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Reduced-Impact Logging Guidelines for Lowland and Hill Dipterocarp Forests in Indonesia

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REDUCED-IMPACT LOGGING GUIDELINES FOR LOWLAND AND HILL DIPTEROCARP FORESTS IN INDONESIA

Plinio Sist[1], Dennis Dykstra[2], and Robert Fimbel[3]

Executive Summary

This report describes Reduced-Impact Logging (RIL) which will be implemented in the lowland and hill dipterocarp forests of the Bulungan Model Forest project in East Kalimantan, Indonesia. It is anticipated that through the implementation and supervision of the RIL practices described in this document, the timber concession operators (INHUTANI II) can expect to: reduce disturbances to soil and residual vegetation by at least 50% in comparison with conventional logging operations where these guidelines are not applied; limit overall direct impacts to the forest to < 25%; conserve wildlife and other forest resources, including non timber forest products (NTFPs), threatened and endangered species, keystone plant resources, and water; diminish direct logging costs by at least 15%; and protect the long-term integrity and value of the permanent forest estate.

INTRODUCTION

International awareness of escalating deforestation rates has caused many tropical countries, including Indonesia, to give priority to the attainment of the International Tropical Timber Organisations (ITTO's) year 2000 objective to bring the forest estate under sustainable management. Progress towards sustainable forest management will promote the implementation of reduced-impact logging (RIL) techniques, which aim to reduce soil disturbance, impacts on wildlife, and damage to residual trees. RIL has been recently implemented and tested in various tropical regions, particularly Southeast Asia (Sabah: Pinard and Putz 1996; East Kalimantan: Bertault and Sist 1995, 1997; Sist *et al.*1998).

In Indonesia, forest management and harvesting operations are regulated under the Tebang Pilih Tanam Indonesia (TPTI) selective logging system (Armitage and Kuswanda 1989). This system allows for all commercial trees > 50-60 cm dbh (the minimum harvest diameter depends on the type of production forest, see glossary) to be removed within a felling cycle of 35 years. RIL practices are recommended under the TPTI; however, these are seldom applied in the field for numerous reasons, including: 1) lack of control over harvesting practices; 2) limited specificity in how to conduct RIL measures; and 3) high financial costs of RIL if combined with enrichment planting.

The RIL guidelines proposed in this document expand upon those outlined in the FAO's Model Code of Forest Harvesting Practices (Dykstra and Heinrich 1996), the RIL specifications developed for the INNO-PRISE concession in Sabah (Pinard *et al.* 1995), and are in accordance with TPTI regulations. They will be tested in the Bulungan Research Forest (Sist 1997; Wollenberg and Sist 1997) in an effort to refine the methods and establish their costs, at a concession scale. These procedures are general by necessity, and will have to be adapted to local concession conditions if RIL is to be successfully implemented.

1. HARVESTING PLANS

The success of RIL in significantly reducing logging damage on forest ecosystems cannot be achieved without the planning of harvesting operations. Harvesting plans must be included in a broader forest management plan, which is a long term (> 20 years) land use plan designed to ensure sustainable management of the forest resource. The harvest planning process takes into account the ecological, environmental, and socio-economic features of the concession, and are of two types: strategic (Figure 1) and tactical (Figure 2.)

1. 1. Strategic plan

Strategic harvesting plans are components of the forest management planning process, and should be designed by an interdisciplinary planning team including foresters, ecologists, logging specialists, engineers, wildlife biologists, and experts in social science. Strategic plans are medium term plans which, under TPTI regulations, are for a 5-year period and are called Rencana Kerja Lima tahun (RKL). In other countries, strategic plans may be for longer periods (10-20 years). The strategic plan provides the following information in written documents and 1:25 000 scale maps:

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Figure 1: Forest management and harvesting plans

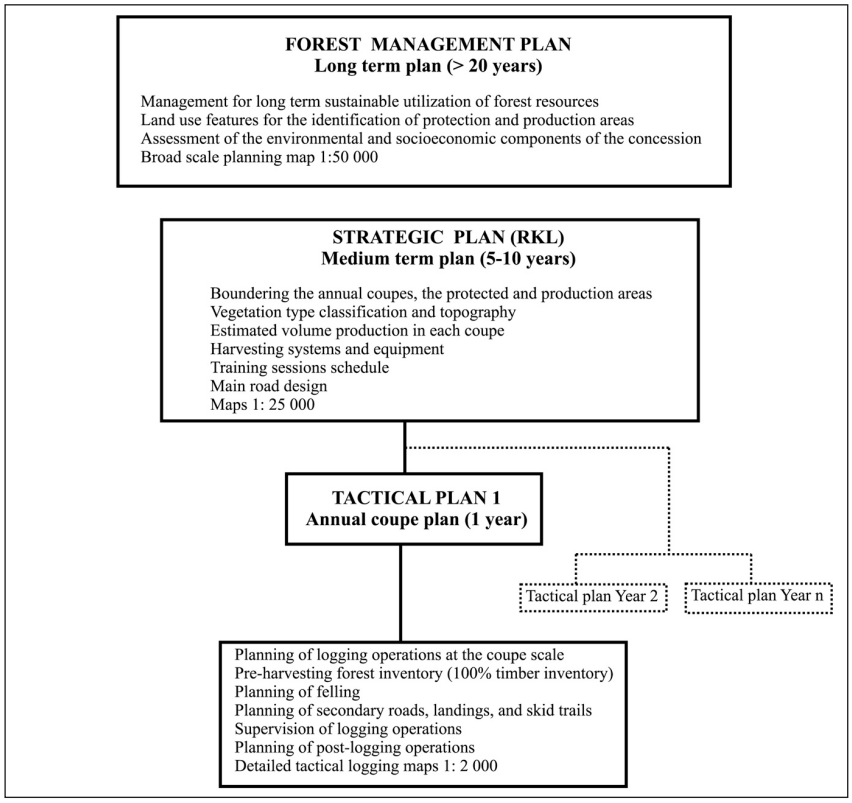
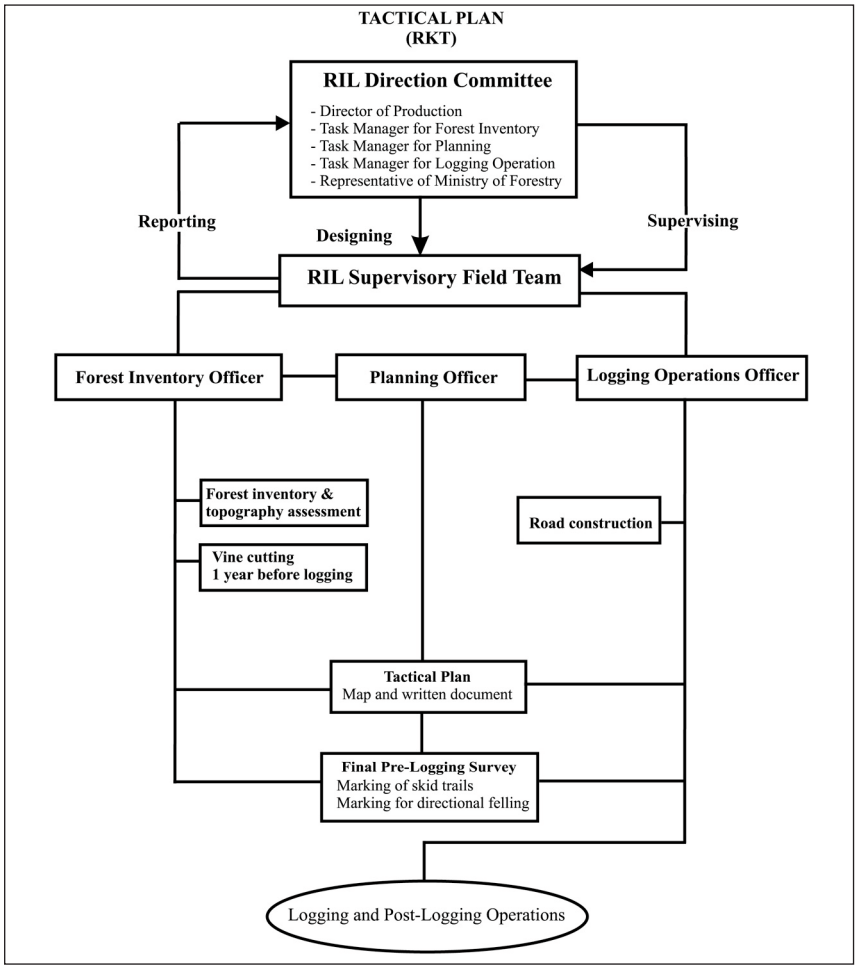


Figure 2: Tactical plan operations sequences



- vegetation types of the area covered by the plan;
- areas selected for timber harvesting and areas to be excluded from silvicultural activities;
- approximate boundaries and size of the annual coupes;
- estimated standing and harvestable volume in each coupe;
- approximate road location for main transportation routes;
- extraction techniques to be used; and
- special conservation measures to be applied.

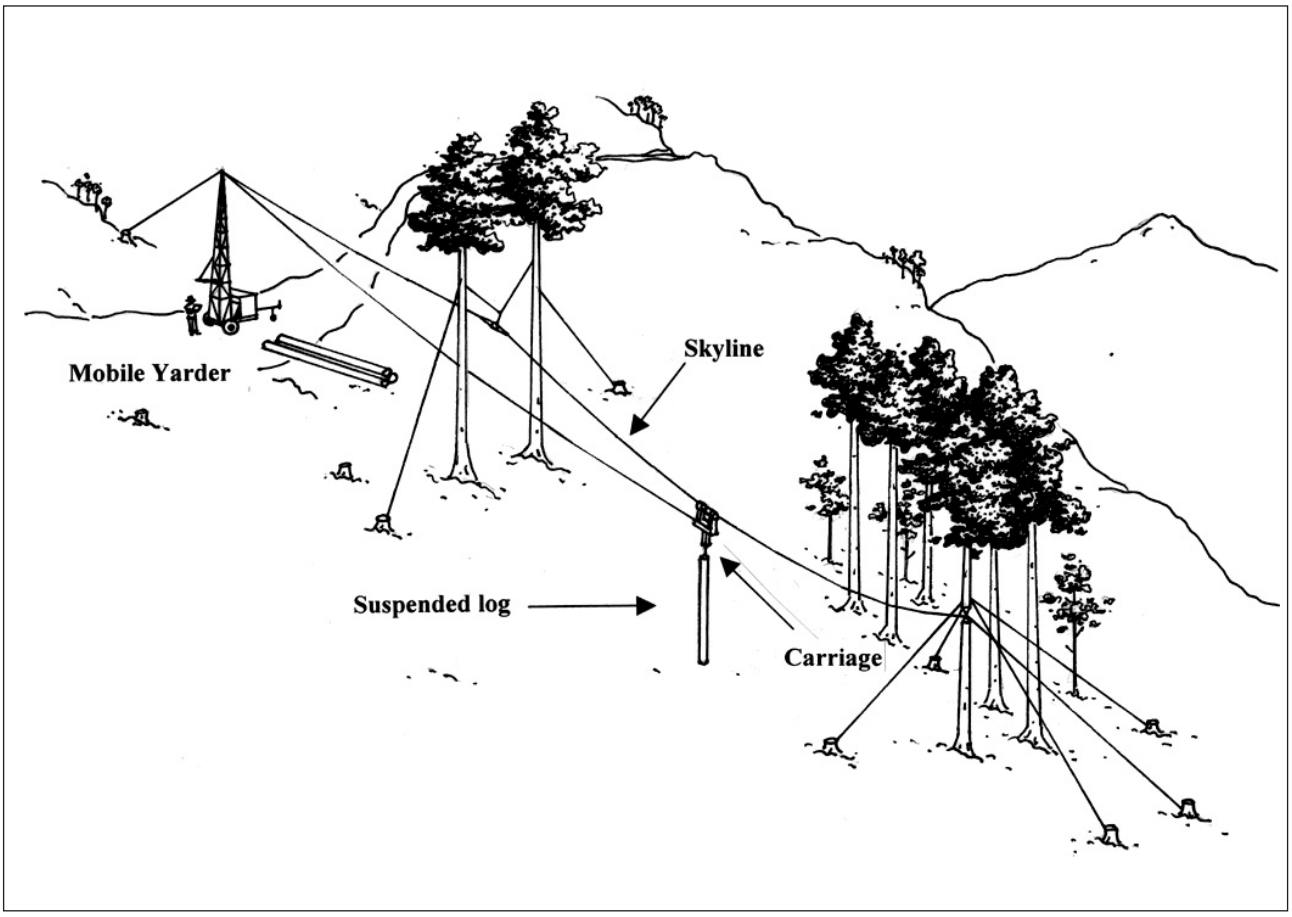
One important task of the strategic plan is to define the type of extraction, which is primarily topography dependent.

- In areas where slopes are mostly <30% (see glossary), ground skidding is permitted.
- In coupes where the slopes mainly range from 30-70%, ground skidding is prohibited because of the extensive damage to both soil and vegetation which results under these conditions. In this range of slopes, skyline yarding systems are an appropriate extraction system (Figure 3).

  The decision to use cable extraction must be based on a pre-harvesting plan, taking into account the technical feasibility, the investment required, and the commercial profitability. Cable systems require special training and expertise to be successfully implemented, especially in Indonesia where cable extraction systems have rarely been used (e.g., in the Sumalindo concession in East Kalimantan, Aulerich 1995). While many different cable extraction systems are available to accommodate different terrain conditions and forest types, skyline systems are considered to have the lowest impact on both soil and forest (Figure 3). This is particularly true when logs are fully suspended to eliminate soil disturbance. Thus, it is very important that sufficient time is allotted to the planning of these cable systems, so that the operation can meet its environmental objectives at a reasonable cost. Finally, according to the terrain condition, extraction planning may suggest the use of both ground skidding and cable extraction in different parts of a coupe.

- Areas with slopes > 70% must be excluded from cutting and should be identified as protection forest. The same is true for riparian zones and areas of unique forest habitat.

Figure 3: Example of skyline with fully suspended logs



1. 2. Tactical plan

Tactical plans provide technical procedures and planning details for the harvesting operations to be carried out in the annual coupe. In TPTI, tactical plans are called Rencana Kerja Tahunan (RKT). Planning and implementation procedures of RIL are included in this operational plan (Figure 2).

2. DEVELOPING RIL GUIDELINES WITHIN THE TACTICAL PLAN

2. 1. Supervising RIL

The harvest design and cutting operations outlined in the tactical plan require careful supervision if RIL measures are to succeed. To accomplish this, a 'RIL Committee' must be developed, with the responsibility of verifying that logging operations are conducted in accordance with RIL guidelines and schedules. This committee should be comprised of the company director, a representative of the Ministry of Forestry, and senior company managers responsible for inventories, planning, and logging operations (Figure 2).

The committee's primary task is to provide direction to a 'RIL Supervisory Field Team' (SFT), who controls and supervises both logging planning and operations in the field. The SFT should be comprised of the forest officers responsible for inventories, harvest planning, and logging operations (Figure 2). The main tasks and responsibilities of the SFT are to:

- control and supervise all the pre-harvesting operations;
- control and supervise the implementation of RIL procedures in the field;
- provide technical expertise and advice to the operators during logging;
- make prompt decisions in the field when RIL guidelines cannot be fulfilled or require interpretation; and
- report regularly to the RIL Committee on the progress of logging operations.

The success of RIL implementation will depend largely on the technical skill of the SFT, which must take the lead in implementing logging operations in accordance with the RIL guidelines. For this reason, forest officers of the SFT need to be trained in RIL techniques and forest engineering.

2. 2. Pre-harvesting operations

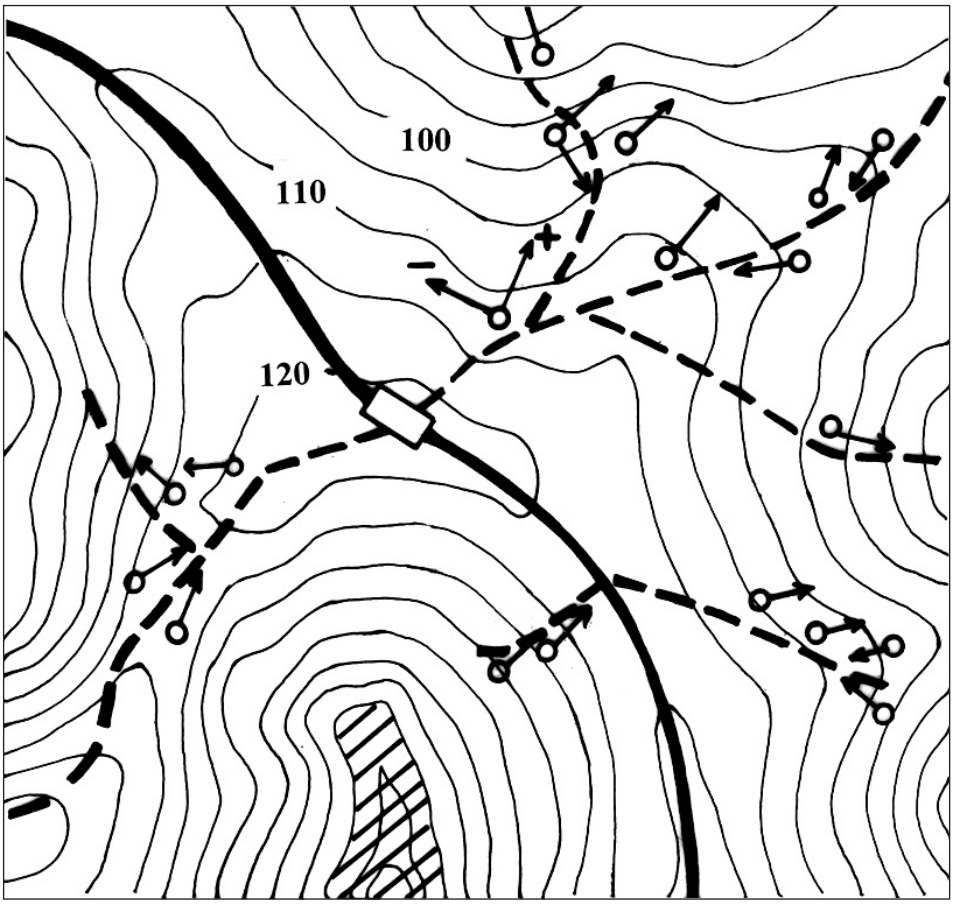
Pre-harvesting activities aim to collect all essential biophysical data to prepare for logging operations in the annual coupe. This information leads to the construction of a tactical logging map and tactical logging plan document (Figures 2 and 4).

2.2.1. Stock survey

The stock survey describes the frequency and distribution of important commercial, ecological, and non-timber forest product (NTFP) tree species across the annual coupe. The list of species to be described for a particular harvest area are stipulated during the forest management planning process (Figure 1), and includes the following categories:

- *All harvestable timber trees (dbh ≥ 50 cm or dbh ≥ 60 cm according the type of the production forest)*. Commercial species and harvesting diameter limits are stipulated in TPTI. Dipterocarps are the dominant commercial species, with stems ≥ 50-60 cm dbh considered harvestable. The minimum harvestable dbh varies with the type of forest (production forest or limited-production forest). Where timber trees have low or no commercial value because of unsuitable shape or external sign of wood rot, these individuals are marked in the field and on the stock map to exclude them from the harvest. Trees presenting risk of splitting are also identified and marked to be excluded from felling.
- *All potential crop trees* (PCT). PCT are commercial timber species with 20 cm ≤ dbh 50 ≤ cm, which are likely to comprise the next harvest. PCT are marked in the field and mapped in an effort to protect them during felling operations.
- *Protected tree species: rare, threatened, or endangered species*. TPTI regulations exclude the felling of certain species (e.g., *Eusideroxylon zwagerii*, *Koompassia excelsa*, *Dyera costulata*). Stems of these and other IUCN Red Book listed species (IUCN 1990), > 20 cm dbh, should be marked, recorded, and mapped to ensure their protection during logging operations.
- *Trees with dbh ≥ 10 cm known by local people to provide non timber forest products* (NTFPs). Local cruisers with a good knowledge of trees providing NTFPs must be part of the stock survey team. The same data as those collected for timber trees must be collected for these trees by the forest inventory team. These trees should be marked, numbered, and their position shown in the map.
- *Important wildlife resource trees.* A select group of tree species that serve as important food resources for wildlife should be marked,

Figure 4: Example of a tactical logging map (Scale 1:2 000, 5 m contour lines) issued after pre-harvesting inventory. The arrows indicate planned directional felling. Logs should be laid at approximately a 30^0 angle with the skid trail. (+ = Good directional felling, angle with skid trail < 30^0; - = Unacceptable, angle with skid trail > 30^0). Buffer zone in hatches. Solid line indicates forest road and dashed lines present skid trails.



recorded, and mapped to protect them during the harvest. The species to be included in this list will be site specific (e.g., MacKinnon *et al.* 1996, provide a table of important food trees for wildlife and people in the forests of Kalimantan).

During the stocking survey, data to be recorded for each tree included in the inventory are:

- tree number;
- commercial or local name;
- position in the cutting block; and
- estimated diameter class (in cm) above the buttresses.

In order to be in line with TPTI forest inventory procedures, all harvestable trees (Group 1 above) will be marked with red labels while PCT and protected species will be marked with yellow labels. The labels must indicate the:

- annual coupe and cutting block (petak);
- number of the tree;
- diameter class; and
- commercial name.

In addition to this marking procedure required by Indonesian forest regulations, it is recommended that marks that can be easily identified in the forest be used. Therefore, harvestable trees should be marked with a painted red ring on the bark, while PCT and protected species should receive a yellow ring.

Finally, the stock survey will be carried out at least 6 months before logging by teams composed of both foresters (for timber) and local cruisers (for NTFPs). Their activities will be supervised by the Forest Inventory Officer of the SFT.

2. 2. 2. Climber cutting

Climbers can seriously compromise both feller safety and directional felling. Therefore, all climbers $\geq$ 2 cm dbh that are attached to the canopy of harvestable

stems should be cut at least 6 months before logging. Climber cutting should normally be done in conjunction with the stock survey, and under the supervision of the Forest Inventory Officer of the SFT.

2. 2. 3.Topography assessment

Because the road and skidding trails network will be mainly designed and planned according to the terrain, it is essential to produce accurate topographic maps using all the modern methods and tools available (e.g., aerial photos, satellite images, radar images). However, if the remote sensing images are not sufficient to produce maps at a suitable scale for logging planning (1:2000), topographic maps must be prepared by an intensive field survey (Klassen 1998). This is often done in conjunction with the stock survey, where the maximum contour interval for a tactical logging map is 5 m, with contour intervals of 1 m or 2 m being preferred.

2. 2. 4. Protected areas

Within the cutting block, all areas are to be harvested except those reserved as:

- **Unworkable areas**: areas that are too steep (> 30% for ground skidding and > 70% for any other logging system), rocky, and/or have very low commercial timber.
- **Sacred areas**: areas that have cultural or religious value for the local residents. Sacred areas must be defined in consultation with local populations and clearly marked as protected areas on the logging plan maps.
- **Conservation areas**: areas that preserve unique and/or fragile habitats, and areas of high biodiversity. These areas must be representative of the different ecosystems occurring in the concession and can only be defined through an assessment of the wildlife community and its habitat within the cutting block (Annex 1). Conservation areas may include unworkable and sacred areas.
- **Stream buffer zones**: areas adjacent to streams (permanent watercourses) where logging activities are not permitted. Streams are considered to be watercourses if they flow for at least 2 months in most years. Stream buffer zones vary in width from 20-200 m according to the size of the watercourse (Table 1). Stream buffer zones must be recorded during the topography assessment and drawn on the tactical plan maps.

All areas appearing to merit protection are noted during the stock survey and/or topography assessment, and subsequently delineated on the tactical plan maps. The following harvesting practices pertain to these areas:

- No trees are to be felled within these protected areas. Trees immediately outside these areas must be felled in a direction away from the protected areas.
- Machine access is normally prohibited in these areas, but can be occasionally permitted, as necessary, by forest engineers in charge of the logging operation. Where permitted, access must cross by the shortest possible distance.
- If a tree has been inadvertently felled into a watercourse, all debris must be removed without disturbance to the watercourse bank.
- No harvesting debris is to be pushed into areas excluded from harvesting.

2. 2. 5. Road, landing, and skid trail planning

2.2.5.1. Road design

Road planning aims to develop an optimal road network that minimises road density while providing access to all harvest areas. The location of the major roads is specified as part of the strategic plan, while secondary roads are addressed in the tactical plan. Major road design may be modified and improved,

Table 1. Total width of stream buffer zones (SBZ) based on stream width

Stream width between banks	SBZ width in metres (width on both sides of the stream and from its centre)
< 1 m	No buffer zone
1-10 m	20 (10)
11-20 m	50 (25)
21-40 m	80 (40)
> 40 m	200 (100)

however, following the pre-harvest topographic assessment carried out during tactical planning.

In RIL, forest roads must be constructed according to environmentally sound engineering practices to minimise soil erosion and stream sedimentation. Although it is beyond the scope of this report to describe these techniques in detail, a few basic rules of environmentally sound forest road engineering warrant review (see Haussman and Pruett 1978 for details on low-impact forest roads).

- **Planning**: proper road planning is essential to reduce road density and minimise soil disturbance.
- **Road width**: although vegetation clearing is necessary to allow sunlight to penetrate and dry the road after rainstorms, the general principle is that the width should be restricted to the minimum that will permit a properly constructed and maintained road on which hauling can be done efficiently and safely (Photos 1 and 2). Experience has shown that proper drainage is much more important than sunlight in permitting roads to dry out quickly after rainstorms.
- **Cutting and filling**: cutting and filling should be minimised to reduce the exposure of bare soil and its potential to erode.
- **Stream crossings**: roads should be kept away from streams and outside of streamside buffer zones. Where a stream crossing is necessary, a crossing structure must be designed and constructed to minimise impacts on the stream and surrounding vegetation (Photo 3).
- **Water diversions**: roadside ditches and properly spaced cross drains (Table 2) should be

Photo 1: Excessive road width

GABON, P.SIST

Photo 2: Well constructed road with no excessive width

SABAH, D.DYKSTRA

Table 2: Minimum cross drain frequency for skid trails and roads (see also Figure 5)

	Slope (%)	Cross drain spacing
On skid trails	< 10	No cross drain
	10-20	30 m
	20-30	20 m
On roads	< 5	No cross drain
	5-15	20 m
	15-20	80 m

Photo 3: Flooded zone created by lack of appropriate drainage structure on road

GABON, P. SIST

Photo 4: Excessive steep road grade

EAST KALIMANTAN, P.SIST

used and maintained to channel water away from the road structure and into the surrounding vegetation.

- **Road grade**: the road grade should be as level as possible, with a maximum grade of 10-20% (Photo 4). Sections of road where the grade approaches 20% must not exceed 500 m length.
- **Access**: controlling access is often the single most important step that forest managers can take to protect the long term integrity of the forest and the wildlife it contains (Fimbel *et al*. in press). Thus, when developing an extraction road network, planners should limit access into concessions to a few gated and patrolled entry points that keep individuals not directly involved in the forest management activities out of the cutting area.
- **Training**: forest roads must be designed and laid out in the field by skilled engineers. Training is therefore essential for the success of proper design and construction. Training sessions must be scheduled in the tactical planning as part of the logging operation plan and supported financially by the concessionaire.
- **Timing**: roads must be constructed at least 3 months before logging to permit them to 'set up' before intensive use begins.

2. 2. 5. 2. Landings

Landing density and surface area can be limited by planning roads and landings prior to logging, drawing on topographic information and harvestable volumes generated in the stock survey and/or topography assessment. To minimise the environmental impacts associated with landings (or temporary log storage areas), the following practices should be executed under the supervision of the SFT Planning Officer:

- develop landings adjacent to roadways;
- restrict their size to < 0.2 ha (approximately 30x60 m);
- avoid placing landings in areas excluded from harvesting; and
- locate landings on ridges to ensure uphill skidding and good drainage of the site.

2. 2. 5. 3. Planning the skid trail network

Skid trails are planned following an analysis of the tree position and topography data provided by the stock surveys and topography assessment. Recording the data in a GIS database will be undoubtedly an advantage for any data analysis and interpretation. Data analysis and skid trail network planning is the responsibility of the Planning Officer of the SFT. The Forest Inventory Officer and Logging Operation Officer should also be consulted for technical advice and assistance. The following rules serve as the foundation of any skid trail design (Figure 4):

- Ground skidding is not allowed on slopes greater than 30%, nor in protected areas or stream buffer zones.
- Stream crossings are not allowed. Where they cannot be avoided, crossing points must be clearly shown on the map and must be approved after a field inspection by the Planning or Forest Inventory Officer of the SFT.
- The skid trail network must be optimised according to the position and density of trees to be felled to minimise the length of trails in the forest.

2. 2. 5. 4. Planning for felling

The major objective of directional felling is to lay logs in position to facilitate extraction. Another aim is to avoid damage to trees that are expected to form part of the timber crop in the next felling cycle (i.e., commercial trees with dbh $\geq$ 40 cm), to stems that warrant a protected status, and to other residual vegetation. Directional felling should be used to protect these trees, which have been identified and recorded during the stock survey. Planning for directional felling is the responsibility of the Planning Officer of the SFT. The main guidelines for planning directional felling are:

- The tree must be felled either toward or away from skid trails or cableways at an oblique angle of approximately 30^0 to the skidding direction, unless the tree can be felled directly onto the skid trail (Figure 4).
- Where possible, trees should be felled in the direction of existing canopy gaps.
- On steep slopes, trees must be felled uphill unless their downhill lean is so great that directional felling techniques are unable to pull the tree uphill.
- Trees adjacent to a stream buffer zone must be felled so that their crowns fall outside the buffer zone.
- Proper felling procedures must be applied in order to avoid splitting of the tree during felling.

Finally, recent studies have demonstrated that the capability of RIL techniques to reduce damage to the residual vegetation by 50%, compared to conventional harvesting practices, cannot be achieved if the felling

intensity is > 8 trees/ha (Bertault and Sist 1995, 1997; Sist *et al*. 1998). In other locations, where silvicultural objectives may vary from those in the TPTI selective system, the maximum number of trees/ha to cut and the effectiveness of RIL techniques to reduce logging impacts compared to conventional logging practices will need to be assessed. Decisions to exclude timber-size trees from harvesting are the responsibility of the SFT and are based on the data provided by the stock survey. In areas with high timber density, very big trees, such as emergent trees, might be excluded from harvest and retained as seed bearers.

2. 2. 6. Final pre-logging RIL survey

Before the logging operation begins, it is necessary to carry out a final pre-logging survey, which will involve the following activities:

- marking the skid trail network in the field by opening wide (2 m) and visible trails in the forest (use of coloured ribbons or painted marks on trees is recommended); the opening of skid trails before felling operation can be also considered as an alternative option, with the main advantage of helping fellers and supervisors in the field when they must check the best feasible direction of felling of each tree;
- checking in the field to determine if the felling directions planned on the map according to the skid trail network and topography are feasible. Before felling, RIL supervisors will go to the field, with the feller to check the natural leaning of the tree which will define the 180^0 felling sector;
- marking the final felling direction by painting a mark on the bole of the tree; and
- marking trees to be excluded from harvesting in areas where the number of harvestable timber trees is >8 trees/ha (repainting stem ring yellow).

2. 2. 7. Tactical maps and written plans

Pre-harvesting inventories and planning must contribute to the development of a tactical map which includes all the information needed to achieve the logging operations as defined in the plan. The tactical map must be at a scale of 1:2 000 and display the following information (Figure 4):

- topographic contour lines (5 m interval or less);
- position of each tree to be felled, marked with its inventory number;
- direction of felling for each tree;
- road network and landing locations;
- skid trail network; and
- stream buffer zones and other exclusion areas.

The tactical plan must also include a written document giving all the technical details on each activity to be carried out (pre-harvesting, harvesting, and post-harvesting).

3. HARVESTING OPERATIONS

3. 1. Felling (team, maps, and material)

Fellers must use the detailed tactical logging map to plan their work. Efficiency of the felling operation can be improved if fellers review the topography and tree position information included in the tactical logging map in advance of each working day. This will help them to decide the sequence of trees to be felled during the day.

Felling operations must be carried out by skilled personnel outfitted with appropriate safety gear and using properly maintained equipment. The fellers must be familiar with directional felling techniques, and the logging company must provide training to the fellers who have no former experience in these techniques. Any decision to fell a tree in a different direction other than the one foreseen in the pre-harvesting plan must be recorded and reported to the SFT Planning Officer.

3. 2. Skid trail marking and opening

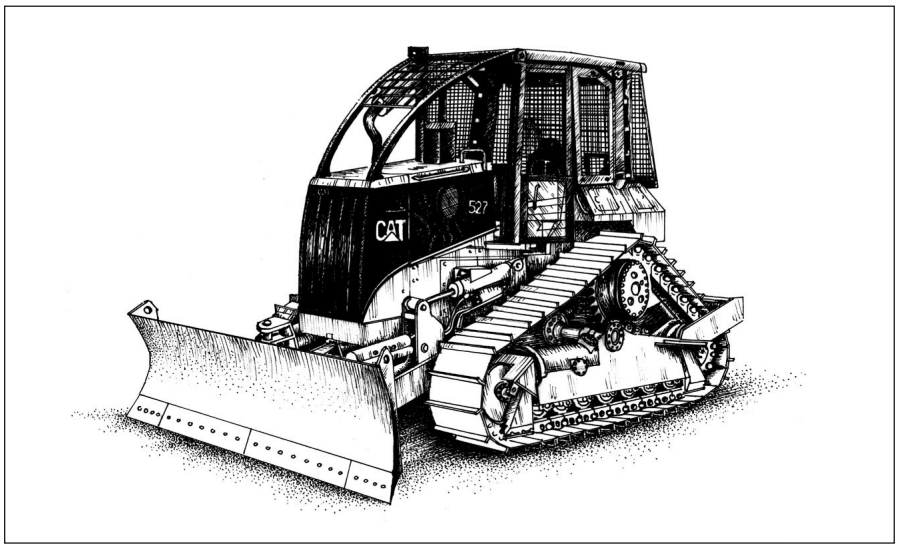
During log extraction the following practices and equipment are recommended:

- Skid trails must be opened according to the planning skid trail network shown in the tactical logging map and in the forest. For this, skidder operators must bring the map to the field and follow the network design.
- Skid trail width must not exceed 4 m.
- Skidder operators are not permitted to leave the marked skid trails without permission of the SFT Logging Operation Officer.
- Skid trails are not allowed to cross streams wider than 5 m or gullies. Where this must be done, crossing must be made at a site where there is a rock base and the stream bed must be protected with logs or a temporarily culvert. The site of the stream crossing must be approved in advance by the SFT Logging Operation Officer.
- Wheeled skidders or crawler skidders (Figures 5A and 5B) should be used in preference to crawler tractors (Figure 5C), given their

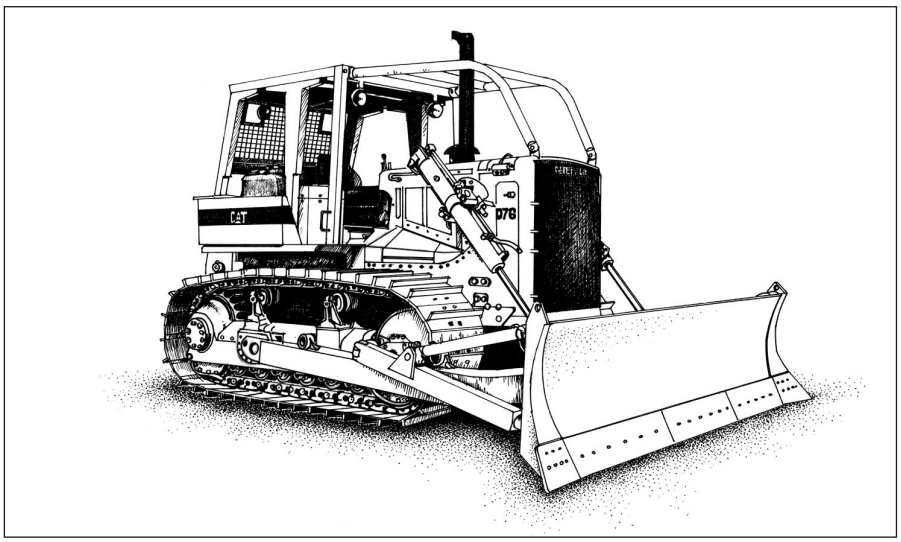
Figure 5: Common types of ground skidding equipment

A. Wheeled skidder

B. Crawler skidder



C. Crawler tractor



smaller size and greater manoeuvrability in the forest (i.e., less likelihood of causing damage to residual stems and soils). The larger crawler tractors should only be used in road construction and maintenance.

- The skidder must have a power winch with at least 30 m of wire rope as well as an arch or other support that will suspend the end of the load off the ground to prevent logs from digging into the soil as they are being skidded.
- The blade of the skidder should not exceed 3m and blading should be avoided as much as possible in order to minimise the impact on soil (Photos 7 and 8).
- Skidding of logs behind the tractor is not allowed on slopes > 30%; on such slopes, logs must be pulled up the hill using the power winch.
- Blading and log extraction during rainy days must be avoided in order to limit soil erosion and compaction.

3. 3. Salary system

RIL techniques require the employment of skilled, well trained, and responsible staff, and a modified piecework remuneration system in which the payment scheme takes into account the quality of the work. The remuneration system used in conventional logging, which only takes into account the commercial volume produced, is not effective in motivating the application of RIL techniques. A compensation system that rewards workers for good practices, and penalizes them for sloppy work, is needed.

4. POST-HARVESTING OPERATIONS

4. 1. Rehabilitation of skid trails

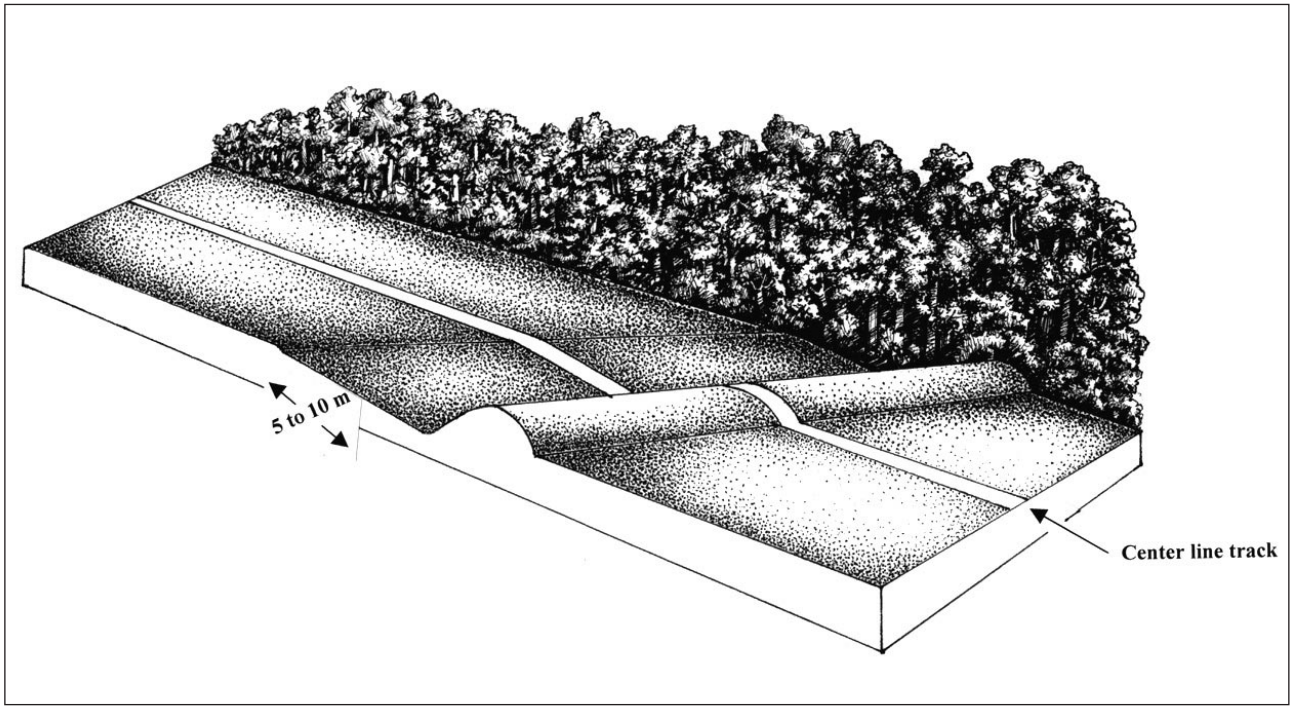
After log extraction, cross drains will be constructed on skid trails in order to limit soil erosion (Figure 6). The following procedures are recommended:

- cross drains should be built at an angle of 60^0 to 80^0 as measured from the longitudinal axis of the skid trail;
- the frequency of cross drains increases with slope (Table 2); and
- any temporary stream crossing structure must be removed from the skid trails.

4. 2. Road closure

Secondary or minor roads, which are not to be used until the next felling cycle, must be closed. Decisions about road closures are the responsibility of the SFT logging operation. Road closure includes the removal

Figure 6: Diagram of a cross-drain construction system



of log culverts and temporary bridges as well the construction of cross drains according to the guidelines listed in Table 2.

4. 3. Other post-harvesting operations

Other important post-harvesting operations include:

- Controlled access to the permanent forest estate. Only those individuals directly involved with forestry operations should be permitted in the permanent forest estate. A possible exception would be to allow local stakeholders access. However, they would need to register their activities with the forest officer. Only ephemeral, subsistence activities would be allowed.
- Proper maintenance of road surfaces, roadside ditches, cross drains, and stream crossings. Secondary or minor roads can be closed off if they will not be used again until the next felling cycle.
- Clean landings and temporary camps. Bark and other vegetal debris are to be burnt, and rubbish, including oil or fuel, drums, and wire rope, are to be removed. Cans and other metallic waste are to be buried.

CONCLUSIONS AND DISCUSSION

Through the implementation and supervision of the RIL practices described in this document, timber concession operators can expect to:

- reduce disturbances to soil and residual vegetation by at least 50% in comparison with conventional logging operations where these guidelines are not applied;
- conserve wildlife and other forest resources, including NTFPs, threatened and endangered species, keystone plant resources, and water;
- diminish direct logging costs by at least 15%;
- protect the long term integrity and value of the permanent forest estate; and limit overall direct impacts to the forest to < 25 %.

Recent studies in Indonesia suggested that damage affecting 25% of the original stands could be a reasonable threshold for sustainability (Bertault and Sist 1995, 1997; Sist *et al*. in press). Sustainable forest management, of which RIL is one component, is essential for the long term health and productivity of forests. RIL in itself is a technical procedure to reduce the environmental impacts associated with timber harvesting operations, and not a single activity that will achieve sustainable forest management.

Avoidance of enrichment planting is likely to be an important economic incentive for concessionaires to apply RIL on a concession scale. Forests harvested with RIL appear to regenerate faster and with a higher percentage of commercial species compared to those logged under conventional practices (Sist, unpublished data), suggesting that residual stands following RIL will be better able to sustain repetitive felling cycles. Research efforts at the Bulungan Research Forest, combined with similar studies being initiated and monitored by CIFOR, CIRAD-Forêt, the Wildlife Conservation Society, and other forestry research institutions, should help to clarify the ecological and economic gains of RIL compared to conventional timber harvesting practices.

Finally, it will be necessary to assess the performance of concessionaires in following the technical guidelines of RIL. This could be conducted by independent interdisciplinary audit teams including foresters, ecologists, logging specialists, forest engineers, economists, wildlife biologists, and experts in social science. Certification groups, or non-governmental conservation organisations, might conduct these independent evaluations. Based on the research carried out by CIFOR on RIL and sustainable forest management (Prabhu *et al.* 1996), it would be possible to define a set of criteria and indicators which could be used for the assessment of the concessionaire's performance in the application of these logging techniques.

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ANNEX 1: Field assessment guidelines for conservation area designation within the strategic plan and tactical planning processes (after WCS 1998)

Habitat characteristics

Principles
Habitat characteristics are used as indirect measures of wildlife populations and the biological diversity comprising an area of forest. They seek to identify unique or sensitive habitats that may warrant protection from harvesting practices. Habitats are evaluated within a portion of the area covered by the stocking survey, using belt transects or fixed dimension plots (depending upon the experience of the inventory crews), systematically covering 2-3% of the stocking survey area. Characteristics of the forest that are assessed include:

- coarse woody debris (standing);
- coarse woody debris (down);
- canopy closure;
- vertical vegetation structure;
- keystone resources; and
- soil litter and decomposition gradient.

Sampling design
The sampling vegetation plot is 0.1 ha (20x50 m). This size is provided for purposes of this example, as 0.1 ha vegetation plots are widely used by foresters and ecologists in the tropics. Other plot configurations may be more appropriate under different tactical planning procedures.

Coarse woody debris (standing)
All dead standing stems ≥ 20 cm dbh within the 0.1 ha plot are measured. Measurements include dbh in 10 cm diameter classes, and an assessment of the stage of stem decay (see four classes below).

(a) Standing decay class 1: standing dead, wood hard, bark on, small branches and/or twigs (< 1 cm diameter) often present.

(b) Standing decay class 2: standing dead, wood soft outside (i.e., 1-2 cm of knife blade easily embedded), bark and branches usually absent.

(c) Standing decay class 3: standing dead, wood soft throughout (i.e., majority of knife easily embedded), bark usually off, structural integrity remaining.

(d) Standing decay class 4: collapsed stem or collapsible under slight pressure, bark usually off (where collapsed to ≤ 1.3 m tall it is classified under 'ground' coarse woody debris, see below).

Coarse woody debris (ground)
All dead fallen stems and limbs ≥ 20 cm dbh within the 0.1 ha plot are measured. To determine the volume of this material, diameters for each piece of fallen material are measured to the nearest 5 cm, at both the small and large ends of the piece, or the point at which the material crosses the plot boundary. The total length of the material is measured to the nearest 10 cm. In addition, the fallen material is classified into one of the following four decay stages:

(a) Ground decay class 1: wood hard, bark on, small branches and/or twigs (< 1 cm diameter) may still be present.
(b) Ground decay class 2: wood soft outside (i.e., 1-2 cm of knife blade easily embedded), bark on or off.
(c) Ground decay class 3: wood soft throughout (i.e., majority of knife blade easily embedded), bark usually off, structural integrity remaining.
(d) Ground decay class 4: log/stump collapsed under own weight, or collapsible by slight pressure of foot, bark usually off.

Canopy closure
The percentage canopy closure is measured at three points within the 0.1 ha plot: the starting edge of the plot (0 m), the mid-point of the plot (25 m), and the ending edge of the plot (50 m). Measurements are taken at a height of 1.3 m and ground level using a spherical densiometer. Simple instructions are included with this device.

Vertical vegetation structure
Canopy cover is measured at 50 points criss-crossing each plot. Beginning at the mid-point of the 0.1 ha plot, and radiating 13 m out parallel and perpendicular to the plot centreline, point-quadrat canopy intercept measurements are taken at 1 m intervals. Vertical to each point (using a SUUNTO clinometer or GRS densitometer), any foliage intercepted within the four designed height classes (0-2, 2-10, 10-20, 20+ m tall) will be recorded with a '1'. An absence of any foliage intercept within a given height class will be indicated by an '0'. Percentage canopy cover for each height strata within a plot is calculated by multiplying the number of foliage encounters in a height class ('1's) by two.

Keystone resources
Keystone resources are species, or groups of species, that play a pivotal role in ecosystem processes and upon which a large part of the community depends. *Ficus* spp. are often perceived as keystone resources in the tropics, given their continuous, aseasonal fruiting. Other keystone plant species may exist within the Tactical Plan area (see MacKinnon *et al.* 1996:431 for an example of important wildlife food trees), and should be considered for inclusion in the inventory process upon their identification.

Soil litter
Depth and gradient of leaf litter decomposition are measured at two random points within the 0.1 ha plot. Using a metric Biltmore stick, the depth of litter to the nearest mm is recorded at 20 cm intervals along the stick (six points). In addition, the gradient of leaf litter decomposition (from least broken down material at the top of the litter layer to most decomposed at the bottom), is noted at either end of the Biltmore stick. Three decomposition classes are used.

(a) Decomposition class 1: Uniform gradient from non-decomposed leaves to soil organic matter.
(b) Decomposition class 2: Non-decomposed leaves resting on bare mineral soil.
(c) Decomposition class 3: No soil litter.

Rapid assessment of wildlife

In the current inventory design, no animal groups are directly measured with the exception of those listed in the IUCN Red Book (IUCN 1990). Sampling procedures will depend on the individual species and their ecology (to be determined following a review of known threatened and endangered wildlife that might occur within the Tactical Plan area). Additional faunal groups, other than those threatened or endangered, might be recommended for inclusion in future inventories, as results are examined from the planned biodiversity impact assessment in the Bulungan Model Forest study (Sist 1997). If valuable ecological information can be collected on select animal groups in a timely fashion, these groups may be included in future pre-harvest inventories.

Animal signs (tracks, dung, diggings, feeding remains, trails, etc.) should be evaluated along transects. The transects are walked at an average speed of 1 km/hr by a local hunter. When a sign is observed from the transect (the observer stays on the transect and does not wander about the forest), it is described, and its location along the transect noted (transects should appear on maps). Finally, the quality of the data is completely dependent on the detection and identification skills of the observer. Therefore, to the extent possible, the same observer(s) is (are) used for all observations pertaining to animal signs across a cutting block.

Conservation area designation

Based upon the findings of the habitat and animal assessments, areas of forest supporting unique structural or compositional characteristics should be considered for protection. In addition, a small portion of common habitat types should be reserved from cutting, in an effort to protect the full range of habitat types occurring within the managed forest. In general, important areas for protection within the production forest landscape include those supporting:

- populations of rare and endangered species;
- high concentrations of endemic species and/or exceptional species richness;
- unusual vegetation habitats, landforms, geology, or other physical features not represented in other protected areas; and
- areas serving as corridors between reserves, especially riparian zones (Sayer and Wegge 1992).

ANNEX 2: Glossary

Annual coupe: Area of forest to be harvested within a period of one year. In Indonesia, it is called Rencana Kerja Tahun(RKT) and usually starts in March.

Bucking: The act or process of transversely cutting the stem of a felled tree into logs.

Buffer zone: Area from which all harvesting equipment and operations are excluded. Buffer zones are usually along streams.

Cable : A flexible steel rope made up of numerous wire stands that are twisted helically together around a core of wire, wire rope, fibre, plastic, or other material.

Cable yarding system: Any of a variety of terrain support systems in which suspended cables are used to convey logs to the landings.

Cableway: The pathway along which logs are yarded with a cable yarding system.

Climbers: Vines that either hang freely, are suspended from the forest canopy, or adhere to the stems of trees. Climbers with woody stems are often called lianas.

Contour lines: lines drawn on a map which link points of the same elevation.

Cutting block: The annual coupe is usually divided into compartments of equal size. In Indonesia each of these compartments is called p*etak* and covers about 100 ha.

Dbh: Diameter at breast height. The diameter of a tree measured at a standard reference height, usually 1.3 m above ground level.

Extraction: The process of transporting logs from the felling site to a landing.

Felling: The act or process of severing a standing tree.

Felling cycle: The planned, recurring number of years between successive harvests on a specific, physical area of land. It is also called harvesting cycle.

Ground skidding: See Skidding.

Harvesting: The aggregation of all operations, including pre-harvest planning and post-harvest assessment, related to the felling of trees and the extraction of their stems or other useable parts from the forest for subsequent processing into industrial products.

Landing: A cleared area where logs are collected during extraction in preparation for transport to the processing facility or other final destination.

Limbing: The act or process of severing the branches from the stem of a felled tree.

Log: Any section of the bole of a felled tree after limbing and bucking.

Logging: The act or process of felling and extracting timber from forests, especially in the form of logs.

Non timber forest products (NTFPs): All biological material, other than industrial roundwood, that may be extracted from the forest, either for commercial purposes, for use within the household, or for social, cultural or religious uses. Also referred to as non wood forest products (NWFPs).

Production forests and limited production forests: Forests defined for selective logging under TPTI regulation. The diameter limit for production forest is 50 cm, while in limited production forests the diameter limit is 60 cm.

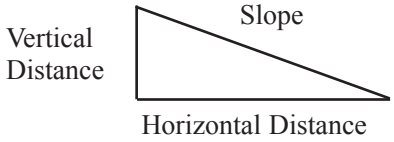
Skidding: Terrain transport in which logs are dragged to the landings, rather than suspended in the air or carried on a vehicle. Also referred to as ground skidding.

Skid trail: The pathway over which logs are skidded in a ground skidding extraction system.

Skyline yarding system: A cable yarding system that makes use of a heavy wire rope (the skyline) that is stretched between two spar trees and used as a track for a skyline carriage (a wheeled device riding along the skyline and carrying logs).

Slope: The slope in % is defined as follows:

$$\frac{\text{Vertical Distance}}{\text{Horizontal Distance}} \times 100 = \text{Slope \%}$$



Stump: The woody base of a tree that remains in the ground after felling.

Timber: Trees suitable for conversion into industrial forest products.