987, although the company had previously been planning and budgeting forest-renewal operations under the old funding mechanisms. PHSP surveys and documents for all uncut openings were started in 1988 and completed by late 1989. Consequently, Tom lacks PHSPs for openings created before 1988, and must base prescriptions for these openings on general observations until post-harvest surveys are done.

—TYPES. The planned post-harvest surveys are of three types. R (regeneration survey) determines the adequacy of natural or artificial restocking, and prescribes fill-planting or replanting where needed. B (brushing survey, on brush-prone sites) determines whether brushing will be needed, and prescribes the type and timing of brushing operations. F (free-growing survey) determines whether the new stand conforms to free-growing standards, or requires further treatment such as brushing or juvenile spacing.

—YEAR(S). Surveys are scheduled for specified years,[8] roughly in accordance with scheduling in Figure 9.

—$/HA, 1989 $. For simplicity, a 1989 dollar cost of $8 per hectare of opening is assumed, regardless of the type of survey or the hectares actually surveyed within the opening.

SITE PREPARATION. Because site preparation is the first step in the forest-renewal sequence, slightly more than half of all site preparation was completed by the end of 1989.

—METHOD. One option is NONE. In the past, site preparation was unnecessary on FELBUNCH openings, because residual debris was sparse and mineral soil suitably exposed. Site preparation was also unnecessary on Block 86.10, which had already been accidentally burned; on several steep, thin-soiled sites where further disturbance was unwanted; and on several sites where natural lodgepole pine seeding was predicted. Future openings with similar characteristics will similarly be left without site preparation.

A second option is PILE, BURN. Machine piling was a natural choice on most openings where terrain had permitted ground skidding. Burning of the piles was prescribed for sanitation against mistletoe and beetles, and also because raw debris piles occupy growing space needed for the new crop. On future cutovers, piling and burning is prescribed where ground-skidding will be used, and on Block 91.03. This block is a large CABYARD block in the SB 30m type; heavy debris is expected and Tom wants to avoid the risk of a broadcast burn escaping into uncut timber along the block's lengthy upper edge.

BDCST BURN is a third option. Broadcast burning is prescribed where site preparation is needed and machine piling is not feasible. Steep topography and moderate-to-heavy debris are found on most CABYARD openings. Planting is usually prescribed, because prompt, natural seeding is not a certainty after broadcast burning.

[8]Note that some surveys and treatments will occur after the year 2000, and are marked "00," "02," "06," etc.

```
SUBZONE                      |     YEARS  SINCE  COMPLETION  OF  HARVEST
(FORST TYPE)                 |
                             |  1     2     3     4     5     6     7     8     9    10    11    12    13    14
-----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
IDF mwl           SITE PREP  | NO SITE PREP.         |     |     |     |     |     |     |     |     |     |     |
(FPl 25m)         REFOR'N    | { ---   NATURAL    SEEDING      -- }         |     |     |     |     |     |     |
                  SURVEYS    --------------------------- regen.----------------------------   free-grow        |
                  FILL-PLANT |     |     |     |     |     |     |FILL |     |     |     |     |     |     |
                  BRUSHING   |     |     |     |     |     |     |NO BRUSHING|     |     |     |     |     |
                  JUV. SPACE |     |     |     |     |     |     |     |     |     |     |     |     |SPACE|
-----------------------------------------------------------------------------------------------------------------
ICH mw2           SITE PREP  |PILE, BURN |     |     |     |     |     |     |     |     |     |     |     |     |
(CHS 35m)         REFOR'N    |  { ---   NATURAL    SEEDING      --- }       |     |     |     |     |     |     |
                  SURVEYS    -------------------------------regen, brush ------------free-grow ------------------|
(SELECTION CUT)   FILL-PLANT |     |     |     |     |     |     |FILL |     |     |     |     |     |     |
                  BRUSHING   |     |     |     |     |     |     |     |     |     |BRUSH|     |     |     |
                  JUV. SPACE |     |     |     |     |     |     |     |     |     |     |     |     |SPACE|
-----------------------------------------------------------------------------------------------------------------
ICH mw2           SITE PREP  |PILE, BURN,|     |     |     |     |     |     |     |     |     |     |     |     |
(CHS 35m)                    |BDCST. BURN|     |     |     |     |     |     |     |     |     |     |     |     |
                  REFOR'N    |     |PLANT|     |     |     |     |     |     |     |     |     |     |     |     |
(CLEARCUT)        SURVEYS    ------------------------regen-------------brush-------free-grow ------------------|
                  FILL-PLANT |     |     |     |     |     |FILL |     |     |     |     |     |     |     |
                  BRUSHING   |     |     |     |     |     |     |     |     |BRUSH|     |     |     |     |
                  JUV. SPACE |     |     |     |     |     |     |     |     |     |     |     |     |SPACE|
-----------------------------------------------------------------------------------------------------------------
ESSF mw2          SITE PREP  |PILE, BURN/|     |     |     |     |     |     |     |     |     |     |     |     |
(SB 30m)                     |BDCST. BURN|     |     |     |     |     |     |     |     |     |     |     |     |
                  REFOR'N    |     |PLANT|     |     |     |     |     |     |     |     |     |     |     |     |
                  SURVEYS    ------------------------regen-------------brush------------------free-grow -------|
                  FILL-PLANT |     |     |     |     |     |FILL |     |     |     |     |     |     |     |
                  BRUSHING   |     |     |     |     |     |     |     |     |BRUSH|     |     |     |     |
                  JUV. SPACE |     |     |     |     |     |     |     |     |     |     |     |     |SPACE|
-----------------------------------------------------------------------------------------------------------------
ESSF mw2          SITE PREP  |NO SITE PREP/    |     |     |     |     |     |     |     |     |     |     |     |
(PlS 25m                     |BDCST.BURN       |     |     |     |     |     |     |     |     |     |     |     |
 OR               REFOR'N    |  { ---   NATURAL    SEEDING      --- }       |     |     |     |     |     |     |
SBPl 20m)                    |  {OR PLANT}     |     |     |     |     |     |     |     |     |     |     |     |
                  SURVEYS    -----------------------------------regen-----------------------------free-grow   |
                  FILL-PLANT |     |     |     |     |     |     |FILL |     |     |     |     |     |     |
                  BRUSHING   |     |     |     |     |     |     |     |     |     |     |BRUSH|     |     |
                  JUV. SPACE |     |     |     |     |     |     |     |     |     |     |     |     |SPACE|
-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
                             0     1     2     3     4     5     6     7     8     9    10    11    12    13    14
                                      YEARS  SINCE  COMPLETION  OF  HARVEST
-----------------------------------------------------------------------------------------------------------------
```

Figure 9. Typical scheduling of post-harvesting surveys and forest-renewal treatments (if required).

—YEAR, $/HA. All site preparation is scheduled to begin within one year of harvesting, and thus to end in 1993. The cost of broadcast burning is $240/ha (in 1989 dollars). The cost of piling and burning is $280/ha. Additional care was needed on Blocks 86.02 and 86.03—the selectively cut streamside openings—and these cost $300/ha in 1987.
—% TRTD, HA TRTD. Depending on such factors as localized topography, debris distribution, or soil condition after logging, site-preparation treatment may be required over 100% of an opening, or over a lower percentage. Trees Tom's estimate of percent treated is shown, together with the equivalent number of hectares treated.
—1989 $. This column shows the treatment cost for each opening, with subtotals and totals. Costs are as of 1989.

PRIMARY REFORESTATION.—METHOD. NAT means natural seeding, on either selectively cut openings or clearcuts. PLANT means planting, with stock, spacing, and other standards as specified in post-harvesting assessments or PHSPs, and planting contracts.
—YEAR. For NAT openings, Tom has specified a six-year period for natural seeding to provide a fully

stocked new stand. Block 89.03, for example, is expected to restock naturally during the years 1990-96. For PLANT openings, a single year is specified. Planting commenced in 1988, and will be completed for all PASS 1 openings in 1994.

—$/HA. Tom recognizes three levels of planting difficulty and cost, as follows:

ICH mw2 (good site, brush-prone, large stock required)

1989 cost, stock + planting = $850/ha planted.

ESSF wc2 (moist, rich, SB variant of the ESSF wc2 ecosystem)

1989 cost, stock + planting = $750/ha planted.

ESSF wc2 (drier PlS and SBPl variants of the ESSF wc2 ecosystem; pine natural seeding is expected to supplement planting)

1989 cost, stock + planting = $680/ha planted.

IDF mw1 (natural seeding expected).

—% TRTD, HA TRTD. As was the case with site preparation, Trees Tom expects to plant 100% of some openings, but as little as 30% of others. The percentages and equivalent hectares are shown for each opening. The peak planting year was 1989, with 189.4 ha planted, but operations approach this level in other years, and at least 100 ha are planted in every year until completion in 1994.

—1989 $. Planting expenditures or budgets are shown for each opening and each year. Planting expenditures peaked in 1989, at $137 222. The total planting bill (1989 dollars) for all years is $716 824, or an average of $741 per hectare planted. This is equivalent to $466 per hectare of *opening*, since planting will cover only 968 of the 1539 ha opened up by PASS 1 harvesting.

FILL-PLANTING, REPLANTING. This is an allowance for supplementary planting on openings where future regeneration surveys determine a need. Some allowance is made, whether the primary reforestation has been natural or artificial.

—YEAR. With the timing of regeneration surveys, fill-planting can start in 1993 at the earliest, and will extend through the year 2000.

—$/HA. Fill-planting is expected to cost more per seedling than primary planting, for reasons already given. Trees Tom estimates that fill-planting of the two openings in the IDF mw1 subzone will cost $300 per hectare fill-planted (e.g. 10% of opening area requiring fill-planting, 600 seedlings/ha, $0.50/seedling). All other openings are expected to average $600 per hectare fill-planted or replanted.

—% TRTD, HA TRTD. Certain openings are likely to require no fill-planting, and others extensive fill-planting or outright replanting. Trees Tom hesitates at this point to guess which openings will fall into which category. However, for budgeting purposes, he places all openings into classes requiring fill-planting of 5, 10, 15, or 20% of their respective areas. The percentages and areas are as shown. The total area budgeted for fill-planting or replanting, at the stated per-hectare cost figures, is 190.6 hectares.

—1989 $. Trees Tom's assumed values for $/HA and % TRTD result in an estimated treatment cost for every opening. The total for all PASS 1 openings is $111 909 in 1989 dollars. This is equivalent to $587 per hectare treated, or $73 per hectare of opening. Before discounting to present values, fill-planting or replanting costs are estimated at 13.5% of primary planting costs, or 7.7% of all forest-renewal expenditures combined.

BRUSHING. Out of the total of fifty-three PASS 1 openings, Trees Tom estimates that portions of 17 openings will require brushing to release newly established conifers from competing shrubs and deciduous trees. Candidate brushing areas are clustered on the lower slopes. Past experience on similar sites indicates that simply cutting the competing vegetation does not provide the necessary release; some form of herbicide application is necessary. Herbicide technology is complex and rapidly changing. A British Columbia Ministry of Forests fact-sheet (British Columbia Ministry of Forests and Lands 1988) provides a current overview of the subject. However, Trees Tom does not plan to commence brushing operations in Rainbow Creek for several years, at which time new techniques may be available.

—TYPE. Seven of the 17 candidate openings are adjacent to Rainbow Creek or its tributary streams, and will require careful treatment by crews on the ground. Streamside buffer zones must be left untreated, brushed without herbicides, or treated with herbicides, but using techniques which prevent stream contamination. Tentatively, these openings will be treated with the hack-and-squirt method (Figure 9), by applying concentrated glyphosate into hatchet slashes penetrating the cambium of target trees. Shrubby vegetation too small for this treatment will be cut with clearing saws, with cut surfaces treated with glyphosate. Overstocked clumps of conifers can be spaced at the same time.

The remaining ten openings are more remote from streams, and can be foliar-sprayed by helicopter, with suitable precautions. Glyphosate, this time in dilute aqueous solution, is the chosen herbicide. The spray concentration and seasonal timing will be designed to kill broadleaved plants, but not to injure conifers.

—YEAR. All ground brushing is scheduled for 1997 (29.8 ha) or 1998 (13.3 ha). This means a lag of 6-9 years after planting (and 11 years after selective cutting on Blocks 86.02 and 86.03).

All aerial spraying is scheduled for either 1998 (143.5 ha) or the year 2000 (41.3 ha). Trees Tom hopes that economies of scale can be achieved by concentrating helicopter time in this way. All openings targeted will be sprayed from 7 to 10 years after planting.

Brushing surveys conducted closer to the scheduled treatment times will determine whether brushing is necessary, and, if so, which options to employ.

—$/HA. Trees Tom estimates that ground treatment will cost $750 per hectare treated, and aerial spraying $300 per hectare. His estimates are as of 1989.

—% TRTD and HA TRTD. As before, Trees Tom estimates that from 20% to 100% of the area of individual openings will need treatment, and the resulting numbers of hectares to be treated are shown for each opening. The total area for treatment is 227.7 ha, of which 184.5 ha are helicopter-sprayed, and only 43.1 ha ground-treated.

—1989 $. The total brushing bill for PASS 1 openings, in 1989 dollars, is $87 698. This is equivalent to $385 per hectare treated, or $57 per hectare of opening.

JUVENILE SPACING.—YEAR. Trees Tom has scheduled juvenile spacing to take place 14 years after harvesting in every case, subject to confirmation by free-growing surveys done in advance. Spacing operations for PASS 1 openings will thus commence in the year 2000, and end in 2006.

—$/HA. Spacing operations nearby were costing about $800/ha in 1989. Trees Tom uses this estimate, even though spacing operations 10 or more years in the future may differ widely in cost and technique from current operations.

—% TRTD, HA TRTD. For budgeting, Trees Tom predicts that most openings will require some spacing, varying from 10 to 50% of opening area. He predicts *no* spacing will be needed on several openings; however, Trees Tom has budgeted for 364.3 ha of spacing, or about 24% of the area harvested in PASS 1 where the opening has already been brushed—at which time surplus conifers would also be cut—and where the opening is at high elevation, exposed, thin-soiled, or for any other reason unlikely to become overstocked.

—1989 $. The total juvenile spacing cost estimated for PASS 1 openings, in 1989 dollars, is $291 408. This exceeds the bill for any other forest-renewal phase except primary reforestation. Spacing will cost $800 per hectare treated, or $189 per hectare of opening.

ALL TREATMENTS COMBINED. This final section of Appendix III shows the total of all forest-renewal expenditures budgeted for each PASS 1 opening.

—1989 $. This is the total for all surveys and treatments. The total expenditure is $1 452 700, in 1989 dollars.

—$/HA OPNG (cost per hectare of opening). Values range between two extreme cases. For Block 88.12 the cost was $266/ha; this block had no site preparation, but it did have natural seeding, modest fill-planting, and spacing. The cost for Block 88.03 was $1 864/ha; this Block was 100% broadcast burned, 100% planted at $750/ha, 15% replanted, 80% brushed by ground crews, and 20% juvenile-spaced. Fortunately for Trees Tom's budget, Block 88.03 is only 6 ha in extent, and is readily accessible from roads. For all PASS 1 openings, the average amount budgeted per hectare of opening is $944.

—M^3 CUT. This is the volume of timber harvested according to the *Harvest Management System* analysis.

—$/$M^3$ (cost per cubic metre cut). This is the forest-renewal cost, still in 1989 dollars, borne by each m^3 of timber taken from the block. The extremes are represented by the same two blocks as before, i.e. Block 88.12 with $0.85/$m^3$ cut, and Block 88.03 with $6.58/$m^3$ cut. The average amount budgeted per m^3 cut is $3.09, still in 1989 dollars.

This completes a rather lengthy explanation of Appendix III. Because it was prepared as a *Lotus* spreadsheet, Trees Tom was able to make quick trial-and-error comparisons of the effects of various combinations of treatments, and can continue to do so in the future.

Discounted Forest-Renewal Expenditures. In contrast to the three-year duration of the remaining PASS 1 harvesting, the forest-renewal program is expected to take 16 years to complete. It is common practice for licensees in British Columbia to estimate future forest-renewal costs, and treat these costs as an accounting liability, to be written off when the work is completed. Books Bill will discount these future costs to the present, as was done previously with road cost estimates (Table 1), and with the discounted silvicultural costs in Appendix II.

Table 8, derived from Appendix III, shows annual forest-renewal expenditures between 1987 and 2006. These are entered for the correct year, as 1989 dollar values, and then compounded or discounted at 6.5% compound interest, to 1989 present values.

Before discounting, expenditures total $337 580 up to the end of 1989. Expenditures for the year 1989 are higher, at $181 576 (in 1989 dollars), than for any other year. While maintenance of the access roads, fill-planting, brushing, or spacing operations have not yet begun, both the site-preparation and the planting programs peak in that year.

Total future expenditures from 1990 to 2006 are $1 206 122. This figure includes a $91 000 allocation for maintenance of access roads under the forest-renewal program. Trees Tom added this item when he realized that road maintenance under the harvesting program would cease in 1992.

The cost of all past and future forest-renewal on blocks harvested during PASS 1, incurred between 1987 and 2006, is $1 543 702 (still in 1989 dollars). The present (1989) value of this $1 543 702 sum is $1 164 841. This amounts to an average charge of $2.48/m^3 (in 1989 dollars) against the 470 053 m^3 cut during all of PASS 1. As was already shown in Appendix II, the specific charge (in 1989 dollars) against the 163 054 m^3 to be harvested from the remaining 15 uncut blocks is slightly less, at $2.33/m^3.

Forest-Renewal Equipment Requirements and Cost Reconciliation. As in the case of Roads Robbie's road program and Logs Louie's harvesting program (Tables 4 and 4a), Trees Tom wants to know what equipment will be required for forest-renewal operations (Table 8), and when. For the present, Trees Tom is content with this information for the period 1990-92, although it could be worked out for a longer period.

The company will rely on local contractors for all routine forest-renewal projects. Except for mechanical site preparation and helicopter applications, the forest-renewal work planned will be less machine intensive and much more labour intensive than either road or harvesting work.

Table 9 is Trees Tom's estimate of the forest-renewal equipment and labour requirements for 1990, 1991, and 1992. Trees Tom has reconciled Table 9, based on expected productivity and per-shift costs of equipment and labour, with the per-hectare costs already estimated in Table 8.

The work is divided into the same activities as in Table 8 (site preparation, planting, etc.). For example, in 1990:

- No road maintenance charges are yet made against the forest-renewal program, because 1990-92 road maintenance is still charged against harvesting.
- Some surveys are required, costing $487.
- A helicopter, drip torch, and ground support system are needed to broadcast burn 24.8 ha of opening. Based on the system's ability to average about two openings, or 60 ha in a day, at a total charge of $14 400, this requires 0.4 shifts, costing $5 952. A nominal charge for ground patrolling and mop-up is included.
- A crawler with brush blade is needed for debris piling and scarification on 41.8 hectares. At the specified productivity and per-shift cost, this will take 9.5 shifts and cost $9 120.
- The debris piles on 35 ha need to be burned, again using the helicopter, but with much-reduced ground support. This is estimated to require only 0.2 shifts, costing $2363. Charges for patrolling or mop-up are considered negligible, since the lighting can be done under extremely safe conditions.
- Planters must plant 164.7 ha, at an estimated 0.6 ha/shift/planter. The charge for each planter, including prorated contractor's charges, is $220/shift. About 275 planter-shifts are required (e.g. 10 planters, 28 shifts). Planting will cost $60 390, and the delivered cost of the seedlings used is $57 915 (165 ha, 1350 seedlings/ha, $0.26 each in 1990).

Table 8. Annual Expenditures on Forest-Renewal Program, PASS 1 Blocks, 1987-2006

Year	Access-road maintenance	Surveys	Site preparation	Reforestation	Fill-plant	Brushing	Spacing	Total, all expenditures	Present (1989) value [a]
1987			$34 475					$34 475	$39 102
1988		$3 625	$39 857	$78 047				$121 529	$129 428
1989		$2 436	$41 918	$137 222				$181 576	$181 576
Through 1989		$6 061	$116 250	$215 269	$0	$0	$0	$337 580	$350 107
1990		$487	$17 635	$118 518				$136 640	$128 300
1991			$23 190	$78 723				$101 913	$89 853
1992		$3 458	$25 458	$108 791				$137 707	$114 000
1993	$11 500	$1 927	$28 344	$95 457	$6 183			$143 411	$111 477
1994	$11 500	$1 301		$100 067	$14 370			$127 238	$92 869
1995	$8 000	$3 454			$18 435			$29 889	$20 484
1996	$8 000	$2 694			$23 586			$34 280	$22 059
1997	$8 000	$1 695			$21 774	$22 350		$53 819	$32 519
1998	$8 000	$487			$0	$52 964		$61 451	$34 864
1999	$8 000	$3 072			$14 904			$25 976	$13 838
2000	$8 000	$2 229			$12 657	$12 384	$59 784	$95 054	$47 547
2001	$5 000	$1 429					$41 440	$47 869	$22 483
2002	$5 000	$1 960					$58 168	$65 128	$28 723
2003	$5 000	$1 355					$27 112	$33 467	$13 859
2004	$5 000	$1 945					$51 048	$57 993	$22 549
2005		$161					$31 240	$31 401	$11 464
2006		$271					$22 616	$22 887	$7 846
1990-2006	$91 000	$27 924	$94 627	$501 556	$111 909	$87 698	$291 408	$1 206 122	$814 735
Total	$91 000	$33 985	$210 877	$716 825	$111 909	$87 698	$291 408	$1 543 702	$1 164 841
Appendix III total								$1 452 700	
Silviculture road access maintenance								91 000	
								$1 543 700	

[a] Compounded or discounted @ 6.5%.

- Fill-planting, brushing, and spacing operations are scheduled, but not for 1990-92. When they start, the 1989 estimated productivities and per-shift costs will be as shown.
- Forest-renewal expenditures for 1990 total $136 227 (1989 dollars). This total is close to the parallel Table 7 estimate, $136 640, which was derived differently, from prevailing per-hectare contract rates.

Map 3, Reforestation Operations. The *Harvest Management System* is not designed for planning forest-renewal operations, at least not at present. Trees Tom prepared Appendix III, Table 8, Table 9, and supporting forest-renewal data using *Lotus* spreadsheets. However, *HMS* can be manipulated to produce maps depicting the scheduled forest-renewal program applied to the same openings shown on Map 2.

Trees Tom will prepare a separate map showing where and when each forest-renewal activity will take place. Map 3 is one example, showing the schedule for natural and artificial reforestation. Map 3 shows the same opening numbers, harvest systems, and roads in black. Colour shading is somewhat different than in Map 2 (see legends).

In addition to the planting sequence, Trees Tom has shown areas where he is confident that natural seeding will be successful. This includes the blocks cut under the selection system, and some clearcut areas with assured seed sources from adjacent stands or pine cones on the ground.

Uncoloured areas are PASS 2 mature timber, stands presently immature, or non-forested areas, none of which will be restocked under the PASS 1 reforestation program.

Optimizing Harvesting and Forest-Renewal Plans

As part of its Forest Licence agreement, the company must restock all its post-1987 cutovers, to the satisfaction of the British Columbia Ministry of Forests. Super Peter's objectives are not only to deliver

Table 9. Forest-Renewal Requirements and Costs, 1990-92

Activity/ equipment/worker	Productivity (ha/shift)	All-found cost (1989 $/shift)	Year 1990 Area required (ha)	Year 1990 Shifts required (no.)	Year 1990 Cost (1989 $)	Year 1991 Area required (ha)	Year 1991 Shifts required (no.)	Year 1991 Cost (1989 $)
Silviculture access, road maintenance	n/a	n/a	None yet			None yet		
Surveys (Appendix III)	n/a	n/a			$487			$0
Site preparation								
Broadcast burn: Helicopter, torch, support	60.0	$14 400	24.8	0.4	$5 952	49.1	0.8	$11 784
Crawler, brush blade	4.4	$960	41.8	9.5	$9 120	40.7	9.3	$8 880
Burn piles: Helicopter, torch, support	160.0	$10 800	35.0	0.2	$2 363	40.7	0.3	$2 747
			101.6	10.1	$17 435	130.5	10.3	$23 411
Planting								
Planter, contract	0.6	$220	164.7	274.5	$60 390	107.8	179.7	$39 527
Stock cost	n/a	n/a			$57 915			$39 366
			164.7	274.5	$118 305	107.8	179.7	$78 893
Fill-plant								
Planter, contract	1.0	$140	None yet			None yet		
Stock cost	n/a	n/a						
Brushing								
Ground: worker, contract	0.3	$120	None yet			None yet		
Aerial: helicopter, spray-boom	80.0	$12 000	None yet			None yet		
Spacing								
Worker, contract	0.4	$120	None yet			None yet		
All forest-renewal work					$136 227			$102 304
Cost from Table 8					$136 640			$101 913

logs as cheaply as possible within the rules governing harvesting, but also to deliver new timber crops as cheaply as possible within the rules governing forest renewal. The company's survival will depend, jointly, on the profitability of its harvesting and sawmilling, and on the continuing health and productivity of its forests. Success in one part of the operation must not be accompanied by failure in another.

All over British Columbia, foresters and loggers are trying, together, to produce the best possible results at the lowest possible aggregate cost, throughout the harvesting-renewal cycle. Peter has instructed his staff to make sure that this happens on every remaining cutblock in Rainbow Creek. With these instructions, Logs Louie and Trees Tom, with periodic help from Roads Robbie, review the harvesting and post-harvesting plans for the remaining 15 uncut PASS 1 blocks.

Review of Roads and Harvesting Systems. Several roads are still unbuilt (see purple roads, Map 2). Helicopter logging is considered, for some or all of the six blocks still unroaded. Logs Louie is discouraged by the heli-logging costs quoted, and Trees Tom by the prospect of future renewal costs on unroaded openings. The 1990 construction program will continue without change.

Where topography is gentle and timber small, many harvesting systems can be considered. This is no longer the case in Rainbow Creek. Reluctantly, because of expected high costs, Logs Louie and Roads Robbie selected the CABYARD system for eight of the 15 remaining blocks (64% of the remaining volume). They believed that steep terrain would make ground-skidding systems unsafe for workers, or would result in site degradation beyond the limits allowed in the current *Interim Harvesting Guidelines for the Interior of British Columbia* (British Columbia Ministry of Forests 1989a). *HMS* estimates of tree-to-mill harvesting costs for the eight CABYARD blocks average $21.12/m^3 (see Table 4), higher than for any other system.

Year 1992			Years 1990-92 combined		
Area required (ha)	Shifts required (no.)	Cost (1989 $)	Area required (ha)	Shifts required (no.)	Cost (1989 $)
None yet			None yet		
		$3 458			$3 945
0.0	0.0	$0	73.9		$17 736
90.9	20.7	$19 833	173.4	39.4	$37 833
82.0	0.5	$5 535	157.7	1.0	$10 645
172.9	21.2	$25 368	405.0	40.4	$66 213
147.8	246.3	$54 193	420.3	700.5	$154 110
		$54 311			$151 592
147.8	246.3	$108 504	420.3	700.5	$305 702
None yet			None yet		
None yet			None yet		
None yet			None yet		
None yet			None yet		
		$137 330			$375 860
		$137 707			$376 260

Two small blocks, 91.01 and 92.01, were designated as MEDCRAWL blocks, because that system is suited for large timber and short-distance low-speed skidding, with favourable or adverse grades. Estimated costs (Table 4) averaged $19.56/m^3$, and were second-highest.

Logs Louie believes that the FELBUNCH system is still the best for Block 90.04 (small dense timber on gently sloping firm ground); and the SMCRAWL system for 90.05 (the same small timber on steeper ground). Table 4 cost estimates are third highest, at $19.16/m^3$ for the SMCRAWL block, but lowest by a considerable margin, at $14.97/m^3$, for the FELBUNCH block. Logs Louie wishes Rainbow Creek had more stands suited to that system.

Finally, Logs Louie still favours the CHOSKID system on the remaining three blocks where there are moderate well-drained slopes and mixed timber sizes. Estimated costs are second-lowest, at $16.80/m^3$ (Table 4).

In 1989 dollars, harvesting on all 15 blocks is expected to average $19.85/m^3$, which is equivalent to $5934/ha, of the 545.3 ha logged.

Review of Forest-Renewal Prescriptions. Trees Tom's original forest-renewal plans (see Appendix III) for the 15 remaining PASS 1 blocks have generally been confirmed by the PHSPs completed in 1988-89.

Steep slopes restrict the site-preparation choices to broadcast burning (four of the fifteen openings), debris-piling on crawler-accessible sites (four blocks), or *no* site preparation (six blocks). Site preparation is planned neither for the steepest CABYARD blocks because treatment is unnecessary and would probably be damaging, nor for the SMCRAWL and FELBUNCH blocks because good conditions for seeding or planting are predicted. With respect to planting, brushing, and spacing operations, Trees Tom's original budgeting appears realistic, until future findings suggest otherwise.

In 1989 dollars, forest-renewal operations on the 15 blocks are expected to cost $3.43/m³ cut, equivalent to $1027 per hectare cut. These forest-renewal costs are roughly 17% of harvesting costs. Provided harvesting does not lead to outright restocking failures, a relatively small reduction in Logs Louie's harvesting costs will pay for a relatively large increase in Trees Tom's forest-renewal costs. Discounting both renewal and harvesting costs to 1989 would have the effect of making renewal costs an even lower percentage of harvesting costs, since forest-renewal expenditures will extend further into the future.

Block 90.02. Neither Logs Louie nor Trees Tom is entirely satisfied with their reviews in one case: Block 90.02. Figure 10 is a section from Maps 1 and 2, enlarged to 1:10 000, showing Block 90.02 and environs. The CABYARD system was originally chosen, because the block combines moderate steepness, large spruce-subalpine-fir timber, and a moist draw with potential for site degradation from ground skidding. Branch Road 3.3, and spur roads SE-3.1 and SE-3.2 (located for cable-yarding) are already built. However Logs Louie believes that two large 130-kW cable skidders, recently bought by C & H Contracting, can handle the slopes, the timber sizes, and the 250-m maximum skid distances.

Figure 10 shows some of the critical skidding directions, distances, and slopes, which Logs Louie has checked on paper and on the ground. The maximum slope shown is 38%, but this can easily be reduced by skidding in a curved path rather than a straight path. If the skidders cannot move some of the largest spruce logs, C & H can use one of its medium crawlers for that purpose and for incidental skid-trail construction. Logs Louie sees no difficulty in arranging to skid this block during the dry months of 1990 (see Table 3). Skidding in dry conditions will prevent site degradation.

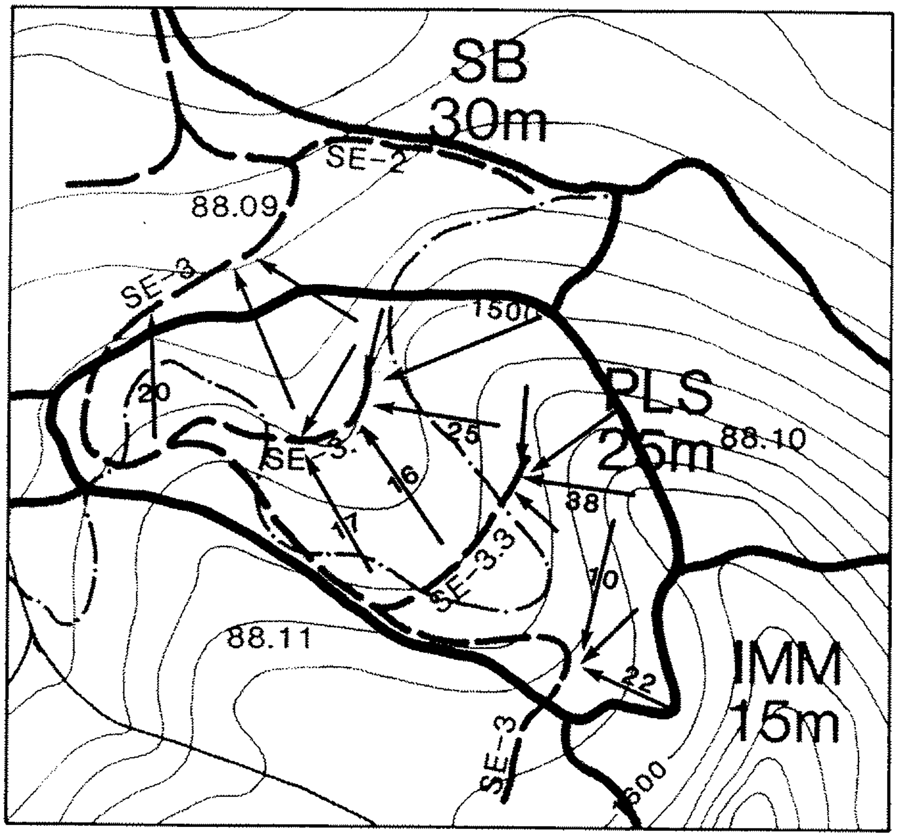

Figure 10. Block 90.02: CHOSKID harvesting system replacing original CABYARD (Scale 1:10 000). Note skid directions and slopes in percent. Contours and forest cover from Map 1; roads and block boundaries from Map 2.

Logs Louie is not surprised to find that the CHOSKID system will lower his estimated direct harvesting costs (Table 10).

Logs Louie can save $1387/ha, or $43 552 on the entire block, by changing to the CHOSKID harvesting system.

He now asks Trees Tom's opinion of the change. Tom has already been wondering whether his blanket "no site preparation" prescription for this block would permit effective planting in heavy slash on the SB 30m portion. This gives him an opportunity to prescribe piling and burning of debris on 60% of the block, at $280 per hectare treated. His forest-renewal costs for Block 90.02 will now increase from $704/ha to $872/ha (Table 11).

In the case of Block 90.02, Logs Louie and Trees Tom have collaborated to deliver the logs more cheaply, preserve the productivity of the site, improve the prospects for a well-stocked new stand, and save $1219/ha in the process.[9]

An outcome this favourable will not occur every time the harvesting and renewal phases are integrated. Often the short-term aggregate costs will be higher, not lower, but the forest-renewal results better. If restocking failures and subsequent rehabilitation costs can be avoided, major savings will result in the long run.

Tom and Louie have no hesitation in revising their plans for Block 90.02. Through the magic of *HMS* and the *Lotus* spreadsheet, they can make the necessary changes to Map 2, Appendix II, Appendix III, and Tables 3, 4, 8, and 9 without major delays. (For purposes of this report, however, Block 90.02 was left unchanged.)

Table 10. Estimated Direct Harvesting Costs, CABYARD and CHOSKID 1990

System	Phase: Harvesting ($)	Phase: Share of roads ($)	Total ($)	Equivalent ($/ha)
CABYARD	212 937	60 613	273 550	8 712
CHOSKID	169 390	60 613	230 003	7 325
Savings				1 387

Table 11. Forest-Renewal Costs for Block 90.02

	Phase: Surveys ($)	Phase: Site preparation ($)	Phase: Planting ($)	Phase: Fill-planting ($)	Phase: Brushing ($)	Phase: Juvenile spacing ($)	Total renewal ($)	Equivalent ($/ha)	Harvesting + renewal ($/ha)
CABYARD	753	-	9 420	1 884	0	10 048	22 105	704	9 416
CHOSKID	753	5 275	9 420	1 884	0	10 048	27 380	872	8 197
Savings									1 219

[9] This amount reduces slightly to a savings of $1154/ha if harvesting and renewal costs are all brought to a 1989 present value, at 6.5% interest.

PASS 2 Planning

PASS 2 areas will go through a cycle similar to that for PASS 1, but the cycle will not commence for nearly 30 years, with the building of some new roads in the year 2018. Construction, harvesting, and forest-management objectives and methods at that time can hardly be predicted with accuracy now. Detailed harvesting and forest-renewal plans like those for PASS 1 should not be made for PASS 2 areas until about the year 2015. This does not mean, however, that these areas can be ignored. Trees Tom needs an idea of probable developments on the PASS 2 areas, chiefly for assurance that he (and his successors) will not be "painted into a corner" by the developments he has planned on PASS 1 areas.

In scanning Maps 2 and 3, Trees Tom realizes that some things related to PASS 2 must be considered now:

- Forest Protection. The mature and immature stands left for PASS 2 were deliberately designed as a ridge-to-ridge firebreak across the valley, to be left intact for several more decades. Protection for these valuable stands would be an important part of the overall protection plan for Rainbow Creek. For example, Tom has considered the risk of damage from broadcast burning next to PASS 2 timber edges, and has chosen to pile and burn, or do no site preparation, in several surrounding PASS 1 blocks.

  Windfall losses may occur in the uncut mature stands, but the location of their outside boundaries should ensure that losses are minimal. If salvage becomes necessary, access is good.

  Further insect infestations like that of the mountain pine bark beetle in 1983 may occur. Responses will depend on the location and type of stand, but Tom can see in general where and how salvage or sanitation cutting could extend from existing roads.
- Recreation Sites. Accessible mature and immature stands left for PASS 2 may become a logical focus for public recreation, after surrounding stands have been cut, and log-hauling traffic diminishes. Consultations and preliminary planning should start soon.
- Future Road Development. Roads opening up Blocks 19.01-22.01 are paper-located (red roads, Map 2). After inspecting Maps 1 and 2, Tom is satisfied that conventional log-hauling roads can readily extend from existing roads into all of the presently immature stands. Field location work is premature, by nearly 30 years.
- PASS 2 Harvesting. Based on the *HMS* printouts for the six PASS 2 blocks, Tom has no doubt that the mature timber can be harvested profitably. Timber values and terrain are, if anything, better than on the remaining PASS 1 blocks.

  Immature stands of fire origin, now over 15 m in height, are located nearby (see Map 1). Soon after PASS 1 harvesting is complete, Tom will assess the potential of these stands to be commercially thinned or harvested. He expects no cutting until about the year 2020, but needs an updated inventory of these immature stands to confirm this.
- PASS 2 Forest Renewal. Forest-renewal planning for PASS 2 areas is also premature, by at least 30 years. By the time detailed plans are needed, new and unpredictable policies, objectives, and technologies will undoubtedly dictate forest-renewal practices.

Having thought through these matters, Trees Tom is confident that his PASS 1 planning contains nothing which would jeopardize the future of Rainbow Creek. This is not to say, however, that Tom expects events to follow the plans in every respect. One of the characteristics of good planning is the extent to which the plans can be quickly altered in response to changing circumstances.

Checking, Reviewing, Modifying, and Approving

The new plan for Rainbow Creek, extended from the plan presented in Handbook No. 4 to include forest renewal for all PASS 1 openings, is now completed in draft form. Now is the time to ask other people to check it thoroughly for errors or omissions, and to correct any found. Then the plan would be presented to a widening circle of people for review, discussion, questions, field inspections, comments, and suggested changes. The circle would progressively change and grow to include, among others:

- Roads Robbie, Logs Louie, and Trees Tom, jointly, as authors of separate parts of the plan.
- Contractors.
- Company specialists in sawmilling, marketing, finances, or other matters raised by the plan.
- Super Peter, who must study, question, adopt, and defend the final plan.
- The Ministry of Forests District Manager and staff, or Region colleagues (all have previously

reviewed similar material in the form of a draft cutting permit application and a series of PHSPs).

- Other government departments whose concerns may be affected.
- Other known users of Rainbow Creek, such as a registered trapper, a rancher, several guides/outfitters, and representatives of the municipal water board.
- The general public, through the public review process.

Super Peter and his staff will make full use of *HMS* monitor displays during their presentations. Finally, they would use *HMS* to produce hard copies of maps, illustrations, and printouts, after all necessary changes have been made.

Approval to execute a forest-management plan does not come automatically or quickly, even when the management unit has already been under management for several years and a routine is in place. Forest managers need all the help they can get. Some of that help can now come from use of the latest GIS technology. The use of GIS technology allows planners to spend more time in the field and it helps to reduce the confusion surrounding the entire planning and review process.

Super Peter and his staff and contractors have taken pains since 1983 to establish and maintain good relations with the other current and potential users of the Rainbow Creek drainage.

Municipal water board members and the owners of a sport fishing resort on Rainbow Lake were originally apprehensive about upstream logging. They have been kept informed of the company's plans, have been consulted about the timing of road-construction projects, and have visited active operations with Super Peter. Water quality and habitat have been maintained to their satisfaction.

The rancher's grazing permit has recently been extended from the lower valley into the limited areas centring around the IDF aw1 sites, near Rainbow Lake. He has similarly been kept informed, and has agreed to help protect new conifer crops by suspending cattle grazing on openings identified by Trees Tom, i.e. until the crops are "cattle-proof." In return, Super Peter has agreed to share in the installation and maintenance costs of cattle-guards and waterholes as needed.

The long-time holder of a registered trapline covering Rainbow Creek has continued to trap on uncut portions of the drainage. He has found, however, that advanced second-growth stands in the lower valley, resulting from logging in the 1930s, have become excellent habitats for marten and beaver. He is now elderly, but his son, a skidder operator with C & H Contracting, has expressed some interest in part-time trapping, subject to favourable fur prices.

Guides/outfitters in the region service non-resident big-game hunters. As well, Rainbow Creek is becoming more and more popular with local deer and elk hunters. Game populations have increased with the forage on new cutovers. Many of the local hunters depend on local harvesting or forestry jobs, and have detailed knowledge of the area and its road network. As with the other user groups, Super Peter and his staff have maintained dialogue with the local fish and game clubs and Ministry of Environment officials regarding game management, safety, road access, and road use issues. The intermixing of industrial operations with hunter access and activities each fall has created problems, but has served as a concrete demonstration that multiple use can work.

These co-users generally understand and support the proposed activities because of the good relations which have been cultivated; and Super Peter and his staff are thankful for this. They realize that use of the area by families and the general public will increase in future, thus creating new problems, but also opportunities to acquire new friends and supporters.

Cutting Permit Application

Most of the information described above (including the change for Block 90.02) was submitted in 1989 as a cutting permit application to the Forest District Manager. The application included all 15 blocks scheduled for 1990-92 cutting. A final version of Map 2 will supersede previous maps accompanying the application, and other official documents such as an updated Five-Year Development Plan.

All proposed roads have been located and marked on the ground, ready for construction in 1990. Similarly, the proposed 1990 cutblock boundaries are ground-located and marked; they have been shown to the contractors concerned, and the area is ready for falling. The 1991 and 1992 cutblocks are not yet fully ground-located and marked, but Logs Louie and Trees Tom have looked at them from surrounding blocks and know they can be harvested with the systems chosen.

Final PHSPs (including the revised one for Block 90.02) have been submitted as part of the application.

DISCUSSION

The total-chance concept means thinking the whole cycle through, from A to Z, before starting work at A. In one form or another, this simple concept applies to most human endeavours. It can be especially useful in the field of forestry, because many years often elapse between A and Z.

In British Columbia, progress has been made in applying the concept to timber harvesting, but frequent changes in forestry objectives, economics, and perceptions have required frequent redefinition of what constitutes the total chance itself, and frequent rethinking of the development/harvesting cycle in individual forests. Nevertheless foresters recognize the obvious benefits of the concept, and are trying to extend it to include the entire development/harvesting/renewal cycle.

"What-ifs" abound in planning for anything as complex as the development/harvesting/renewal cycle on a forest. What if A is delayed? What if B costs more than predicted? What if C becomes unnecessary, but D must be done early? And so on. Forest planners who have failed to consider the "what-ifs" are destined for some rude shocks.

"What-nows" will also abound during forest operations, regardless of the "what-ifs" already considered. What do we do *now*, in response to unpredicted events X, Y, and Z? What will B cost *now*, following further unpredicted changes in the weather, labour or product markets, insect populations, international trading climate, or government fiscal policies?

A geographic information system like the *Harvest Management System* can be of enormous assistance in preparing the original development/harvesting cycle, studying a large number of "what-ifs," and providing operational responses to the "what-nows."

In British Columbia, a forest-renewal equivalent to the *Harvest Management System* has not yet been developed. The forest-renewal cycle for Rainbow Creek was appended to the harvesting cycle already finalized by *HMS*, rather than being linked directly to it. Without this linkage, changes in either cycle would require a step-by-step reworking of the other.

An extension of *HMS*, to include the forest-renewal portion of the cycle, is desirable. Perhaps the new package should be called "Harvest and Renewal Management System" or "HRMS."

CONCLUSIONS

In 1983, almost all of the planning emphasis for Rainbow Creek was on beetle-attacked trees, new road construction, and commencement of harvesting operations. In 1990, about half the emphasis is on the early stages of forest renewal. In 1993, the emphasis will have shifted almost entirely from harvesting to forest renewal, along with continued concern for forest protection, water quality, recreation, fish and wildlife, and no doubt other issues not yet recognized.

Invented for illustration purposes, Rainbow Creek is a small drainage, already extensively harvested, and free of many of the complexities that managers of real forests may face.

Is planning of the sort illustrated too elaborate and costly in real life? Not in the 1990s. All interested parties need to see exactly what the short-term and long-term objectives are, and how they will be met. The government and the public want assurances that Crown lands will retain their productivity and integrity, and will continue to support regional economies. A forest company wants the same assurances, as well as operating profits and continuity. Forest planning can provide these assurances, but it must be comprehensive, and must be reviewed frequently.

Baskerville[10] outlines six criteria for evaluating forest-management performance. Briefly paraphrased, these are:

- Are all users of the forest identified?
- Is there a set of attainable, measurable policy goals?
- Is there a plan of management which identifies a target forest structure, and a spatial and temporal developmental pattern to meet the specified users' needs?
- Is there a realistic and geographically explicit implementation schedule?
- Is there a detailed and geographically explicit record of the implementation?
- Is there regular feedback, to compare reality with forecasts?

Baskerville suggests a current lack of linkage exists between goal-setting and implementation on the forest. He cautions that "...models, and such hi-tech items as geographic information systems, are crucial to management design and implementation, *but only if they are used intelligently with respect to what happens in the forest.*"

Geographic information systems can make important contributions to integrated resource management, if they can provide rapid and thorough analyses of the "what-ifs" during initial planning, intelligent responses to the "what-nows" posed by later human or natural interventions, and regular and geographically specific measures of forest-management performance.

The concluding sentence of FERIC Handbook No. 4 expressed the hope that the handbook would help "to eliminate those uncertainties which can be eliminated, and to deal wisely with the ones that remain." That is also the hope for this report.

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APPENDIX I

Annual Expenditures on Road and Bridge Construction [a]

Year	Road	Length (m)	Construction original estimate	Cost as built	Unbuilt, 1989 estimate	Built or unbuilt ($/m)
1984	N Main	2 650	$74 000	$74 000		$27.92
1984	S Main	2 350	$78 000	$78 000		$33.19
1984	N-2	3 850	$97 300	$97 300		$25.27
1984	N-2.2	400	$7 600	$7 600		$19.00
		9 250	$256 900	$256 900		$27.77
1985	N Main	1 050	$27 000	$27 000		$25.71
1985	S Main, bridges	2 350	$143 100	$143 100		$60.89
1985	N-2.1	3 250	$119 000	$121 380		$37.35
1985	N-2.1.1	300	$7 500	$7 650		$25.50
1985	N-2.1.2	850	$32 200	$32 844		$38.64
1985	N-3	1 400	$50 000	$51 000		$36.43
1985	N-3.1	500	$13 000	$13 260		$26.52
		9 700	$391 800	$396 234		$40.85
1986	N-2.5	700	$28 600	$29 755		$42.51
1986	N-2.4	600	$16 800	$17 479		$29.13
1986	SE-3	2 300	$87 200	$90 723		$39.44
1986	SE-1 (A)	400	$13 300	$13 837		$34.59
1986	SE-2	1 750	$47 400	$49 315		$28.18
1986	NE-3.1	150	$3 000	$3 121		$20.81
1986	SE-2.1	300	$5 400	$5 618		$18.73
1986	N-2.3	300	$12 700	$13 213		$44.04
1986	NE-2	1 050	$24 360	$25 344		$24.14
1986	NE-1	350	$5 200	$5 410		$15.46
1986	NE-3	1 550	$40 700	$42 344		$27.32
1986	NE-6	350	$7 000	$7 283		$20.81
		9 800	$291 660	$303 443		$30.96
1987	NE-4.3	1 800	$112 200	$119 068		$66.15
1987	NE-4.1	1 200	$48 100	$51 044		$42.54
1987	NE-5.1	200	$5 200	$5 518		$27.59
1987	NE-4.4	900	$21 600	$22 922		$25.47
1987	NE-5	1 400	$65 200	$69 191		$49.42
1987	NE-4.2	1 100	$59 200	$62 824		$57.11
1987	NE-4	3 250	$116 500	$123 631		$38.04
		9 850	$428 000	$454 197		$46.11
1988	NE-3.2	850	$22 100	$23 922		$28.14
1988	S-3.1	900	$16 200	$17 535		$19.48
1988	SE-3.3	400	$12 000	$12 989		$32.47
1988	S-3	1 200	$27 158	$29 397		$24.50
1988	SE-3.4	300	$13 400	$14 505		$48.35
1988	SE-3.1	400	$11 200	$12 123		$30.31
1988	SE-1 (B)	4 400	$213 700	$231 316		$52.57
		8 450	$315 758	$341 787		$40.45

...continued on next page

Year	Road	Length (m)	Construction original estimate	Cost as built	Unbuilt, 1989 estimate	Built or unbuilt ($/m)
1989	S-2.7	400	$8 000	$8 833		$22.08
1989	S-2.9	400	$8 800	$9 716		$24.29
1989	S-2.8	500	$10 000	$11 041		$22.08
1989	S-2	5 900	$259 200	$286 178		$48.50
1989	S-2.6	800	$16 000	$17 665		$22.08
1989	S-2.2	1 350	$40 500	$44 715		$33.12
1989	S-2.1	500	$9 000	$9 937		$19.87
1989	S-1 (A)	550	$13 200	$14 574		$26.50
		10 400	$364 700	$402 658		$38.72
Subtotal, 1984-89		57 450	$2 048 818	$2 155 219		$37.51
1990	S-2.5	1 000	$60 000		$66 245	$66.24
1990	S-1 (B)	2 750	$95 200		$105 108	$38.22
1990	N-1.1	300	$7 200		$7 949	$26.50
1990	S-1.1	1 300	$48 400		$53 438	$41.11
1990	S-2.4	900	$19 800		$21 861	$24.29
1990	N-1	2 150	$86 200		$95 172	$44.27
Subtotal, 1990		8 400	$316 800	$0	$349 773	$41.64
Total, PASS 1 roads		65 850	$2 365 618	$2 155 219	$349 773	
Total, built + unbuilt		65 850			$2 504 992	$38.04
2018	SE-3.2	800	$31 600		$34 889	$43.61
2018	NE-2	200	$4 640		$5 123	$25.61
2018	SE-1.1	700	$12 600		$13 911	$19.87
		1 700	$48 840	$0	$53 923	$31.72
2019	S-3.2	600	$22 629		$24 984	$41.64
2019	S-3	700	$15 842		$17 491	$24.99
2019	S-2.2	150	$4 500		$4 968	$33.12
2019	S-2.3	350	$8 400		$9 274	$26.50
2019	S-3.2	100	$3 771		$4 164	$41.64
2019	S-2.3	150	$3 600		$3 975	$26.50
		2 050	$58 742	$0	$64 856	$31.64
Total, PASS 2 roads		3 750	$107 582	$0	$118 779	$31.67
Total, PASS 1 + PASS 2		69 600	$2 473 200	$2 155 219	$468 552	
Total, built + unbuilt		69 600			$2 623 771	$37.70

[a] Historical cost increase rate, 1984-89: 2% per annum since 1984
Future construction (1990+): Original estimates inflated at 2% to 1989, but not beyond. Not yet discounted.

APPENDIX II

1989 Logging Costs

1990-92. 15 BLOCKS. 1989 LOGGING COST TABLE.

Date or report	: January 9, 1990	
Report year	: 1990	
Cost table used	: 1	
Logging table used	: 1	
Minimum logging cost ($)	: 0	
Maximum logging cost ($)	: 10 000	

Report based on:

Attributes

YEAR	: 1990	1991	1992
ENVIRONMENT	: --- ALL ---		
HARVEST SEQUENCE	: --- ALL ---		
DEV BY MAIN RD	: --- ALL ---		
SELECTIVE LOG	: --- ALL ---		
REGEN TYPE	: --- ALL ---		
NEW-OLD LOG	: --- ALL ---		

Reported areas MUST satisfy the conditions in all of the attributes

Logging systems selected:

CABYARD
CHOSKID
FELBUNCH
LGPSKID
MEDCRAWL
SMCRAWL

Cutblocks from map TCHANCE:

				Production m^3/shift			Shifts required		
Block	Logging system	Area	Volume	Fall	Yard	Load	Fall	Yard	Load
90.01	CHOSKID	40.7	13 659	100	150	260	137	91	53
90.02	CABYARD	31.4	10 075	140	140	160	72	72	63
90.03	CABYARD	81.9	22 909	140	140	160	164	164	143
90.04	FELBUNCH	43.6	13 395	400	300	400	33	45	33
90.05	SMCRAWL	45.5	13 389	70	60	260	191	223	51
90.06	CABYARD	4.5	1 348	140	140	160	10	10	8
91.01	MEDCRAWL	27.3	10 383	90	120	200	115	87	52
91.02	CHOSKID	10.1	3 601	100	150	260	36	24	14
91.03	CABYARD	66.9	20 925	140	140	160	149	149	131
91.04	CABYARD	20.1	6 335	140	140	160	45	45	40
91.05	CABYARD	21.4	5 966	140	140	160	43	43	37
92.01	MEDCRAWL	8.0	2 421	90	120	200	27	20	12
92.02	CABYARD	105.4	27 550	140	140	160	197	197	172
92.03	CHOSKID	4.7	1 200	100	150	260	12	8	5
92.04	CABYARD	33.8	9 898	140	140	160	71	71	62
	Total/average	545.3	163 054	125	131	186	1 032	1 294	876

Logging Totals:

Logging system	Area (ha)	Volume (m^3)	Production Fall (m^3/shift)	Production Yard (m^3/shift)	Production Load (m^3/shift)	Shifts required Fall	Shifts required Yard	Shifts required Load
CHOSKID	55.5	18 460	100	150	256	185	123	72
CABYARD	365.4	105 006	140	140	160	751	751	656
FELBUNCH	43.6	13 395	406	298	406	33	45	33
MEDCRAWL	35.3	12 804	90	120	200	142	107	64
SMCRAWL	45.5	13 389	70	60	263	191	223	51
Totals	545.3	163 054	125	131	186	1 302	1 249	876

Volumes by Species:

Species	% logged	Volume logged (m^3)	Grade 1 Name	Grade 1 %	Value/m^3	Value
Bl	100	26 325	SAWLOG	100	$35.00	$ 921 375
Cw	100	7 852	SAWLOG	100	42.00	329 784
Fd	100	1 595	SAWLOG	100	45.00	71 775
Hw	100	4 228	SAWLOG	100	39.00	164 892
Pl	100	51 055	SAWLOG	100	45.00	2 297 475
S	100	71 999	SAWLOG	100	52.00	3 743 948
Totals		163 054			46.18	$7 529 249

Total logging summary:

Total falling cost	:	$ 502 745	
Total yarding cost	:	1 194 666	
Total loading cost	:	452 031	
Total logging fixed cost	:	0	
Total rehab cost	:	0	
Total haul cost	:	1 087 028	
Total direct harv cost	:	$3 236 470	
Total spur road cost	:	1 059 779	
Total, all direct costs	:	$4 296 249	
Total value	:	$7 529 249	
Total volume	:	163 054	m^3
Total area	:	545	ha
Average volume/ha	:	299.18	m^3/ha
Cost, $/$m^3$			
Direct costs (above)	:	$26.35	$/$m^3$
Share of main roads	:	0.69	$/$m^3$
Road maintenance	:	1.00	$/$m^3$
Area administration	:	3.50	$/$m^3$
Stumpage	:	10.00	$/$m^3$
Discounted silv. cost (see below)	:	2.33	$/$m^3$
		$43.87	$/$m^3$

Discounted Silviculture Costs: [a]

Phase	Cost (1989 $)	Median year spent	Discounted over (yrs)	Present value (1989 $)
Surveys	$ 14 246	1995	6	$ 9 763
Site preparation	76 992	1992	3	63 738
Primary reforestation	304 315	1993	4	236 551
Fill-planting	39 390	1998	9	22 348
Brushing	20 015	2000	11	10 012
Spacing	104 904	2005	16	38 300
	$559 862			$380 712

Discounted cost/m³ = $380 712 ÷ 163 054 m³
= $2.33 m³

[a] Future forest-renewal costs, discounted to 1989 present values.
Discount interest factor: 6.50% p.a.

APPENDIX III

Forest-Renewal Program, Scheduling, Costs

20-Mar AP3-SILV.WK1 A1..R112; S1..AJ112; AK1..BB112

APPENDIX III. FOREST RENEWAL PROGRAM, SCHEDULING, COSTS. HECTARES TREATED AND YEAR-CUT SUBTOTALS ADDED.

COSTS ARE CURRENT (1989) REGARDLESS OF WHEN INCURRED.

YR/BLOCK	HA	HARV SYSTEM	MAIN BGC SUBZ.	MAIN TBR TYPE	PHSPs (PRE-HARVEST, OFFICIAL) YEAR	PHSPs $/HA	PHSPs 1989 $	POST-HARVEST SURVEYS TYPES*	YEARS	$/HA	1989 $
86.01	15.1	FELBUNCH	IDF mw 1	FPL	NOT			R,F	92,99	$16	$242
86.02	14.7	MEDCRAWL SEL	ICH mw 2	CHS				R,B,F	92,92,99	$24	$353
86.03	19.2	MEDCRAWL SEL	ICH mw 2	CHS				R,B,F	92,92,99	$24	$461
86.04	67.3	FELBUNCH	IDF mw 1	FPL	IN			R,F	92,99	$16	$1,077
86.05	28.1	CHOSKID	ICH mw 2	CHS				R,B,F	92,92,96	$24	$674
86.06	5.7	CABYARD	ICH mw 2	CHS				R,B,F	92,92,96	$24	$137
86.07	23.7	MEDCRAWL	ICH mw 2	CHS	EFFECT			R,B,F	92,92,96	$24	$569
86.08	46.6	CABYARD	ESSF wc 2	PLS				R,F	93,00	$16	$746
86.09	25.4	MEDCRAWL	ESSF wc 2	PLS				R,F	93,00	$16	$406
86.10	6.9	CABYARD	ESSF wc 2	SBPL	UNTIL			R,F	89,96	$16	$110
	252.7										$4,774
87.01	21.2	CHOSKID	ESSF wc 2	SB				R,B,F	92,95,99	$24	$509
87.02	11.0	MEDCRAWL	ESSF wc 2	SB	1988			R,B,F	92,95,99	$24	$264
87.03	42.2	CABYARD	ESSF wc 2	PLS				R,F	94,01	$16	$675
87.04	36.5	CABYARD	ESSF wc 2	SB				R,B,F	92,95,99	$24	$876
87.05	56.2	CABYARD	ESSF wc 2	PLS				R,F	94,01	$16	$899
87.06	60.8	LGPSKID	ESSF wc 2	SBPL				R,F	90,97	$16	$973
87.07	16.8	SMCRAWL	ESSF wc 2	PLS				R,F	94,01	$16	$269
	244.7										$4,465
88.01	34.1	SMCRAWL	ESSF wc 2	PLS				R,F	95,02	$16	$546
88.02	6.2	CABYARD	ESSF wc 2	PLS				R,F	95,02	$16	$99
88.03	6.0	CABYARD	ESSF wc 2	SB				R,B,F	93,96,00	$24	$144
88.04	47.6	CHOSKID	ESSF wc 2	SB				R,B,F	93,96,00	$24	$1,142
88.05	38.9	SMCRAWL	ESSF wc 2	PLS				R,F	95,02	$16	$622
88.06	9.1	CABYARD	ESSF wc 2	PLS				R,F	95,02	$16	$146
88.07	46.0	CABYARD	ESSF wc 2	PLS				R,F	95,02	$16	$736
88.08	13.9	SMCRAWL	ESSF wc 2	PLS				R,F	95,02	$16	$222
88.09	30.0	CHOSKID	ESSF wc 2	SB				R,B,F	93,96,00	$24	$720
88.10	24.6	CABYARD	ESSF wc 2	PLS				R,F	95,02	$16	$394
88.11	14.2	CHOSKID	ESSF wc 2	PLS				R,F	95,02	$16	$227
88.12	17.3	CABYARD	ESSF wc 2	PLS				R,F	95,02	$16	$277
88.13	3.4	CABYARD	ESSF wc 2	SB				R,B,F	93,96,00	$24	$82
	291.3										$5,357
89.01	23.0	CHOSKID	ESSF wc 2	SB	88	$8	$184	R,B,F	94,97,01	$24	$552
89.02	3.1	CABYARD	ESSF wc 2	SB	88	$8	$25	R,S,F	94,97,01	$24	$74
89.03	17.7	CABYARD	ESSF wc 2	PLS	88	$8	$142	R,F	96,03	$16	$283
89.04	46.9	SMCRAWL	ESSF wc 2	PLS	88	$8	$375	R,F	96,03	$16	$750
89.05	61.9	CABYARD	ESSF wc 2	SBPL	88	$8	$495	R,F	92,99	$16	$990
89.06	5.3	SMCRAWL	ESSF wc 2	PLS	88	$8	$42	R,F	96,03	$16	$85
89.07	11.2	CABYARD	ESSF wc 2	PLS	88	$8	$90	R,F	96,03	$16	$179
89.08	36.4	SMCRAWL	ESSF wc 2	SBPL	88	$8	$291	R,F	92,99	$16	$582
	205.5						$1,644				$3,497
90.01	40.7	CHOSKID	ESSF wc 2	SB	88	$8	$326	R,B,F	95,98,02	$24	$977
90.02	31.4	CABYARD	ESSF wc 2	PLS	88	$8	$251	R,F	97,04	$16	$502
90.03	81.9	CABYARD	ESSF wc 2	SBPL	88	$8	$655	R,F	93,00	$16	$1,310
90.04	43.6	FELBUNCH	ESSF wc 2	PLS	88	$8	$349	R,F	97,04	$16	$698
90.05	45.5	SMCRAWL	ESSF wc 2	PLS	88	$8	$364	R,F	97,04	$16	$728
90.06	4.5	CABYARD	ESSF wc 2	PLS	88	$8	$36	R,F	97,04	$16	$72
	247.6						$1,981				$4,287
91.01	27.3	MEDCRAWL	ICH mw 2	CHS	89	$8	$218	R,B,F	96,00,01	$24	$655
91.02	10.1	CHOSKID	ICH mw 2	CHS	89	$8	$81	R,B,F	96,00,01	$24	$242
91.03	66.9	CABYARD	ESSF wc 2	SB	89	$8	$535	R,B,F	96,99,03	$24	$1,606
91.04	20.1	CABYARD	ESSF wc 2	PLS	89	$8	$161	R,F	98,05	$16	$322
91.05	21.4	CABYARD	ESSF wc 2	SBPL	89	$8	$171	R,F	94,03	$16	$342
	145.8						$1,166				$3,167
92.01	8.0	MEDCRAWL	ESSF wc 2	SBPL	89	$8	$64	R,F	95,04	$16	$128
92.02	105.4	CABYARD	ESSF wc 2	SBPL	89	$8	$843	R,F	95,04	$16	$1,686
92.03	4.7	CHOSKID	ESSF wc 2	SBPL	89	$8	$38	R,F	95,04	$16	$75
92.04	33.8	CABYARD	ESSF wc 2	PLS	89	$8	$270	R,F	99,06	$16	$541
	151.9						$1,215				$2,430
ALL	1539.5					$4	$6,006			$18	$27,978
CK	1539.5							ALL SURVEYS ----			$33,984

YR/BLOCK	SITE PREPARATION METHOD	YEAR	$/HA	% TRTD	HA TRTD	1989 $	PRIMARY METHOD	REFORESTATION YEAR	$/HA	% TRTD	HA TRTD	1989 $
86.01	NONE				0.0	$0	NAT	87-93			0.0	$0
86.02	PILE,BURN	87	$300	80%	11.8	$3,528	NAT	88-93			0.0	$0
86.03	PILE,BURN	87	$300	80%	15.4	$4,608	NAT	88-93			0.0	$0
86.04	NONE				0.0	$0	NAT	87-93			0.0	$0
86.05	PILE,BURN	87	$280	100%	28.1	$7,868	PLANT	88	$850	100%	28.1	$23,885
86.06	BDCST BURN	87	$240	100%	5.7	$1,368	PLANT	88	$850	100%	5.7	$4,845
86.07	PILE,BURN	87	$280	100%	23.7	$6,636	PLANT	88	$850	100%	23.7	$20,145
86.08	BDCST BURN	87	$240	30%	14.0	$3,355	PLANT	88	$680	50%	23.3	$15,844
86.09	PILE,BURN	87	$280	100%	25.4	$7,112	PLANT	88	$680	50%	12.7	$8,636
86.10	(ALREADY BURNED)				0.0	$0	PLANT	88	$680	100%	6.9	$4,692
					124.0	$34,475					100.4	$78,047
87.01	PILE,BURN	88	$280	100%	21.2	$5,936	PLANT	89	$750	100%	21.2	$15,900
87.02	PILE,BURN	88	$280	100%	11.0	$3,080	PLANT	89	$750	100%	11.0	$8,250
87.03	BDCST BURN	88	$240	30%	12.7	$3,038	PLANT	89	$750	50%	21.1	$15,825
87.04	BDCST BURN	88	$240	100%	36.5	$8,760	PLANT	89	$750	100%	36.5	$27,375
87.05	NONE				0.0	$0	PLANT	89	$750	50%	28.1	$21,075
87.06	PILE,BURN	88	$280	70%	42.6	$11,917	PLANT	89	$680	70%	42.6	$28,941
87.07	PILE,BURN	88	$280	50%	8.4	$2,352	PLANT	89	$680	50%	8.4	$5,712
					132.3	$35,083					168.9	$123,078
88.01	PILE,BURN	88	$280	50%	17.1	$4,774	PLANT	89	$680	50%	17.1	$11,594
88.02	BDCST BURN	89	$240	100%	6.2	$1,488	PLANT	90	$750	50%	3.1	$2,325
88.03	BDCST BURN	89	$240	100%	6.0	$1,440	PLANT	90	$750	100%	6.0	$4,500
88.04	PILE,BURN	89	$280	100%	47.6	$13,328	PLANT	90	$750	100%	47.6	$35,700
88.05	PILE,BURN	89	$280	50%	19.5	$5,446	PLANT	90	$680	50%	19.5	$13,226
88.06	NONE				0.0		PLANT	90	$680	50%	4.6	$3,094
88.07	BDCST BURN	89	$240	50%	23.0	$5,520	PLANT	90	$680	60%	27.6	$18,768
88.08	PILE,BURN	89	$280	50%	7.0	$1,946	PLANT	90	$750	50%	7.0	$5,213
88.09	PILE,BURN	89	$280	100%	30.0	$8,400	PLANT	90	$750	100%	30.0	$22,500
88.10	BDCST BURN	89	$240	40%	9.8	$2,362	PLANT	90	$680	50%	12.3	$8,364
88.11	PILE,BURN	89	$280	50%	7.1	$1,988	PLANT	90	$680	50%	7.1	$4,828
88.12	NONE				0.0	$0	NAT	89-95			0.0	$0
88.13	NONE				0.0	$0	PLANT	89	$750	100%	3.4	$2,550
					173.2	$46,692					185.1	$132,662
89.01	PILE,BURN	90	$280	100%	23.0	$6,440	PLANT	91	$750	100%	23.0	$17,250
89.02	NONE				0.0	$0	PLANT	91	$750	100%	3.1	$2,325
89.03	NONE				0.0	$0	NAT	90-96			0.0	$0
89.04	PILE,BURN	90	$280	40%	18.8	$5,253	PLANT	91	$750	30%	14.1	$10,553
89.05	BDCST BURN	90	$240	40%	24.8	$5,942	PLANT	91	$750	60%	37.1	$27,855
89.06	NONE				0.0	$0	PLANT	91	$680	100%	5.3	$3,604
89.07	NONE				0.0	$0	PLANT	91	$680	30%	3.4	$2,285
89.08	NONE				0.0	$0	PLANT	91	$680	60%	21.8	$14,851
					66.5	$17,635					107.8	$78,723
90.01	PILE,BURN	91	$280	100%	40.7	$11,396	PLANT	92	$750	100%	40.7	$30,525
90.02	NONE				0.0	$0	PLANT	92	$750	40%	12.6	$9,420
90.03	BDCST BURN	91	$240	60%	49.1	$11,794	PLANT	92	$750	80%	65.5	$49,140
90.04	NONE				0.0	$0	PLANT	92	$680	30%	13.1	$8,894
90.05	NONE				0.0	$0	PLANT	92	$680	30%	13.7	$9,282
90.06	NONE				0.0	$0	PLANT	92	$680	50%	2.3	$1,530
					89.8	$23,190					147.8	$108,791
91.01	PILE,BURN	92	$280	100%	27.3	$7,644	PLANT	93	$850	100%	27.3	$23,205
91.02	PILE,BURN	92	$280	100%	10.1	$2,828	PLANT	93	$850	100%	10.1	$8,585
91.03	PILE,BURN	92	$280	80%	53.5	$14,986	PLANT	93	$750	100%	66.9	$50,175
91.04	NONE				0.0	$0	PLANT	93	$680	40%	8.0	$5,467
91.05	NONE				0.0	$0	PLANT	93	$750	50%	10.7	$8,025
					90.9	$25,458					123.0	$95,457
92.01	BDCST BURN	93	$240	100%	8.0	$1,920	PLANT	94	$750	100%	8.0	$6,000
92.02	BDCST BURN	93	$240	100%	105.4	$25,296	PLANT	94	$750	100%	105.4	$79,050
92.03	BDCST BURN	93	$240	100%	4.7	$1,128	PLANT	94	$750	100%	4.7	$3,525
92.04	NONE				0.0	$0	PLANT	94	$680	50%	16.9	$11,492
					118.1	$28,344					135.0	$100,067
ALL					794.9	$210,876					968.0	$716,824
			$137 /HA OPNG						$466 /HA OPNG			
			$265 /HA TRTD						$741 /HA TRTD			

"PLANT" COST = STOCK + PLANTING

YR/BLOCK	FILL-PLANTING, REPLANTING YEAR	$/HA	% TRTD	HA TRTD (EQUIV)	1989 $	TYPE	BRUSHING YEAR	$/HA	% TRTD	HA TRTD (EQUIV)	1989 $
86.01	94	$300	10%	1.5	$453					0.0	$0
86.02	94	$600	20%	2.9	$1,764	GROUND	97	$750	60%	8.8	$6,615
86.03	94	$600	20%	3.8	$2,304	GROUND	97	$750	60%	11.5	$8,640
86.04	94	$300	10%	6.7	$2,019					0.0	$0
86.05	96	$600	15%	4.2	$2,529	AIR	98	$300	80%	22.5	$6,744
86.06	96	$600	15%	0.9	$513	GROUND	97	$750	40%	2.3	$1,710
86.07	96	$600	15%	3.6	$2,133	AIR	98	$300	80%	19.0	$5,688
86.08	95	$600	5%	2.3	$1,398					0.0	$0
86.09	95	$600	5%	1.3	$762					0.0	$0
86.10	95	$600	10%	0.7	$414					0.0	$0
				27.9	$14,289					64.1	$29,397
87.01	93	$600	15%	3.2	$1,908	AIR	98	$300	80%	17.0	$5,088
87.02	93	$600	15%	1.7	$990	AIR	98	$300	80%	8.8	$2,640
87.03	95	$600	15%	6.3	$3,798					0.0	$0
87.04	93	$600	15%	5.5	$3,285	AIR	98	$300	80%	29.2	$8,760
87.05	95	$600	15%	8.4	$5,058					0.0	$0
87.06	95	$600	10%	6.1	$3,648					0.0	$0
87.07	95	$600	10%	1.7	$1,008					0.0	$0
				32.8	$19,695					55.0	$16,488
88.01	96	$600	5%	1.7	$1,023					0.0	$0
88.02	96	$600	5%	0.3	$186					0.0	$0
88.03	94	$600	15%	0.9	$540	GROUND	97	$750	80%	4.8	$3,600
88.04	94	$600	15%	7.1	$4,284	AIR	98	$300	60%	28.6	$8,568
88.05	96	$600	15%	5.8	$3,501					0.0	$0
88.06	96	$600	15%	1.4	$819					0.0	$0
88.07	96	$600	15%	6.9	$4,140					0.0	$0
88.08	96	$600	15%	2.1	$1,251					0.0	$0
88.09	94	$600	15%	4.5	$2,700					0.0	$0
88.10	96	$600	15%	3.7	$2,214					0.0	$0
88.11	96	$600	15%	2.1	$1,278					0.0	$0
88.12	96	$600	15%	2.6	$1,557					0.0	$0
88.13	94	$600	15%	0.5	$306	GROUND	97	$750	70%	2.4	$1,785
				39.7	$23,799					35.7	$13,953
89.01	95	$600	15%	3.5	$2,070	AIR	98	$300	80%	18.4	$5,520
89.02	95	$600	15%	0.5	$279	GROUND	98	$750	100%	3.1	$2,325
89.03	97	$600	15%	2.7	$1,593					0.0	$0
89.04	97	$600	10%	4.7	$2,814					0.0	$0
89.05	97	$600	10%	6.2	$3,714					0.0	$0
89.06	97	$600	10%	0.5	$318					0.0	$0
89.07	97	$600	10%	1.1	$672					0.0	$0
89.08	97	$600	15%	5.5	$3,276					0.0	$0
				24.6	$14,736					21.5	$7,845
90.01	96	$600	10%	4.1	$2,442	GROUND	98	$750	25%	10.2	$7,631
90.02	99	$600	10%	3.1	$1,884					0.0	$0
90.03	99	$600	10%	8.2	$4,914					0.0	$0
90.04	99	$600	10%	4.4	$2,616					0.0	$0
90.05	99	$600	10%	4.6	$2,730					0.0	$0
90.06	99	$600	10%	0.5	$270					0.0	$0
				24.8	$14,856					10.2	$7,631
91.01	97	$600	15%	4.1	$2,457	AIR	2000	$300	80%	21.8	$6,552
91.02	97	$600	15%	1.5	$909	AIR	2000	$300	60%	6.1	$1,818
91.03	97	$600	15%	10.0	$6,021	AIR	2000	$300	20%	13.4	$4,014
91.04	99	$600	10%	2.0	$1,206					0.0	$0
91.05	99	$600	10%	2.1	$1,284					0.0	$0
				19.8	$11,877					41.3	$12,384
92.01	2000	$600	15%	1.2	$720					0.0	$0
92.02	2000	$600	15%	15.8	$9,486					0.0	$0
92.03	2000	$600	15%	0.7	$423					0.0	$0
92.04	2000	$600	10%	3.4	$2,028					0.0	$0
				21.1	$12,657					0.0	$0
ALL				190.6	$111,909					227.7	$87,698
		$73 /HA OPG						$57 /HA OPG			
		$587 /HA TRTD						$385 /HA TRTD			

Extra costs to fill-plant:
more walking
brush, imm.
manual s.p., screefing
larger stock

YR/BLOCK	JUVENILE SPACING YEAR	$/HA	% TRTD	HA TRTD (EQUIV)	1989 $	ALL TREATMENTS COMBINED 1989 $	$/HA OPNG	M3 CUT	$/M3
86.01	2000	$800	70%	10.6	$8,456	$9,151	$606	5251	$1.74
86.02			0%	0.0	$0	$12,260	$834	3386	$3.62
86.03			0%	0.0	$0	$16,013	$834	3460	$4.63
86.04	2000	$800	50%	33.7	$26,920	$30,016	$446	22825	$1.32
86.05	2000	$800	15%	4.2	$3,372	$45,072	$1,604	11182	$4.03
86.06	2000	$800	20%	1.1	$912	$9,485	$1,664	2318	$4.09
86.07	2000	$800	15%	3.6	$2,844	$38,015	$1,604	9345	$4.07
86.08	2000	$800	30%	14.0	$11,184	$32,527	$698	15801	$2.06
86.09	2000	$800	30%	7.6	$6,096	$23,012	$906	7996	$2.88
86.10	2000	$800	0%	0.0	$0	$5,216	$756	1702	$3.06
				74.7	$59,784	$220,767	$874	83266	$2.65
87.01	2001	$800	10%	2.1	$1,696	$31,037	$1,464	7584	$4.09
87.02	2001	$800	10%	1.1	$880	$16,104	$1,464	3646	$4.42
87.03	2001	$800	20%	8.4	$6,752	$30,089	$713	14251	$2.11
87.04	2001	$800	0%	0.0	$0	$49,056	$1,344	13196	$3.72
87.05	2001	$800	30%	16.9	$13,488	$40,520	$721	15563	$2.60
87.06	2001	$800	30%	18.2	$14,592	$60,070	$988	15013	$4.00
87.07	2001	$800	30%	5.0	$4,032	$13,373	$796	5296	$2.53
				51.8	$41,440	$240,249	$982	74549	$3.22
88.01	2002	$800	30%	10.2	$8,184	$26,121	$766	9718	$2.69
88.02	2002	$800	30%	1.9	$1,488	$5,586	$901	1962	$2.85
88.03	2002	$800	20%	1.2	$960	$11,184	$1,864	1700	$6.58
88.04	2002	$800	20%	9.5	$7,616	$70,638	$1,484	14645	$4.82
88.05	2002	$800	30%	11.7	$9,336	$32,131	$826	12277	$2.62
88.06	2002	$800	30%	2.7	$2,184	$6,243	$686	2837	$2.20
88.07	2002	$800	30%	13.8	$11,040	$40,204	$874	13726	$2.93
88.08	2002	$800	40%	5.6	$4,448	$13,080	$941	4376	$2.99
88.09	2002	$800	0%	0.0	$0	$34,320	$1,144	9993	$3.43
88.10	2002	$800	40%	9.8	$7,872	$21,205	$862	7462	$2.84
88.11	2002	$800	20%	2.8	$2,272	$10,593	$746	4457	$2.38
88.12	2002	$800	20%	3.5	$2,768	$4,602	$266	5440	$0.85
88.13	2002	$800	0%	0.0	$0	$4,723	$1,389	1118	$4.22
				72.7	$58,168	$280,630	$963	89711	$3.13
89.01	2003	$800	0%	0.0	$0	$32,016	$1,392	7547	$4.24
89.02	2003	$800	0%	0.0	$0	$5,028	$1,622	981	$5.13
89.03	2003	$800	20%	3.5	$2,832	$4,850	$274	5301	$0.91
89.04	2003	$800	20%	9.4	$7,504	$27,249	$581	14723	$1.85
89.05	2003	$800	20%	12.4	$9,904	$48,901	$790	16541	$2.96
89.06	2003	$800	30%	1.6	$1,272	$5,321	$1,004	1684	$3.16
89.07	2003	$800	30%	3.4	$2,688	$5,914	$528	3589	$1.65
89.08	2003	$800	10%	3.6	$2,912	$21,913	$602	9107	$2.41
				33.9	$27,112	$151,192	$736	59473	$2.54
90.01	2004	$800	20%	8.1	$6,512	$59,809	$1,470	13659	$4.38
90.02	2004	$800	40%	12.6	$10,048	$22,106	$704	10075	$2.19
90.03	2004	$800	20%	16.4	$13,104	$80,917	$988	22909	$3.53
90.04	2004	$800	30%	13.1	$10,464	$23,021	$528	13395	$1.72
90.05	2004	$800	30%	13.7	$10,920	$24,024	$528	13389	$1.79
90.06	2004	$800	0%	0.0	$0	$1,908	$424	1348	$1.42
				63.8	$51,048	$211,784	$855	74775	$2.83
91.01	2005	$800	40%	10.9	$8,736	$49,468	$1,812	10383	$4.76
91.02	2005	$800	40%	4.0	$3,232	$17,695	$1,752	3601	$4.91
91.03	2005	$800	30%	20.1	$16,056	$93,392	$1,396	20925	$4.46
91.04	2005	$800	20%	4.0	$3,216	$10,372	$516	6335	$1.64
91.05	2005	$800	0%	0.0	$0	$9,823	$459	5966	$1.65
				39.1	$31,240	$180,749	$1,240	47210	$3.83
92.01	2006	$800	30%	2.4	$1,920	$10,752	$1,344	2421	$4.44
92.02	2006	$800	20%	21.1	$16,864	$133,226	$1,264	27550	$4.84
92.03	2006	$800	30%	1.4	$1,128	$6,317	$1,344	1200	$5.26
92.04	2006	$800	10%	3.4	$2,704	$17,035	$504	9898	$1.72
				28.3	$22,616	$167,330	$1,102	41069	$4.07
ALL				364.3	$291,408	$1,452,700	$944	470053	$3.09
								OK	
		$189 /HA OPG				$944 /HA OPG			
		$800 /HA TRTD				(N/A)			

N = 53 OPENINGS (EXCL. PASS 2)

= work completed

* R = REGENERATION SURVEY
B = BRUSHING SURVEY
F = FREE-GROWING SURVEY

SURVEY COST IS $8/HA OF OPENING , REGARDLESS OF SURVEY TYPE

APPENDIX IV

List of Organizations and Individuals Contacted

Association of British Columbia Professional Foresters, Annual Meeting, Penticton (many personal contacts, panel discussions on *Forest Land: The Challenge of Sharing*)

British Columbia Ministry of Forests

- Campbell River Forest District—Bruce McKerricher, Small Business Forest Enterprise Program.
- Chilliwack Forest District—Bruce Oakley, Timber; Les Anderson, Silviculture.
- Cranbrook Forest District—John Przecsek, Silviculture.
- Kamloops Region—Yo Yano, Silviculture; Clark Roadhouse, Timber; Bernie Ivanco, Recreation; Geza Toth, Valuation.
- Prince George Region—Leverne Merkle, Timber; Mike Connor, Silviculture.
- Vancouver Region—John Howe and Len Leroux, Timber.
- Victoria—Mike Wyeth and Paul Diggle, Silviculture; Dave Laurie, Engineering; Kamill Apt, Integrated Resources, Recreation Section.
- Victoria—Lois Dellert and Al Becker, Inventory; Andrew Mitchell, Integrated Resources; Bela Hirczy, Engineering.
- Williams Lake—Al Randall, Silviculture; Peter Guise, Timber.

Coast Silviculture Committee, Nanaimo Workshop (many contacts and much new information on Coast silviculture research)

Crestbrook Forest Industries Ltd., Cranbrook—Craig Lodge, Dave Basaraba, John Konkin, Wayne Morrison, Dave Melenka, Toby Grippich.

Evans Products Company Ltd., Golden Division—Brett Salmon, Division Forester.

Fletcher Challenge Canada Limited

- Armstrong Division—Bill Coulter, Division Forester.
- Kelowna Division—Fred Swetitch, Logging Supervisor; Kelly Fay, Forestry Supervisor.

Forestry Canada, Victoria—Glenn Manning, Departmental Representative for Project.

MacMillan Bloedel Limited

- Cameron Division—Bernie Waatainen, Division Forester.
- Nanaimo—Dave Handley, Designed Forest Manager; Pat McDonnell, Inventory; George von Westarp, Silviculture.

Northwood Pulp and Timber Limited, Prince George—Norm Crist, Silviculture; Meredith Spike, TFL Forestry Supervisor.

Quest Wood Products, A Division of Tolko Industries Ltd., Quesnel—Wayne Boudreau, Operations Forester; Eric Bodman, Forester.

Southern Interior Silviculture Committee Workshop, Penticton (many personal contacts; panels on resource users in the mid-elevation (Montane spruce) zone, the pre-harvest silviculture prescription (PHSP) process, and Southern Interior forest research update.

Tolko Industries Ltd., Lavington—Kim Young, Operations Forester.

Weldwood of Canada Limited

- Quesnel—John Breadon, TFL Forester.
- Williams Lake—John Mansell, Woodlands Manager.

West Fraser Mills Ltd.,Quesnel—Al Waters, Silviculture; Paul Scott, Cutting Permits and phsps.

Weyerhaeuser Canada Limited, Kamloops—Steve Tolnai, Chief Forester; Rich Hodson, Planning Forester; Rod Willis, Silviculture Forester.