JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

The Development Survey on the Water Resources in the Republic of Paraguay

FINAL REPORT

Volume II

(Master Plan Study Area)

MARCH 1994

Nippon Koei Co., Ltd.
Water Resources Development Public Corporation
Japan International Water Resources Corporation

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

The Development Survey on The Forest Resources in Brunei Darussalam

FINAL REPORT

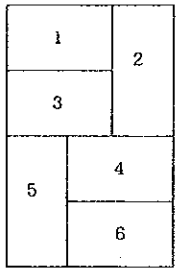
Volume 1

(Model Plantation Area)

MARCH 1994

Forest Civil Engineering Consultants Foundation
Pasco International Inc.

MODEL PLANTATION AREA



1. Peat swamp forest
   -Type 3.2(2)-
2. Kapur paya
   -Type 2.2(1)-
3. GPS survey
   (Point6)
4. Technology transfer
   at survey area
5. Soil profile
   (Ferric Acrisols)
6. Gully erosion
   experimental plot

PREFACE

In response to a request from the Government of Negara Brunei Darussalam, the Government of Japan decided to conduct a development study on the Forest Resources and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent to Negara Brunei Darussalam a study team headed by Mr. KOICHI AKIYA, seven times during the period from April 1992 to January 1994.

The team held discussions with the officials concerned of the Government of Negara Brunei Darussalam, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Negara Brunei Darussalam for their close cooperation extended to the team.

March, 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

CONTENTS

FINAL REPORT Volume1

INTRODUCTION ---------- 1
EXECUTIVE SUMMARY ---------- 5
I FORESTS, FORESTRY AND SOCIOECONOMIC ENVIRONMENT OF BRUNEI DARUSSALAM- 25
1. Current Status of Forests in Brunei Darussalam ---------- 27
2. System of Forest Administration and Organisation ---------- 27
2.1. Organisation of the Forestry Department ---------- 27
2.2. Forest System of Brunei Darussalam ---------- 29
3. National Economy, Forests and Forestry ---------- 30
4. Trends of Forestry and Forest Products Industry ---------- 32
II MODEL PLANTATION AREA ---------- 35
1. Items and Area of the Survey ---------- 37
1.1. Survey Items ---------- 37
1.2. Survey Area ---------- 39
2. Aerial Photography and Preparation of Topographic Maps ---------- 44
2.1. Outline of Work ---------- 44
2.2. Aerial Photography ---------- 45
2.3. Control Point Survey ---------- 47
2.4. Field Verification ---------- 49
2.5. Preparation of Topographic Maps ---------- 49
2.6. Final Results ---------- 53
3. Forest Survey ---------- 54
3.1. Survey Design ---------- 54
3.2. Field Survey ---------- 62
3.3. Estimation of Stand Volume ---------- 77
3.4. Considerations of Results of the Forest Survey ---------- 90
3.5. Vegetation Maps ---------- 92
4. Soil Survey ---------- 93
4.1. Field Survey ---------- 93
4.2. Results of Soil Survey ---------- 97
4.3. Soil Map ----------102

4.4. General Considerations of Soil Survey Results ----------109
5. Forest Inventory Book ----------111
6. Natural Environmental Assessment Survey ----------113
6.1. Purpose of Environmental Assessment in Model Plantation Area ---113
6.2. Flowchart for Environmental Assessment ----------113
6.3. Identification of Factors Affecting Environment ----------115
6.4. Environment Conservation Control of Impact Factors ----------124
7. Forest Operation Guidelines ----------146
7.1. Purposes of Forest Operations ----------146
7.2. Forest Operations Measures ----------147
7.3. Basic Approach to Operation Methods ----------149
8. Recommendations for Future Forest Operations ----------161
8.1. Basic Matters ----------161
8.2. Concrete Matters Based on Survey Results ----------162

References ----------165
<Appendices> ----------167

FINAL REPORT Volume2

EXECUTIVE SUMMARY
III NATIONAL PARK AREA

FINAL REPORT Volume3

IV FOREST MANAGEMENT GUIDELINES

List of Figures

Figure	Description	Page
Figure-1	Location of survey area	4
Figure-2	Location of rain gauge and water level gauge	18
Figure-3	Observation points of Temburong main stream route	20
Figure-4	Flowchart for National Park environment assessment	22
Figure-5	Suggested approach to establishing guidance and management structure for National Park	24
Figure-6	Forestry department organisation	28
Figure-7	Flowchart: From the survey design to forest inventory book, vegetation maps and soil maps	38
Figure-8	Stratigraphy of the Brunei area	41
Figure-9	Geological map	42
Figure-10	Relationship between forest type, configuration and topography	57
Figure-11	Stand type	59
Figure-12	Shape of small sample plots	61
Figure-13	Location of small sample plots	63
Figure-14	Flow-chart of data arrangement	66
Figure-15	Classification system of data	69
Figure-16	Location of soil survey points	96
Figure-17	Flowchart of environmental assessment in Model Plantation Area	114
Figure-18	Location of environmental assessment survey plots	115
Figure-19	Location of experimental area	118
Figure-20	Progress of gully erosion	119
Figure-21	Quadrat of gap planting (Plot No. 12)	136
Figure-22	Quadrat of gap planting (Plot No. 1, Plot No. 2)	136
Figure-23	Quadrat of gap planting (Plot No. 13)	137
Figure-24	Survival and crown projection diagram of Kapur bukit enrichment (Block A)	137
Figure-25	No. 2 Belt-transect of Kapur bukit plantation at Lamunin	138
Figure-26	No. 1 Belt-transect of natural forest at Bukit Sawat	139
Figure-27	Lower storey trees and regenerated seedlings in No. 1 belt	140
Figure-28	No. 5 Belt-transect of secondary forest at Merangking	141
Figure-29	Survival and crown projection diagram of Acacia mangium (Block I)	142
Figure-30	Survival and crown projection diagram of Klinki pine (Block F)	142
Figure-31	Survival and crown projection diagram of Kapur bukit (Block N)	143
Figure-32	Survival and crown projection diagram of Kapur paya (Block N)	144
Figure-33	No. 3 Belt-transect of Klinki pine at Lamunin	145
Figure-34	No. 4 Belt-transect of Klinki pine at Lamunin	145

List of Tables

Table	Description	Page
Table-1	Forest types	5
Table-2	Stratified standard	8
Table-3	Area and stand volume by stratum	9
Table-4	Volume by group and D.B.H class	10
Table-5	Plan of forest operations	15
Table-6	Forest types	27
Table-7	Exports by commodity sections	31
Table-8	Log and sawn timber production	33
Table-9	Production and import of timber	34
Table-10	Contrast between forest type classification by Anderson and of this survey	55
Table-11	Classification of crown density	60
Table-12	Number of small sample plots by area	62
Table-13	Number of small sample plots by stratum	64
Table-14	Stratified standard	67
Table-15	Commercial value by stratum	77
Table-16	Standard interpretation card	79
Table-17	Crown diameter classification	81
Table-18	Crown density classification	81
Table-19	Area by forest type	84
Table-20	Coefficients(d_2), used for standard deviation calculation	86
Table-21	Estimation of the standard error in mean stand volume	87
Table-22	Average stand volume by stratum	87
Table-23	Area and stand volume by stratum	89
Table-24	Forest inventory book(ex.)	112
Table-25	Erosion in Saw Timber Plantation	122
Table-26	Plan of forest operations	164

List of Appendices

Appendix	Description	Page
App. Table-1	List of principal instruments employed	169
App. Table-2	List of photographs	170
App. Table-3	List of photos and films for delivery	171
App. Table-4	Volume table	172
App. Table-5	Species list (Group A)	197
App. Table-6	Species list (Group B)	197
App. Table-7	Species list (Group C)	198
App. Table-8	List of complete enumeration results by plot	199
App. Table-9	List of complete enumeration results by stratum	200
App. Table-10	Number of species by stratum	200
App. Table-11	Number of dominant species by stratum	201
App. Table-12	Number by group and D.B.H class	202
App. Table-13	Number by D.B.H class and stratum	202
App. Figure-1	Number by D.B.H class and stratum	203
App. Table-14	Number by stratum and storey	206
App. Table-15	Species by stratum -2.1(1)-	207
App. Table-16	Species by stratum -2.2(1)-	207

Appendix	Description	Page
App. Table-17	Species by stratum -3.1(1)-	207
App. Table-18	Species by stratum -3.1(1.EX)-	208
App. Table-19	Species by stratum -3.1(2)-	208
App. Table-20	Species by stratum -3.2(2)-	208
App. Table-21	Species by stratum -3.3(3)-	209
App. Table-22	Species by stratum -3.5(1)-	209
App. Table-23	Species by stratum -5(2)-	209
App. Table-24	Species by stratum -5(2.EX)-	210
App. Table-25	Species by stratum -5(4)-	210
App. Table-26	Species by stratum -8-	210
App. Table-27	Volume by group and D.B.H class	211
App. Table-28	Volume by stratum and storey	211
App. Table-29	D.B.H by stratum	212
App. Table-30	Clear length by stratum	212
App. Table-31	Crown diameter by stratum	212
App. Table-32	Measurement value of average crown diameter and crown density	213
App. Table-33	Sampling number of large sample plots by stratum	214
App. Figure-2	Soil profile chart (sample)	215
App. Table-34	Guideline for soil profile description	216
App. Table-35	Soil classification from profile surveys	218
App. Table-36	Simplified key diagnostic horizons	221
App. Figure-3	Plan of gully erosion experimental plot	222
App. Figure-4	Lateral profile of gully erosion experimental plot	222
App. Figure-5	Plan of sheet erosion experimental plot	222
App. Figure-6	Standard diagraph of log buried work	223
App. Figure-7	Standard diagraph of gabion buried work	223
App. Figure-8	Standard diagraph of brush culvert work	223
App. Figure-9	Standard diagraph of log crib work	224
App. Figure-10	Standard diagraph of fence work	224
App. Figure-11	Standard diagraph of gabion check dam	224
App. Figure-12	Standard position of works	225

INTRODUCTION

Background to the Survey

Forest areas represent approximately 80% of total land of Brunei Darussalam and natural forests of various types exist throughout the country. Most of these natural tropical forests are invalued natural assets in global terms.

As part of its policies to develop domestic resources, the Government of Brunei Darussalam placed emphasis on the promotion of forestry in its Fifth Five-Year Plan (1986 to 1990). In January, 1989, the Government of Brunei Darussalam placed the Forestry Department under the jurisdiction of the Ministry of Industry and Primary Resources, moving it from the jurisdiction of the Ministry of Development. In November of the same year, the Government of Brunei Darussalam announced National Forestry Policies and decided to manage forests from a long-range viewpoint, taking environmental conservation and sustainable utilisation of forest resources etc., into consideration.

Firstly, in terms of the forestry production policy, the Government of Brunei Darussalam has reduced the amount of logging, thus conserving natural forest, so that the sustainable utilisation of the forest would be achieved. At the same time, to meet the domestic demand for timber, the Government started the plantation project in 1992 using a 35,000ha area of the forest. The artificial plantation of exotic spieces like Acacia mangium or Klinki pine etc. and of indigneous species like Kapur etc., have been carried out for the project. If such plantation were to be continuously carried out at the rate of 950ha every year, it will be possible for Brunei Darussalam to become self-sufficient by producing 200,000 m^3 of timber, which is the annual domestic demand for the future. The 50,000ha surveyed area of the Model Plantation covers the most of this plantation project area.

Secondly, from the conservation policy aspect, the Brunei Government is taking the coservation of the diversity of the forest ecosystem into consideration, and trying to manage the genetic resouces. At the same time, the Government is urgently planning to develop and maintain the National Park and the Recreational Forests, so that the forests in Brunei will be used for

the study of tropical forests, cultural, educational and recreational purposes.

However, with regard to the plantation project, many technical problems need to be solved, for instance, selecting the operation method, deciding on the appropriate areas for the plantation, choosing the species for the plantation, preventing soil erosion and so on. Furthermore, with respect to the utilisation of the National Park, firm, detailed, proposals regarding its utilisation without influencing the ecosystem of the natural forest, which is undisturbed at present, the facilities required, notices being given to the visitors, and forest management plans relating to the Park, need to be drawn up.

For this reason, in December 1989, the Government of Brunei Darussalam requested the Government of Japan to provide cooperation for this development survey. In response to this request, in December, 1990, a contact mission confirmed the implementation of the development survey. In November 1991, an S/W mission consulted with those concerned in Brunei Darussalam on the details of the survey. The items to be implemented in the survey were decided thereafter.

Objectives of the Survey

In accordance with the above description, this survey was carried out in two areas, one in the Model Plantation which is 50,000ha crossing Daerah Tutong and Daerah Belait, and including the plantation project area, and the other in 10,000ha in Daerah Temburong, to study the development of the natural forest as a National Park.

The objectives of the survey in the Model Plantation were to take new aerial photographs to examine the state of the forest for its utilisation in line with the National Forestry Policy of Brunei Darussalam, to prepare 1/20,000 topography maps, vegetation maps, soil maps based on the topography maps, to produce a Forest Inventry Book and to give some advice on the forest operation based on to the results of this survey as a whole.

The objectives of the survey in the National Park area were to make a vegetaion map indicating the present state of the forest, to make a plan for the development of the Park, including the facilities for the Park, and to provide guidelines for the forest management of the National Park. All the objectives described here were made in order to achieve the use of the National Park for

tourism and educational purposes, while at the same time, ensuring that environmental and conservation issues are taken into consideration, which is one of the main aspects of the National Forestry Policy of Brunei Darussalam.

About the Survey Areas

The Model Plantation survey area crosses both Daerah Tutong and Daerah Belait in the western part of Brunei. This area of 50,000ha, includes the Stateland Forest of watersheds along the Tutong River and the Belait River but does not include the National Forest Estate.

The National Park survey area is 10,000ha of the National Park in the upstream area of the Temburong River in Temburong which belongs to the National Forest Estate.

Both survey areas are shown in Figure-1.

About the Survey Team, and other matters

Headed by the team leader, three members in the aerial photograph team, four members in the Model Plantation area team, and four members in the National Park area team, conducted preliminary, full-scale and verification surveys over three years. As a result of these surveys, a final report was compiled.

In its first part, the report briefly describes forests and forestry in Brunei Darussalam to deepen understanding on the background and other factors of the survey. The report then continues to present the results of the surveys of the Model Plantation area and the National Park area respectively.

For convenience, the survey report covering the National Park has been prepared as separate volume 2 and 3.

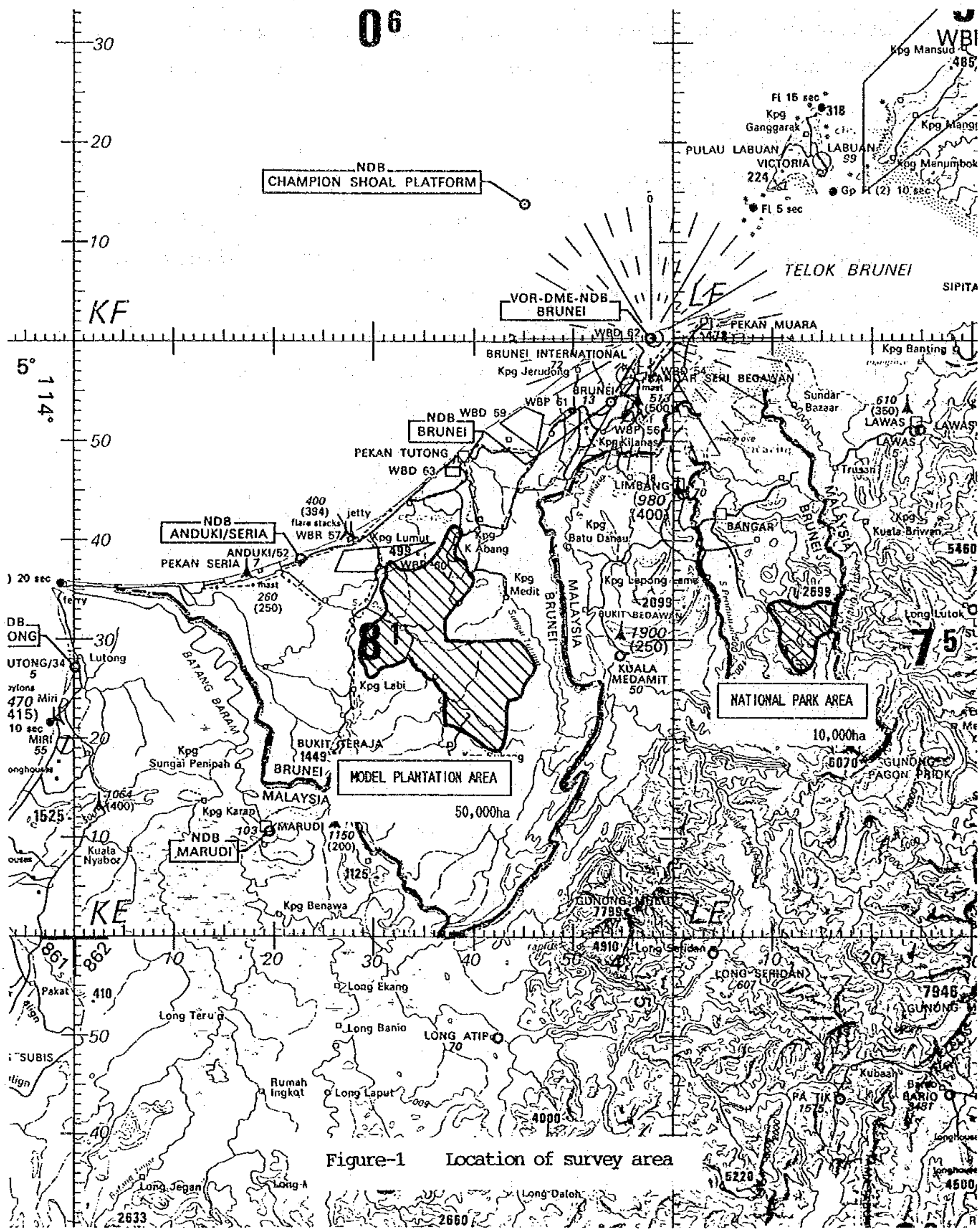


Figure-1 Location of survey area

EXECUTIVE SUMMARY

FORESTS, FORESTRY AND SOCIOECONOMIC ENVIRONMENT OF BRUNEI DARUSSALAM

1. Current Status of Forests in Brunei Darussalam

Forest area of Brunei Darussalam covers 81% of its surface, and 73% of its surface is natural forest. There are a several of types of natural forest as shown in Table-1, most of them being still undisturbed and precious assets to the world.

Table-1 Forest types

Forest Type	Area (ha)	%
Primary Forests	341,184	72.7
a. Mangrove	18,418	3.9
b. Freshwater swamp forest	12,668	2.7
c. Peat swamp forest	90,884	19.4
d. Kerangas	3,455	0.7
e. Mixed dipterocarp forest	192,575	41.1
f. Montane forest	7,196	1.5
g. Mixed Type a~f	15,988	3.4
Secondary Forest	127,786	27.3
Plantation	76	0.0
Total Forest Cover	469,046	100.0

By Anderson and Marsden (1984)

2. System of Forest Administration and Organisation

At present (1993), the Forestry Department consists of a Headquarters divided into nine sections, and five local branches employing about 370 staff. The forest land in Brunei is divided into two types, one is National Forest Estate to be used permanently as forests, and the other is Stateland Forest, whose purpose of use can be designated as other than for forests after cutting. The National Forest Estate is further devided into five types in accordance with the expected functions of the forests; Protection Forest, Production Forest, Recreation Forest, Conservation Forest and Research Reserve.

The survey area of 50,000ha of Model Plantation belongs to the Statland Forest at present, but is expected to be incorporated in the National Forest

Estate after plantation.

3. National Economy, Forests and Forestry

The population density of Brunei Darussalam is low, 44 per square kilometer. The major source of the national revenue depends on exporting oil and natural gas. The gross domestic product (GDP) per capita is high, about US$19,200, and high GDP make it difficult to maintain an Agriculture and Forestry industry.

4. Trends of Forestry and Wood Industry

The forest preserving action, based on "National Forestry Policy" was implemented in 1990, and as a result the volume of logging was reduced dramatically. At present, Brunei Darussalam can replace this reduction by importing timber. However, plantation has begun in the 35,000ha of Statland Forest, aiming self-sufficiency in domestic demand for timber. In addition, development of new forest parks, seed production for plantation, and afforestation of denuded land, and other activities have also been started.

MODEL PLANTATION AREA

1. Items and Area of the Survey

Aerial photographs of about 350,000ha of forest region in Daerah Belait and Daerah Tutong were taken. The accurate topography maps of 1/20,000 were prepared for about 50,000ha of the total photographed area. By using this topography map, the vegetation and soil maps and the Forest Inventory Book etc., were prepared, based on the forest and soil surveys conducted.

The survey area in the Model Plantation area was 50,000ha of Stateland, extending over Daerah Belait and Daerah Tutong. The general features of the area were surveyed, such as boundaries, watersheds, topography, geology, meteorology, road existence, communities and population.

The southern part of the area was surveyed using the Belait and Tutong Rivers, and the central and northern parts were surveyed mainly using roads.

The industries in the survey area and its vicinities were agriculture and forestry. Agriculture was conducted around the communities to supply the

needs of the residents themselves. Felling and planting were conducted under the management of the Forestry Department.

2. Aerial Photography and Preparation of Topographic Maps

A total of 512 aerial photos, along 24 courses, 1/25,000 in scale, covering about 350,000ha, were taken.

Using two existing control points, 18 new control points were surveyed by GPS. Minor order levelling was conducted by direct levelling for a distance of about 150km using several national bench marks in Lamunin Village and on the road between Sg. Liang and Labi.

Aerial triangulation of 116 models was performed by analytical block adjustment using the independent model method. The elements such as sample plots satisfied class B accuracy of the JICA standard, using a plotter.

Based on the results of aerial triangulation, plotting manuscripts for 14km x 20km were prepared, covering the plotted area of 50,000ha on a scale of 1/20,000. The plotting manuscipts were edited using already existing 1/50,000 topographic maps. Original topographic maps on a scale of 1/20,000 were prepared by drawing the maps by the fair drawing method.

3. Forest Survey

Emphasis in the survey was placed on forest management, on selecting plantation species, and on preparing vegetation maps effective in studying environmental conservation countermeasures. Forests were divided based on ecological characteristics, rather than by stand volumes. Basically, the division was made based on the forest type divisions of Anderson and others, shown in Table-2, and was made by interpreting topography and stand types from the aerial photographs. The minimum unit of the interpretation divisions was generally 5ha. Photo interpretation was performed by selecting necessary standard plots (large samples) for each forest type, from the aerial photographs. Small samples were selected from 12 strata as survey targets from the large samples, and complete enumeration of these small samples was performed on the ground. A regression formula of measured volumes of the small sample plots, as well as of crown density and crown diameter of the large sample plots, was prepared to estimate the stand volumes for each stratum,

and for the entire plots.

Table-2 Stratified standard

Stratum			Forest type
2	Freshwater swamp forest	2.1(1)	Levee alluvium
		2.2(1)	Lower level alluvium
3	Peat swamp forest (PSF)	3.1(1)	Mixed swamp forest (MSF) Dense even, small crowns
		3.1(2)	Mixed swamp forest (MSF) Dense uneven, medium crowns
		3.2(2)	Mixed swamp forest (MSF) Dense uneven, large emergents
		3.3(3)	Alan bunga forest
		3.5(1)	Padang alan forest
5	Mixed dipterocarp forest (MDF)	5(2)	Dense uneven, medium or large emergents
		5(3)	Dense even, medium crowns
		5(4)	Dense uneven, medium and large crowns
8	Secondary forest	8	Generally over 25 years old
9		9	Forest plantations
10		10	Cultivation, cleared land & village
11		11	Unstocked land & land slide
(S)			Sparse density
(EX)			Exploited Forest

A total of 38 places in the small sample plots were surveyed to identity tree species, whether upper- or lower-level trees, diameter breast height, clear length, crown diameters and other parameters. The results of the field survey of the small sample plots were analysed by volume for each species, stem dominance, clear length, crown density and other parameters, by sample plot and forest type, using a personal computer. The kind of species and proportion of commercial species by stratum, volumes by hectare and other information was obtained.

The forest interpretation work by aerial photographs was performed in the following four stages: (1) Preliminary interpretation for forest type division. This was used to select small sample plots to be surveyed in the field survey on the ground. (2) Precision interpretation to prepare standard interpretation cards and stand aerial volume tables. (3) Reinterpretation of (1) to prepare forest type maps. (4) Precision interpretation of the large sample plots needed for estimating volume by forest type.

Vegetation maps of the 50,000ha survey area, 1/20,000 in scale, were prepared based on the results of the aerial photograph interpretation and field survey of the standard plots.

The areas of each forest type measured from the vegetation maps are shown in Table-3. The stand volumes of each forest type estimated from the results of the standard plots survey are also shown in Table-3. The accuracy

Table-3 Area and stand volume by stratum

Stratum	Area ha	Stand volume m^3
2.1(1)	1,107.93	248,078.82
2.2(1)	3,780.18	903,655.81
2.2(1.EX)	99.05	15,056.19
3.1(1)	67.54	20,490.83
3.1(1.EX)	360.49	65,710.84
3.1(2)	2,033.69	770,931.21
3.1(2.EX)	831.44	170,436.89
3.2(2)	567.89	180,888.30
3.2(2.EX)	606.54	128,925.54
3.3(3)	583.51	338,238.57
3.3(3.EX)	364.19	81,546.51
3.5(1)	391.34	163,159.43
5(2)	13,087.36	4,911,620.77
5(2.EX)	8,770.35	2,229,326.50
5(3)	358.70	149,551.00
5(4)	1,848.89	868,810.05
5(4.EX)	14.97	3,408.62
8	1,057.31	176,723.02
Sub total	35,931.37	11,426,558.90
2.2(1.S)	67.88	135.76
3.2(2.S)	28.67	430.05
8(S)	67.49	269.96
Sub total	164.04	835.77
T o t a l	36,095.41	11,427,394.67

of this estimated total stand volume was better than we expected. The limit of reliance/accuracy is 95% which is higher than expected rate of 80%, and the limit of random/possible error is 10% which is lower than expected rate of 20%.

The stand volume per hectare of each forest type shown in Table-4 is lowest in the Secondary Forest (Stratum 8), 205m³, and highest in Alan Forest (Stratum 3.3, 3.5), 528 - 585m³. The stand volume of the Peat Swamp Forest (Stratum 3.1, 3.2) and Mixed Dipterocarp Forest (Stratum 5) is 331 - 448m³,

Table-4 Volume by group and D.B.H class

Unit : m³/ha

Stratum	Group	D<40	40≦D	Total	Stratum	Group	D<40	40≦D	Total
2.1(1)	A	27.849	11.592	39.441	3.3(3)	A	22.571	472.215	494.786
	B	76.145	96.201	172.346		B	35.648	19.359	55.007
	C	10.200	7.981	18.181		C	10.044	24.835	34.879
	Total	114.194	115.775	229.969		Total	68.264	516.409	584.673
2.2(1)	A	103.135	44.190	147.325	3.5(1)	A	69.102	336.541	405.644
	B	60.774	6.990	67.764		B	55.338	14.765	70.103
	C	29.881	32.938	62.818		C	21.688	30.844	52.531
	Total	193.789	84.118	277.907		Total	146.128	382.150	528.278
3.1(1)	A	136.073	63.022	199.095	5(2)	A	24.118	99.056	123.174
	B	120.868	40.723	161.590		B	60.128	128.950	189.077
	C	22.902	64.793	87.695		C	22.659	39.637	62.295
	Total	279.843	168.538	448.380		Total	106.904	267.643	374.546
3.1 (1.EX)	A	58.140	89.633	147.773	5 (2.EX)	A	17.439	52.966	70.405
	B	72.290	39.660	111.950		B	47.392	64.094	111.486
	C	0.742	0.000	0.742		C	29.092	25.871	54.962
	Total	131.173	129.293	260.465		Total	93.923	142.930	236.853
3.1(2)	A	38.761	151.463	190.224	5(4)	A	32.396	261.594	293.991
	B	54.574	103.632	158.206		B	63.476	48.931	112.407
	C	24.107	20.545	44.652		C	9.011	24.242	33.253
	Total	117.443	275.640	393.082		Total	104.883	334.768	439.650
3.2(2)	A	30.965	98.181	129.146	8	A	73.829	23.127	96.956
	B	59.528	102.142	161.670		B	66.671	6.663	73.333
	C	14.282	25.906	40.188		C	25.010	9.710	34.721
	Total	104.775	226.229	331.004		Total	165.510	39.500	205.010
					Total	A	38.665	159.412	198.077
						B	58.672	71.927	130.599
						C	18.566	27.198	45.764
						Total	115.903	258.537	374.440

(with the exception of Exploited Forest), are second highest after Alan Forest. The Freshwater Swamp Forest (Stratum 2) has a volume of 230 - 278m^3 which is the second lowest after the Secondary Forest. The stand volume of each stratum of trees whose diameter is 40cm and above varies more than those whose diameter is less than 40cm. In Group A of commercial species, the Alan Forest (Stratum 3.3, 3.5) has the highest volume of trees whose diameter is 40cm and above, have high commercial values. The Mixed Dipterocarp Forest (Stratum 5(4)) comes second after the Alan Forest. The group which has the lowest volume of the high commercial value trees is the Freshwater Swamp Forest (Stratum 2.1).

4. Soil Survey

Survey points were decided for various soil types using existing soil and topographic maps, as well as aerial photos. Soil profiles at 65 points were surveyed. The profiles were recorded in accordance with the FAO guideline.

The survey verified the soil type distribution corresponding to the topographical classification. Hills mainly consisted of red-yellow podzolic soil. According to the major classification by the FAO/UNESCO system, Cambisols and Gleysols were mixed in the hills which had Acrisols as the principal soil type. Deposits of peat could be found in low swamps and valleys. In these topographical areas, Histosols and Gleysols were the principal soil types, and Cambisols and Acrisols were mixed. In some places, Fluvisols could also be detected. Arenosols, called Kerangas, was also found.

Soil maps 1/20,000 in scale, were prepared using the topographic maps 1/20,000 in scale, prepared by this survey, as base maps.

Integrating the survey results, the distribution of places having soil types which have high erodibilities, as well as the existence and distribution of places having strong acid soil requiring attention in selecting tree species, were pointed out. Precautions relating to forest operations were described in terms of the practical application of scientific, economic and social principles to the administration and working of a forest estate for specified objectives. The principal distribution points of several other soil types, were also specified.

5. Forest Inventory Book

Using vegetation maps 1/20,000 scale prepared after entering the results of the forest survey on them, areas were measured in accordance with the forest types. The forest division numbers, altitude, gradient, soil type, forest types, areas, principal tree species, number of trees, volumes and other information were entered on them to prepare a forest inventory book. The present condition of the 326 blocks in the entire area of the Model Plantation area, including information such as forest stands, was included.

6. Natural Environment Assessment Study

The anticipated factors impacting on the environment were picked up and a fact-finding survey of these factors was conducted to study possible maintenance countermeasures which might be taken in order to minimize impacts which forest operations in the Model Plantation area could cause.

The surfaces of slopes which were denuded by erosion were eroded 2.22cm in nine months. Erosion was extensive on steep slopes where Layer A was washed out. Erosion was prominent in gullies and the growth of trees planted on the eroded slopes was extremely poor. Sediment produced by erosion was easily carried downstream.

Erosion can be prevented mainly by forest operations methods. Eroded areas must be restored by simple works using logs or branches.

Operation methods like selective logging or clear cutting of small areas other than clear cutting of large areas were also proposed, quoting the results of experimental plots by the line and gap planting methods which were implemented in the JICA Forestry Research Project, Brunei.

The survey of mixed Dipterocarp forests showed that patch improvements or line planting can be employed. Examples from Secondary Forest surveys showed that clear cutting of small areas and line planting are possible.

Information about disease and pest damage should be gathered and control of disease and pest damage should be studied in future for A. mangium and Klinki pine as plantation species.

Also improvements in nursery practice technology relating to species for plantation are necessary, and the required seeds must be provided.

7. Forest Operation Guidelines

The purposes of forest operations were considered to lie in producing a sustainable supply of forest products, in demonstrating functions of forests for public benefit, and in contributing to regional development.

The necessity of dividing forests in accordance with purposes such as forestry production and environmental conservation, and of standardising operation methods for the individual forests, were pointed out.

Table-5 shows some of the criteria for a forest operation plan in accordance with the combination of forest type and its associated soil type. These criteria were obtained from the vegetation map, the soil map and the Forest Inventory Book prepared by this survey.

In forest operations, matters requiring precautions such as the layout of cutting sites, skidding methods, selection of plantation species, weeding, pruning and thinning were mentioned. Improvements and expansions of nurseries and forest roads were proposed.

The necessity of restoration measures such as simple fence work was mentioned for controlling erosion and floods. Erosion control, particularly, should be taken into consideration in the future, and preventive measures should be introduced into the management of cutting methods.

8. Recommendations for Future Forest Operations

The major premises for forest operations is to preserve sound forests, to maintain and enhance the contents and quality of the forests for the future, and to protect the forests and their surrounding environment. From this point of view, we would like to make the following proposals for the Model Plantation area based on the overall results of the survey.

1. Planting blocks for Model Plantation development should be dispersed so as to avoid opening of large clear felled areas at any one time, which will encourage soil erosion.

Dispersing planting blocks will provide green buffer zones, therefore, clear cutting should not be carried out on adjacent blocks until earlier plantings have developed a ground cover.

2. Thorough investigation and screening of exotic species should be carried

out before they are introduced for local plantation development, to ensure productivity with minimal risks of pests and outbreaks of diseases .

3. Mixed Dipterocarp Forest covers two thirds of the survey area, and contains more than 70% of its timber volume.

While the major plantation development area is expected to be situated in this area, there are certain portions of land, where local topography and poor soil nutrient content require special management consideration.

Areas which have poor soil nutrient content, should be planted with species which do not demand a lot of nutrients.

Forest with a high proportion of valuable commercial trees should be maintained in its natural condition, and managed through natural regeneration and timber stand improvement, such as enrichment planting, and should be harvested by selective management techniques.

4. Peat Swamp Forest has strongly acidic soil, Histosols. In many places within this forest type, plantation seems impossible due to the prevailing conditions. Also, as some forest types have difficulty in regenerating naturally in these areas, care should be taken in dealing with Peat Swamp Forest.

Freshwater Swamp Forest is excellent in protecting river banks, and has a function in holding sediment from upper slopes. Therefore this forest should be kept undisturbed.

5. Soil of gently sloping land contains medium- and fine-grained Acrisols, and is the best soil for plantation in survey area. But because its soil nutrition is poor, it is necessary to choose the correct site preparation method which will not result in the loss of the surface layer of organic matter.

6. Sandy soil of sloping land has a high tendency to soil erosion. Therefore a lot of care should be taken in plantation establishment and road construction. Sheathing by wicker work and other appropriate measures are recommended to prevent soil erosion.

Table-5 Plan of forest operations

Topography	Forest Type / Soil Type	Matters Requiring Attention	Area	Felling Method	Regenerating Method
Along Rivers ↑ (1) Riparian low swamp - Lowland	Freshwater swamp forest 2 Gleysols	Riparian forests need protection. Poor workability due to soft ground. Fine-grained soil and drainage rather poor.	All areas	Felling prohibited	-
(2) Low-altitude flat land	Peat swamp forest 3.1 and 3.2 Secondary forest 8 Gleysols Histosols	Workability is poor in low swamps. Fine-grained soil and drainage rather poor. Afforestation needs caution. Riparian forests need proteciton. Poor drainage and strong in acidity. Not suitable for afforestation except special species.	Lowland Low swamps	Clear cutting of small area Felling prohibited	Afforestation -
(3) Same as above.	Alan bunga forest 3.3 Histosols	Regeneration is difficult. Protection as pure forest needed. Poor drainage and strong in acidity. Not suitable for afforestation except special species.	All areas	Felling prohibited	-
(4) Same as above.	Padang Alan forest 3.5 Histosols	Alan can be reserved by natural regeneration. Workability is poor in low swamps. Poor drainage and strong in acidity. Not suitable for afforestation except special species.	Lowland Low swamps	Selection felling Felling prohibited	Natural regeneration -
(5) Hilly land Fine wavy topography	Lowland mixed Dipterocarp forest 5(2),5(2.EX) Acrisols	Natural regeneration is possible. Erosion control and prevention is necessary. Soil conservation is needed for steep slopes and coarse-grained ground.	Gentle slop Steep slope	Clear cutting of small area Selection felling	Afforestation Natural regeneration Enrichment
(6) Hill land	Mixed Dipterocarp forest 5(3),5(4),5(4.EX) Acrisols	Distributed in steep slopes around hill tops. Large in volume. Variations are small. Soil conservation is needed for steep slopes and coarse-grained ground.	All areas	Selecton felling	Natural regeneration Enrichment

↓ Inland

Remarks
1. Areas by forest type are as follows:
   Sturatum 2 : 5,069.32ha Strata 3.1,3.2 and 8 : 5,623.40ha Sturatum 3.3 : 947.70ha Stratum 3.5 : 391.34ha
   Strata 5(2) and 5(2.EX) : 21,894.33ha Strata 5(3),5(4) and 5(4.EX) : 1,124.80ha
2. Lowland in (2) for clear cutting of small areas is scatttered and group clear cutting is dosirable as the felling method.
3. Gentle slopes are suitable for clear cutting of small areas in (5). Strip clear-cutting is specially desired for Stratum 5(2.EX).
4. Kapur paya, which is a domestic species, is desirable as an afforestation species for (2) when availability of seeds and production of nursery stocks are condiered.
5. A domestic species, such as Kapur, is desirable as an afforestation species for (5) when conservation of natural ecosystem is considered. However, a fast growing species (Acacia mangium) should also be considered for areas with deteriorated site environment due to poor forest stand condition such as in Stratum 5(2.EX).

NATIONAL PARK AREA

1. Purpose and Items of the Survey

In order to use the National Park for tourism and educational purposes, while at the same time paying attention to conservative management of the forest , the survey produced descriptions of forest types and forest stand structure over the 10,000ha area in the watershed of the Temburong River, In addition, information on rainfall, water levels, flow rates, collapsed land, and details of mammals and birds within the National Park area were collected. Proposals are included relating to the design of nature trail routes and the planning of facilities for the Park, together with their possible environmental impacts. By combining the results of all the surveys, we have produced guidelines for the conservation and management of forests within the area of the National Park.

2. General Description of the Temburong River Watershed and its Forests

The survey area is in the watershed of the Temburong River, having Bt. Pagon (1,850m) as its highest point. The landscape consists of steep slopes of sandstone, and shale from the Paleocene period , and shallow soil containing gravel covers the slopes. The average annual temperature is high, 27 -28 °C. The average annual rainfall is over 4,000mm and the average rainfall for each month exceeds 250mm.

From the upstream area to the river-mouth of the Temburong River, which includes areas outside the survey area, various kinds of natural forests such as Montane Forest, Mixed Dipterocarp, Kerangas, Peat Swamp and other types of forests such as secondary forests are distributed.

3. Forests in the National Park

In order to clarify the types and structure of the forest comprising the National Park, interpretation of aerial photographs and field surveys of forest structure was carried out.

Two main forest types can be identified by interpretation of the aerial photographs. One has relatively continuous and smooth crowns distributed

on the ridges, and the other has crowns of tall trees uneven in height distributed below the middle parts of the slopes.

The survey of the forest structure was carried out by the two methods, one by the Belt-transect method of 18 plots of 50 x 5m and the other by the Line transect method, shown in Figure-2. The result of these surveys were the same as the interpretation of the aerial photographs, with two forest types being identified. One is "Mixed Dipterocarp Forest, which has even and dense crowns, few emergents, and with a tree height of less than 50m" distributed in the upper parts of ridges, and the other "Mixed Dipterocarp Forest which has dense crowns, uneven crown heights, with many emergents of more than 50m in tree height" distributed below the middle parts of the slopes.

During the field survey, more than 80 species were identified, 26 of them being Dipterocarp. Emergents higher than 41m were found in 19 of these species, with 13 species of emergents being identified as Dipterocarp.

4. Forest Land Conservation

Rainfall, which has an influence on forest land conservation, was measured for about 9 months from September 1992 by a data logger type of rain gauge situated close to the entrance to the National Park. This is the lowest part of the river in the survey area as shown in Figure-2.

During this period, the highest rainfall in one day was 142.0mm, and the the highest rainfall in one month was 621.5mm. Rain often falls from early evening to night time, and 80% of the total rainfall was measured during this period. The highest rainfall in one hour was 69.5mm.

The water level, which is vital for boat transportation, since the only access to the National Park is by the Temburong River, was measured for about a year from September 1992 at a point on the Temburong River slightly upstream from the National Park entrance, as shown in Figure-2. The highest and lowest average water level in one month differ from each other by about 1m. The water level at night time is 10cm higher than during day time, reflecting the characteristic of rainfall time described before. The highest and the lowest water level in one year differ from each other by 4.12m.

The maximum rise in the water level after rainfall was 3.4m after one hour. The water level fell 1.0m in three to four hours, returning to the stable

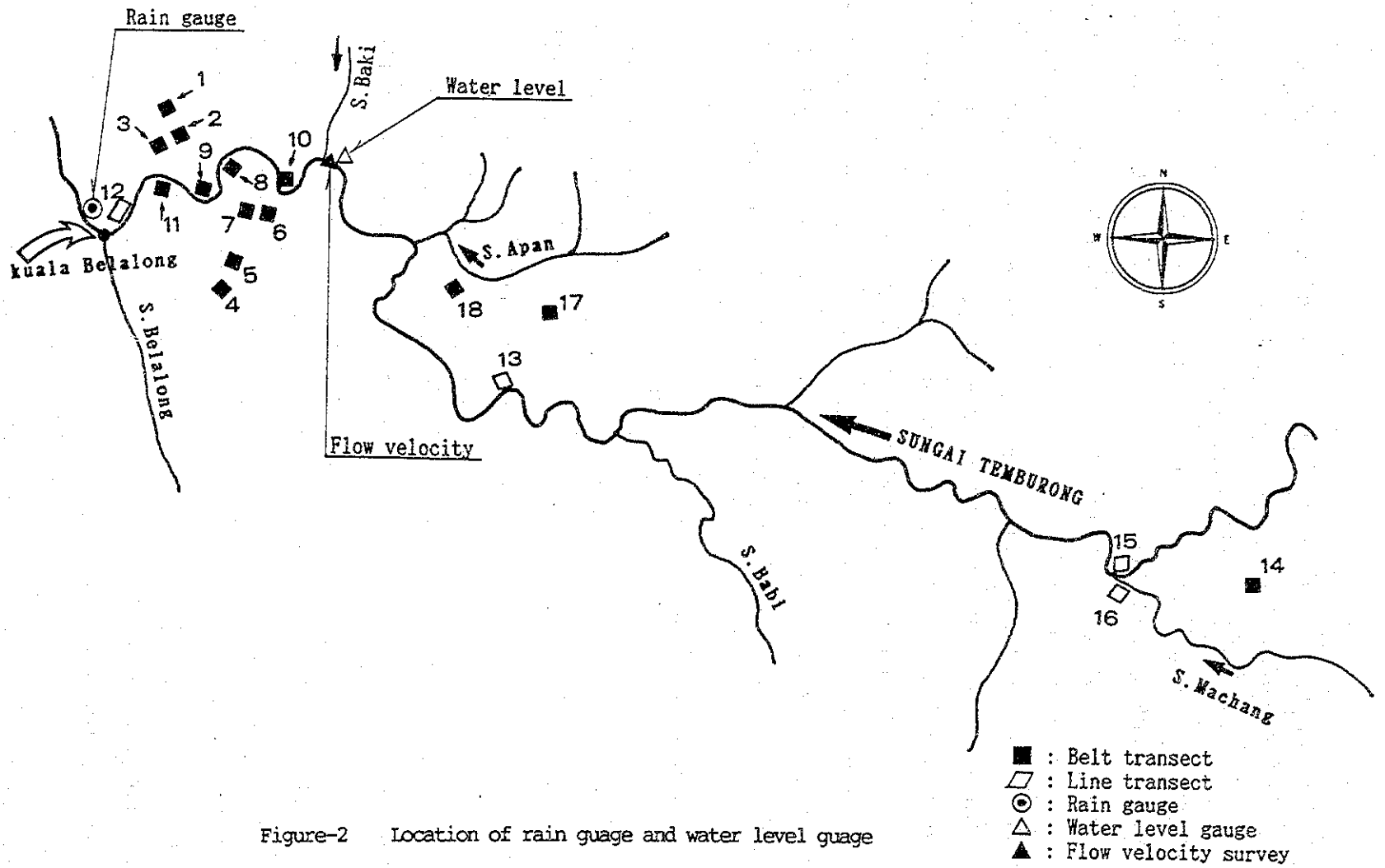


Figure-2 Location of rain guage and water level guage

level after falling slowly for 20 to 30 hours thereafter.

The specific drought water discharge rate was very small, 12.9 liters/s/km^2. This rate is very close to the rate in Japan's Tertiary region, and given that the rainfall here is high, this could be due to the soil having a low permeability to water.

The survey of collapsed land was carried out by interpretation of aerial photographs, together with a field survey by boat and on foot. Twenty hillside landslides totalling 12.22ha in area, and 25 bank collapses totalling 0.86ha were measured.

There were 511 fallen trees, and driftwood was found in 203 places between Batang Duri which is the departure point for the National Park, and Sg. Machang in the Park.

Sedimentary earth on stream beds did not vary greatly as long as the water level increases remained at two to three metres, as was the case during the survey period.

5. Animals in the National Park

A survey conducted by perusing and checking literature showed that 55 species of mammals existed in the area including the National Park. As a result of interviewing the FD staff and workers at the site, we added an additional 17 mammal species.

A total of 239 bird species, including Helmeted Hornbills, could be found. Most of the bird species were those inhabiting in crowns. The number of bird species living in undergrowth communities was 55. A total of 124 species were inhabiting close to the waterside, 132 species on slopes less than 460m in altitude, and 83 species on slopes higher than 460m.

6. National Park Development Plan

The concept of ecotourism to minimize impacts to the ecosystem was employed in the design of the utilisation plan for ordinary users.

The area downstream of the confluence of Sg. Machang was selected as an area allowing day trips during the high-water level season.

Three routes were selected as nature observation courses, allowing users to observe the forests within a walking distance of less than two hours. The

first route is the Temburong Main Stream Route, shown in Figure-3, to observe

Figure-3 Observation points of Temburong main stream route

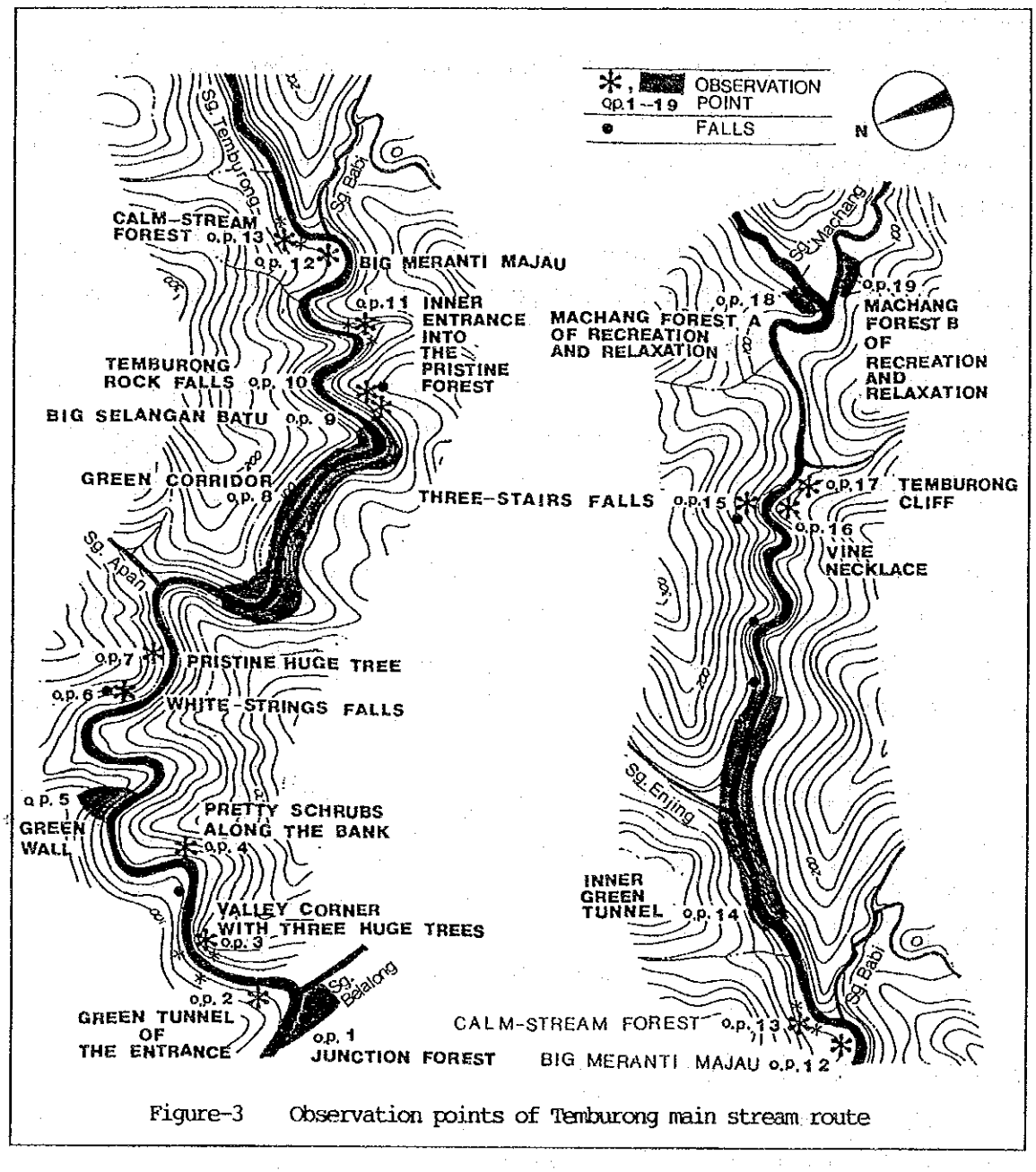


Figure-3 Observation points of Temburong main stream route

forest landscapes on a large scale along the main stream of the Temburong River. The second route is the Apan Tropical Rain Forest Observation Route spread over a distance of about 2km allowing viewing of trees in tropical rain forests over 360° from the confluence of Sg. Apan. The third route is the Kuala

Belalong Forest Observation Route which is suitable when the water level is low or for short-time observation.

7. Development Facilities Plan

The basic policies in drawing up the plan was to have the minimum facilities required for safety and convenience of the users, while avoiding the cutting of trees for the sake of installing these facilities as much as possible. Although the plan for management facilities, observation facilities, resting facilities, public toilets and jetties all require new installations, the plan for nature trails is only to improve existing footpaths in line with the policy described above. The installation of signboards, information boards, etc., was also mentioned, together with recommendations regarding the appropriate location of facilities, their structure and size. Notes on using and managing of these facilities are also included.

8. Harmonisation of Park Utillisation with the Ecosystem

Possible impacts from Park developememt on the natural ecosystem were checked by the flow chart shown in Figure-4, and a study undertaken on conservation of the natural environment.

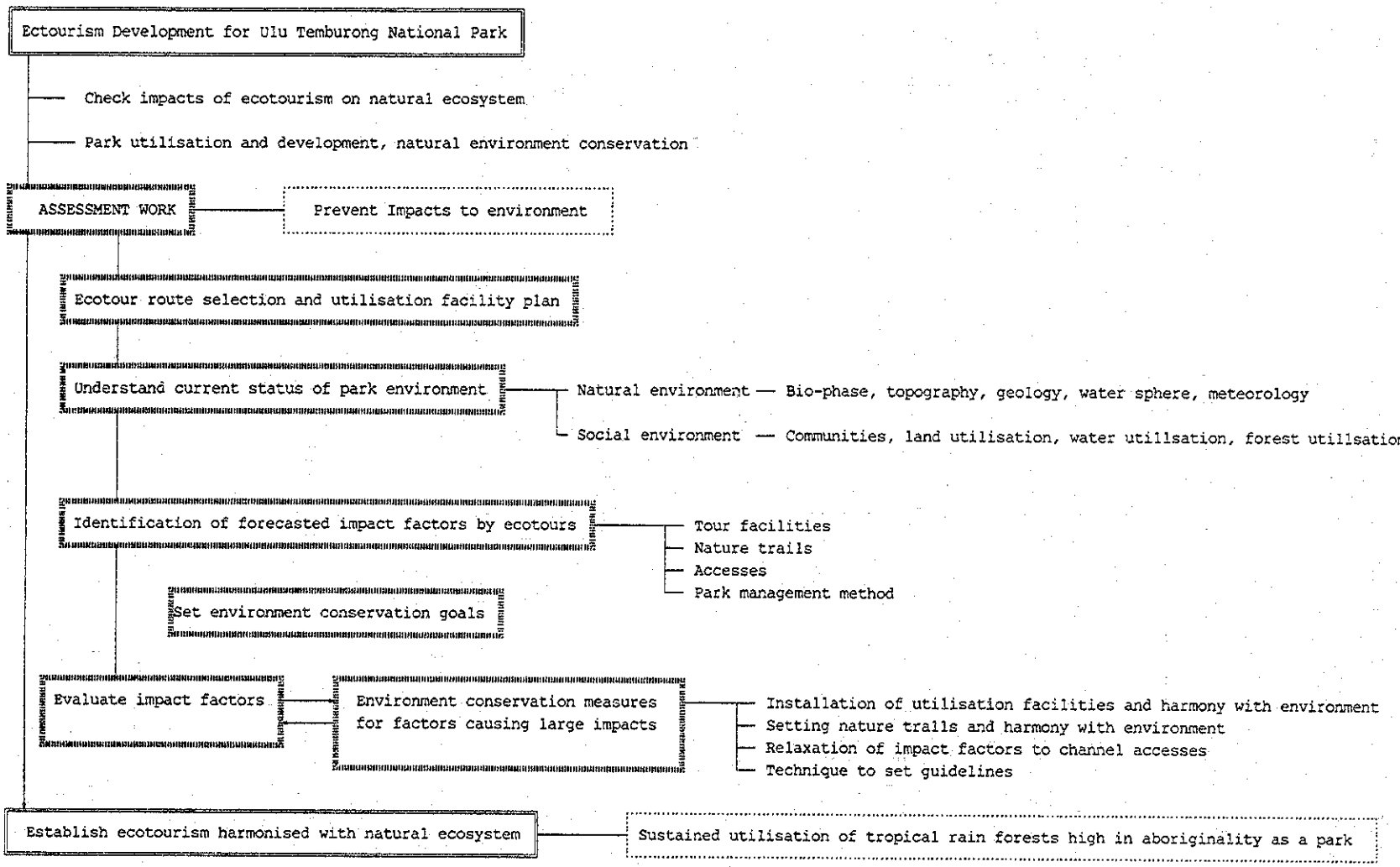
The relationship between four environmental factors, namely, development facilities, nature trails, accesses and park management method, and three environmental elements, namely, natural environment, social and cultural environment and psychological environment affected by these factors, was studied. Recommendations were also made on the following matters: Park facilities and nature trails harmonising with the environment, reduction of impact factors due to channel access, how to deal with the area surrounding the Park as a buffer zone, and the relationship with U.B.D/Kuala Belalong Field Studies Centre.

9. Recommendations for Development and Management of Temburong National Park

The following matters arising from the overall results of the survey should be noted for the future management of the National Park.

1. The fundamental premises for Park development is that the nature of the

Figure-4 Flowchart for Narional Park environment assessment



existing precious tropical rainforest in the Park should not be disturbed. To secure the primitive state of the forest is important.

2. One aspect of the Park development would be for educational and/or research purposes, requiring minimal facilities such as walking paths etc.. However, for all types of developement, it is essential that efforts are directed to ensure that impacts on the Park are minimal.

Only supervised use of the Park should be allowed, and non-disturbance of the ecosystem should be the first priority. Also the forest surrounding the National Park should be managed in the same way as the Park, and any clear cutting of the outer edges of the forest surrounding Park should be avoided.

3. A careful study has been undertaken for the use of the Park by the general public. It is advisable for ecotour participants to learn the attitude, "enjoy nature without disturbing it". To achieve this, ecotour participants should be led by a guide who has sufficient scientific knowledge, and in such a way as to understand the joy of observing nature and the importance of nature.

4. The principle is to be employed that where the construction of facilities requires cutting down trees, these should be outside the National Park.

5. To carry out ecotours, transport should be improved. The access, from the capital Bandar Seri Begawan to Bangar by boat, from Bangar to Batang Duri by car, and from Batang Duri to Kuala Belalong by small boat, needs to be improved, so that the public can make travel arrangements more easily.

6. Danger might occur when the water level rises during the rainy season, and when shallow banks appear during the dry season in the river from Batang Duri to Kuala Belalong. Safety countermeasure should be planned.

7. Three ecotour routes for return day tours from the capital Bandar Seri Begawan, have been set by this survey. With the possibility of tours of 2-3 days in mind, promotion could be by way of day tours, which would draw people's attention to the rare forest ecology and scenery of the National Park. After raising national and international awareness, tours of 2 - 3 days should be planned gradually afterwards. Facilities should also be improved gradually. In order to enhance the reputation of the National Park, a brochure or leaflet should be compiled, which includes research data on forest ecology, animals and fish.

8. Clarify the roles of the Forest Department, District Office and local guides.

It is necessary to establish a management structure for development and management of the National Park, including the expected role of the University of Brunei Darussalam. The possible roles of each group are shown in Figure-5.

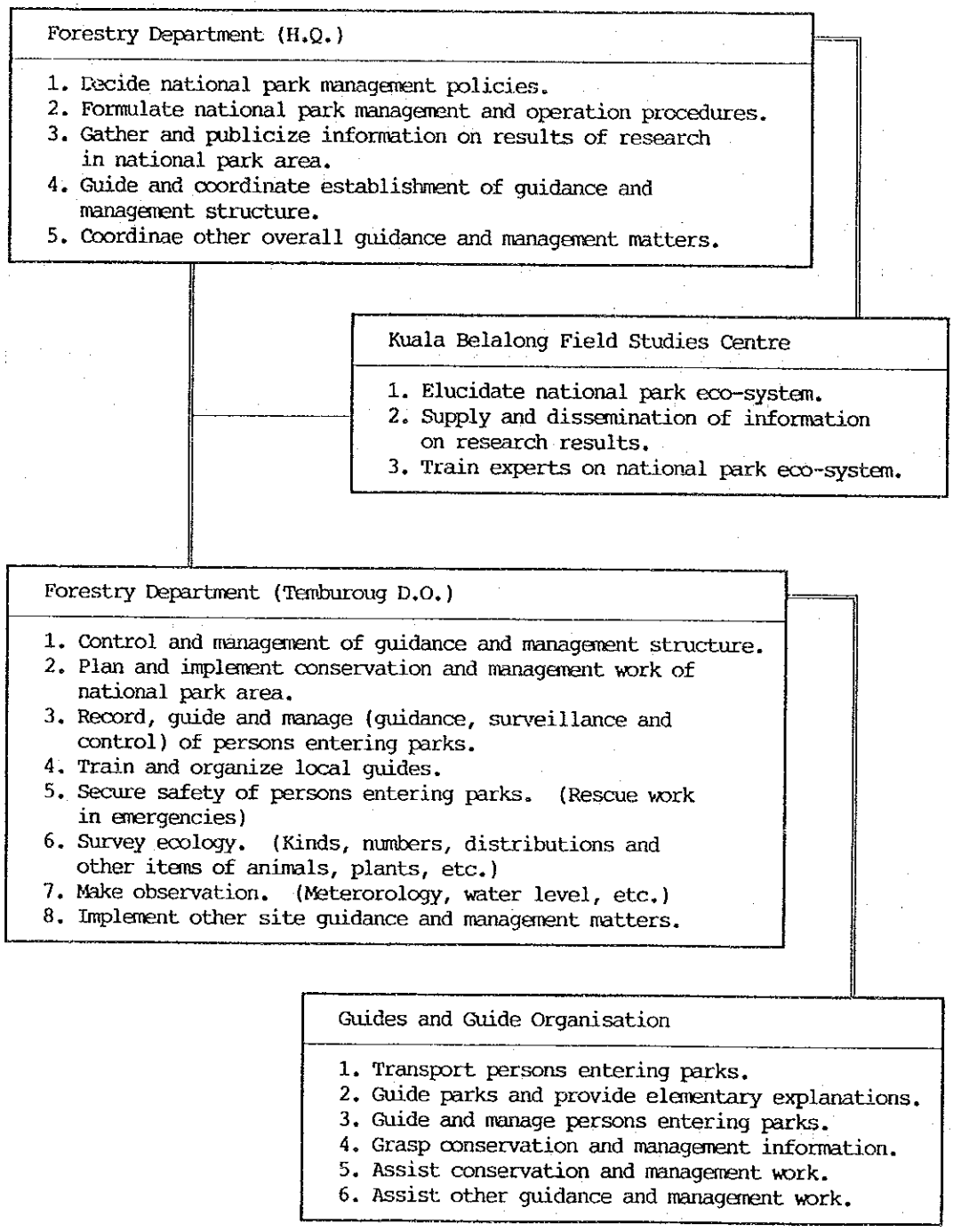


Figure-5 Suggested approach to establishing guidance and management structure for National Park

I FORESTS, FORESTRY AND SOCIOECONOMIC ENVIRONMENT OF BRUNEI DARUSSALAM

1. Current Status of Forests in Brunei Darussalam

As shown in Table-6, forests in Brunei Darussalam total 469,046ha in area, representing 81% of the total land area. Of the total land area, 73% consists of natural forests. Mixed Dipterocarp forests containing a variety of Dipterocarp family species are dominant in the natural forests, accounting for 41% of them. Next comes peat swamp forests situated in inland area, such as forests of shorea albida, accounting for 21%. In addition, mangrove forests near estuaries, freshwater swamp forests covering fresh water along small rivers, montane forests in mountain areas above on altitude of 2,500ft (762m), Kerangas forests growing in areas having infertile soil conditions, and various other natural forests can be found. The forests of Brunei Darussalam are forests valuable to the world, in that these tropical forests are preserved in a natural condition over such a large area, and contain many types of natural forests.

Table-6 Forest types

Forest Type	Area (ha)	%
Primary Forests	341,184	72.7
a. Mangrove	18,418	3.9
b. Freshwater swamp forest	12,668	2.7
c. Peat swamp forest	90,884	19.4
d. Kerangas	3,455	0.7
e. Mixed dipterocarp forest	192,575	41.1
f. Montane forest	7,196	1.5
g. Mixed Type a~f	15,988	3.4
Secondary Forest	127,786	27.3
Plantation	76	0.0
Total Forest Cover	469,046	100.0

By Anderson and Marsden (1984)

2. System of Forest Administration and Organisation

2.1. Organisation of the Forestry Department

The Forestry Department of Brunei Darussalam belonged to the Ministry of Development when Brunei Darussalam became an independent state in 1984. In 1989, the agricultural, forestry and fishery group became independent from the Ministry of Development and was placed under the

jurisdiction of the Ministry of Industry and Primary Resources. Figure-6 shows the organisation of the Forestry Department in 1993. The department administration office is located in the capital of Brunei Darussalam, Bandar Seri Begawan with branches in five other locations, namely, Temburong, Lamunin, Tutong, Sungai Liang and Kuala Belait. The department has approximately 370 staff members.

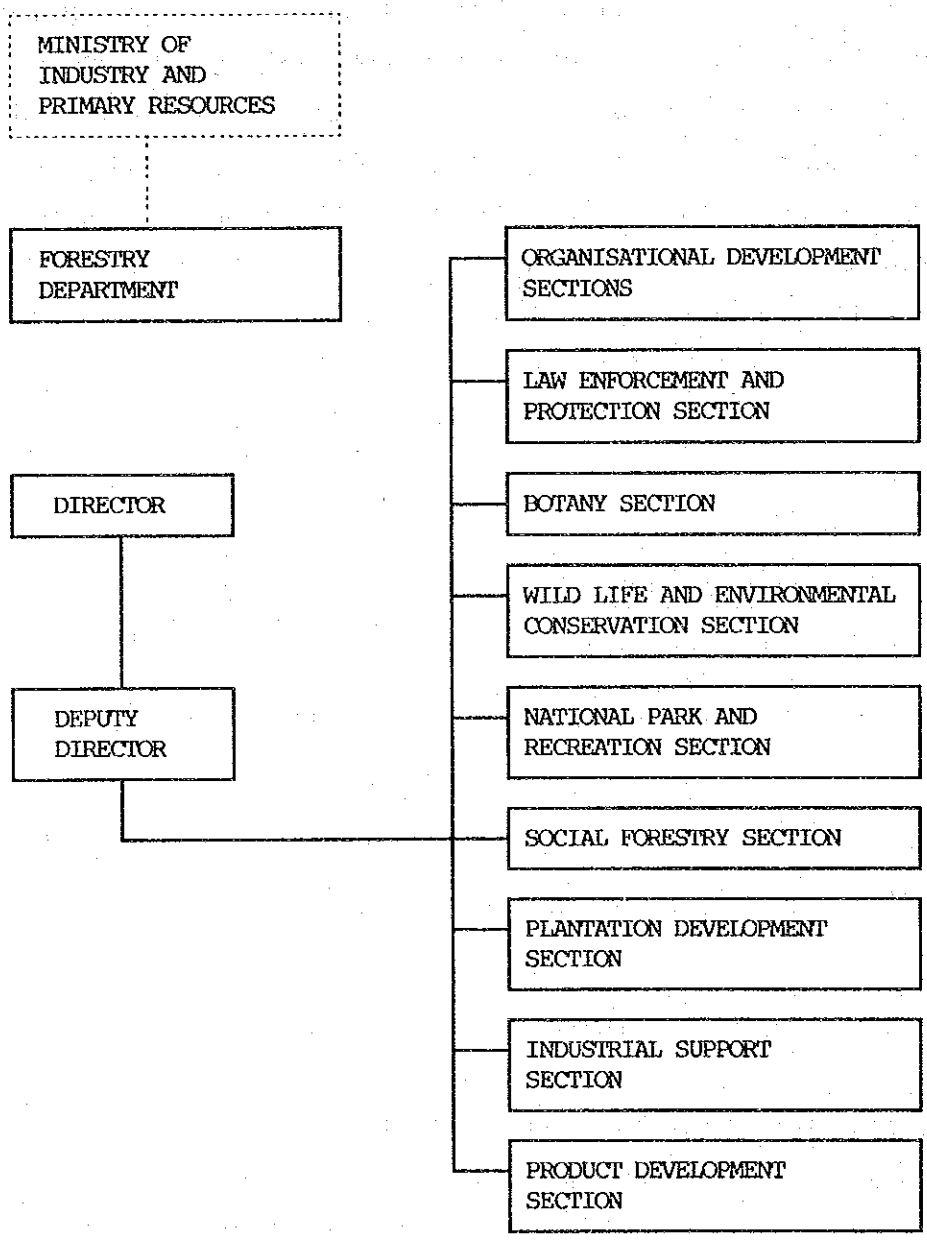


Figure-6 Forestry department organisation

2.2. Forest System of Brunei Darussalam

As a principle, forest land in Brunei Darussalam is owned by the State, but is divided into two land types according to its intended function. One type is National Forest Estate, to be used permanently as forests. The other type is Stateland Forest, whose use may be designated other purposes than forestry after cutting such as farm land and residential housing land. In 1993, the National Forest Estate totalled 241,097ha and Stateland Forest, 227,949ha, representing 41.8 and 39.5% of national land, respectively.

The National Forest Estate, to be managed by the Forestry Department in the future, is sub divided into the following five categories according to their expected functions:

1) Protection Forests

Forests to be protected intact as a principle for conservation of soil and water. As of 1993, protection forests totalled 18,562ha.

2) Production Forests

Forests for timber production, the majority being mixed Dipterocarp forests, where the method of cutting emploing selection cutting methods. Production forests total 146,106ha.

3) Recreation Forests

Five forest recreation parks comprise the recreation forests totalling 1,630ha.

4) Conservation Forests

Forests to be preserved while valuable animals and plants are conservatively utilised for scientific, educational, tourism and other purposes. A total of 72,123ha is designated as conservation forests.

5) Research Reserves

Forests for research and studies of forest development and conservation, which total 2,676ha.

The Forestry Department is planning to incorporate 89,037ha of forests currently registered as Stateland into the National forest estate. As a result, the national forest estate will account for 57.3% of the total national land of Brunei Darussalam.

The Forestry Department, which was incorporated into the newly formed Ministry of Industry and Primary Resources in 1989, established National

Forestry Policy in the same year and classified the National Forest Estate into five types, namely, Protection Forests, Production Forests, Recreation Forests, Conservation Forests and National Parks. In 1991, 48,857ha in the Ulu Temburong was designated as the first National Park. This area had been designated previously as conservation forests, and was re-designated as also a National Park.

Of the two survey areas in this survey, the 50,000ha in the model plantation area belongs to the Stateland. This area is expected to be incorporated in the National Forest Estate after plantation. The 10,000ha in the National Park area is located within the National Forest Estate and is designated both as National Park and conservation forests.

3. National Economy, Forests and Forestry

According to statistics compiled by the Government of Brunei Darussalam, in 1990, the country had a population of 256,500 persons and national land area of 5,765Km^2. The population density of Brunei Darussalam of 44 persons per Km^2 was low among the Asian countries. The census in 1986 showed that the labour population of Brunei Darussalam was approximately 86,000 persons in that year. Central and local government employees accounted for half of the labour population and foreign labourers totaled about 30,000 persons. The unemployment rate was 6.1%.

Table-7 shows exports to 1988 as a source national revenue indicating the characteristics of the economy of Brunei Darussalam. Total exports peaked in 1980 and gradually decrease thereafter. The major exports by commodity sections are oil and natural gas. Fluctuations in exports are caused by the supply and demand situation, and price fluctuations of oil and natural gas.

The wealth of the nation, which is rich and affluent, is due to the fact that exports of oil and natural gas surpass the total budget of the country. Stagnating oil prices after 1980 have resulted in a change in forestry policy of Brunei Darussalam in the 1990s, and recent philosophy places emphasis on environment conservation.

The gross domestic product (GDP) per capita in 1990 was high, about

Table-7 Exports by commodity sections

Milion Dollars

COMMODITY SECTIONS	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total Exports	3,999.98	4,195.21	5,796.49	9,852.94	8,591.73	8,153.26	7,170.68	6,813.94	6,532.89	3.990.10	4,005.61	3,436.45
Food and live animals	3.91	3.68	3.69	4.45	4.50	4.88	5.44	8.30	10.04	17.66	17.76	21.31
Beverages and tobacco	0.33	0.24	0.22	0.26	0.93	1.31	2.51	4.20	3.70	5.40	6.19	5.74
Crude materials inedible, except fuels	1.72	2.10	3.21	2.72	1.57	1.17	1.40	1.60	1.54	2.61	1.21	2.84
Minerals fuels, lubricants and related materials	3,960.16	4,105.27	5,703.80	9,714.34	8,499.70	8,074.91	7,092.82	6,729.53	6,435.62	3,877.70	3,906.81	3,351.86
Animals and vegetable oils and fats	0.04	0.06	0.03	0.02	-	0.32	0.46	0.27	0.14	0.04	0.12	0.23
Chemicals	1.02	1.19	2.89	7.86	3.83	2.00	2.98	4.95	3.27	2.49	1.72	1.89
Manufactured goods classified chiefly by materials	10.06	6.83	7.06	31.09	29.23	13.88	12.18	9.89	10.77	14.05	10.65	12.94
Machinery and transport equipments	21.13	28.74	30.16	44.93	30.20	44.13	41.91	32.07	55.31	55.29	40.73	28.63
Miscellaneous manufactured articles	1.90	47.04	45.22	46.82	21.32	10.55	10.77	21.08	10.86	13.19	16.89	9.77
Miscellaneous transactions and commodities not elsewhere classified	0.01	0.06	0.21	0.45	0.44	0.11	0.21	2.05	1.64	1.66	3.51	1.23

Source ; Brunei Darussalam Statistical Yearbook 1990

US$19,200. High GDP, and the limited domestic consumption due to the small population, makes it difficult to maintain manufacturing industries. Agriculture, forestry and fishery are not an exception. The proportion of imports to meet the demand for agricultural products is increasing year after year. In forest products, nearly all processed goods such as plywood are imported at present.

4. Trends of Forestry and Forest Products Industry

Due to the fact that all forests in both the National Forest Estate and Stateland of Brunei Darussalam are managed by the State, forestry and the forest products industry in Brunei Darussalam were greatly changed by the implementation of National Forestry Policy established in 1989. The policy set out the basic approach to management of the National Forest Estate, promotion of environmental forestry, maintenance of the forest products industry and the enhancement of tropical forestry technologies not only for the National Forest Estate, but also for Stateland.

In line with these policies, the Forestry Department implemented a cutting reduction policy as a specific measure setting the upper limit of the harvest volume from natural forests to 100,000m^3 beginning in 1990. As a result, the production of logs and sawn timber in Brunei Darussalam has decreased since 1990 as shown in Table-8. During this period, the recovery rate of sawn timber has increased to mitigate the reduction in the production quantity. As shown in Table-9, however, imports of sawn timber have increased since 1990. All products except sawn timber,such as plywood, are imported. The scale of the domestic demand in Brunei Darussalam for these and other products is small and there will be no problems in meeting the shortage of forestry products throught imports.

In 1993, the number of sawmill operators in Brunei Darussalam totalled 24. As domestic production is decreasing, the Forestry Department is encouraging these operators to merge. Sawmill operators are licensed to cut trees in the National Forest Estate or Stateland, and the same operators that cut and transport trees, operate the sawmills.

An afforestation policy has been implemented mainly to convert the

Stateland Forests which are low in productivity, into artificial forest land. The policy includes plans for increasing productivity by planting fast growing exotic species, thereby achieving self suffciency in timber production. A plan has been drawn up to plant trees for sawmill operations on approximately 35,000ha of land.

By continuing to plant 950ha of land each year, it will be possible to produce 200,000m^3 of logs per annum when the plan reaches completion.

The implementation of this plan requires securing a labour force, protection of planted trees, and the development of new technologies related to conservation of plantations.

As a tangible result of state forestry policies, three Forest Recreation Parks were opened in 1993, footpaths inside the National Parks have been built or improved, seeds for plantation are being produced, afforestation of denuded land, and research on environment conservation and forest utilisation, is being conducted.

Table-8 Log and sawn timber production (unit : cu.m.%)

YEAR	LOG	SAWN TIMBER	RECOVERY RATE
1983	180,455	86,686	48
1984	203,682	89,739	44
1985	198,218	97,025	49
1986	196,334	86,842	44
1987	182,199	88,973	49
1988	140,842	72,488	51
1989	215,938	101,059	47
1990	101,600	67,200	66
1991	90,800	54,150	60
1992	98,507	60,894	61

Source : Forestry Department

Table-9 Production and import of timber

	1989	1990	1991
D O M E S T I C			
SAWLOG	215,938.0㎥	101,600.0	90,800.0
SAWN TIMBER	101,059.0㎥	67,200.0	60,894.0
I M P O R T			
SAWLOG	—	—	213.0
SAWN TIMBER	6,123.1㎥	51,237.7	46,694.5
SAWN PILES	519.6㎥	—	26.5
MOULDINGS	13,604.1mrun	48,780.6	88,850.0
PARQUET/MOSAIC	17,246.3㎡	33,148.8	8,763.9
PLYWOOD	2,366.416㎡	1,947,704.6	2,178,815.7
VENEER	1,741.5㎡	1,146.8	1,767.2
OTHER/POLES	63,418.8㎡	90,508.5	99,647.0
BAKAU BOARDS	30,000pcs	32,680.0	16,600.0
OTHERS	—	—	—

Source : Forestry Department

II MODEL PLANTATION AREA

1. Items and Area of the Survey

As mentioned in the S/W signed in November 1991, the purpose of the survey is to prepare topographic maps to a scale of 1/20,000, together with soil maps and vegetation maps of the model plantation area covering approximately 50,000 ha.

The survey area is located in Daerah Belait and Daerah Tutong as shown on the map attached to the S/W. Subsequentry, as a result of consultation with the Forestry Department of Brunei Darussalam. The survey area was focused on the Bukit Sawat area bordering the Bukit Sawat and Ukong areas of the Andulau Forest Reserve border in the north, the Labi Hills Forest Reserve border along the Belait River in the west, to the Sukang area and the Rambai area bordering the Merimbun National Park border in the east.

1.1. Survey Items

In the survey, the aerial photographs were taken first. The present condition of forests and the distribution state of soil was defined by combining the results of aerial photo interpretation, with a field survey. It was decided that the present status of forests would be defined by placing emphasis on forest type classification using ecological characteristics.

The results of forest and soil surveys available at present would be studied and examined to enhance accuracy and efficiency in conducting the forest and soil surveys. Using Anderson's forest type classification method, the field survey of the forests was designed and planned by preliminary interpretation of the aerial photographs beforehand.

The forest survey was conducted using the stratified double sampling method by dividing into forest types. The survey consisted of large sample plots for aerial photograph interpretatioion and small sample plots taken from the large sample plots for a field survey.

In surveying the sample plots, points selected on photographs were accessed, and forest composite factors were surveyed. The similarities between the results of the field survey and photo interpretation values were found, and correlation between the two was sought to estimate each stratum and the entire forest area.

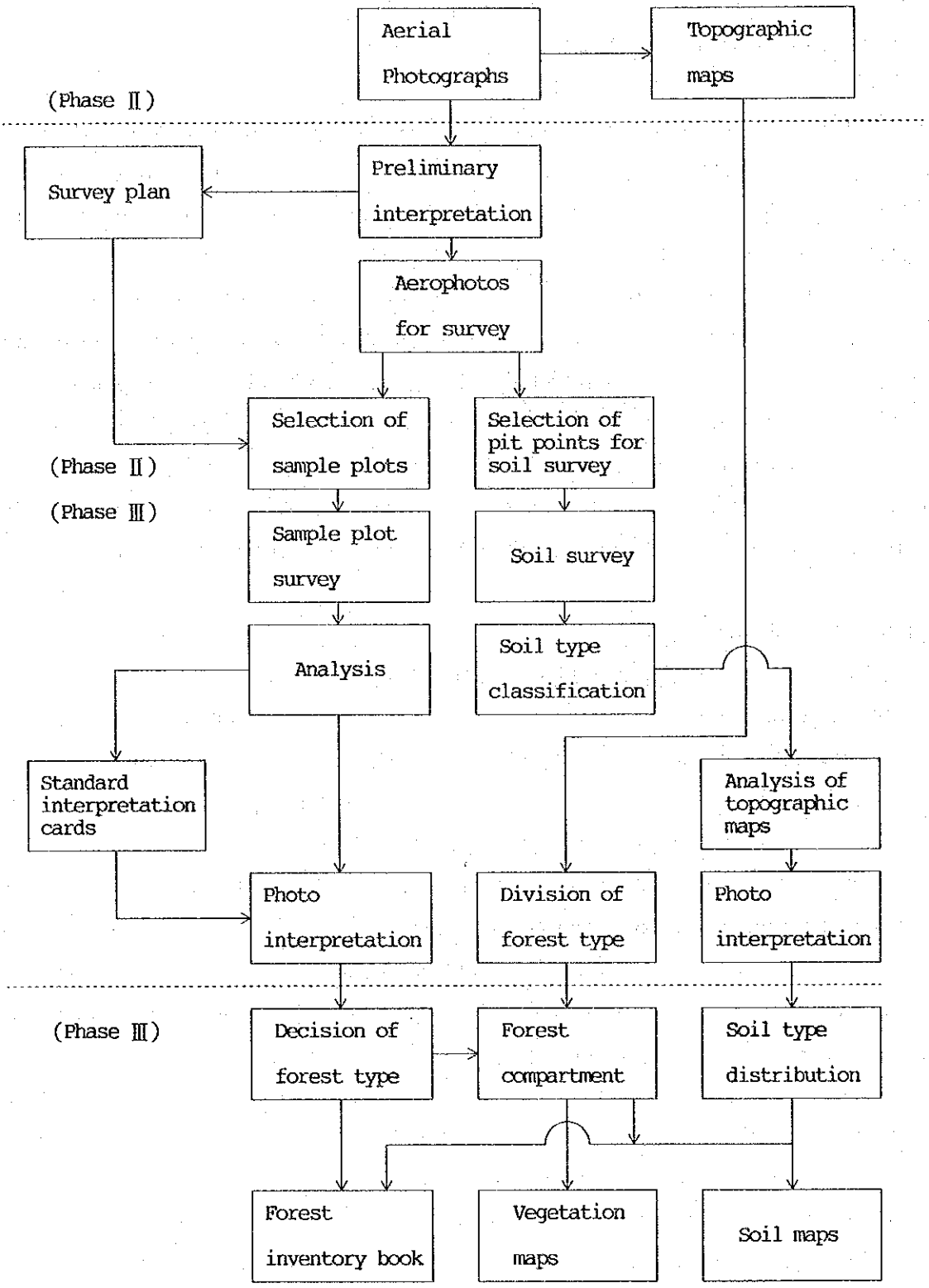


Figure-7 Flowchart : From the survey design to forest inventory book, vegetation maps and soil maps

Soil had a strong correlation particularly with topography. The distribution of soil types in the entire survey area was estimated based on the correlation between the typical soil types found in the field survey, the results from interpretation of topography, and of forest type.

Figure-7 Flowchart illustrates process, from survey design to the preparation of forest inventory book, forest type maps and soil maps.

1.2. Survey Area

The survey area consisted of the watersheds of two rivers, the Belait and Tutong Rivers. Both of these rivers flow north, meandering from south to north.

The topography was gentle, small relief, wavy topography, and altitude varied from about 2 to 100m. The lowest altitude point was the banks of the Belait River at Kampong (Kg.) Sungai Ubar in the northwestern part of the survey area. The highest altitude point was 106m on an independent peak located 7km east-northeast (900m east of a new road) of Kg. Apak-Apak along the Belait River.

The average meteorological observation data from the Brunei Darussalam International Airport in the five years between 1986 and 1990 is as follows.

1) Temperature

Average maximum and minimum temperatures 31.8 and 23.3°C

2) Relative humidity

Average maximum and minimum humidities 96 and 68%

3) Rainfall depth

Annual rainfall depth 2,628mm, annual rainy days 168 days (more than 1mm/day)

4) Hours of sunlight

Average hours of sunlight per day 7.2 hours

Brunei Darussalam is also affected by the monsoon. The prevailing winds blow from southwest to northeast between April and October and from northeast to southwest between November and March. The season when northeast winds blow is generally called the rainy season.

The geology of Brunei Darussalam mainly consists of sedimentary rocks

formed in the Tertiary and Quaternary Periods and is a very young stratum. The inland mountain areas are older. The stratum gradually becomes younger from low montane zones to hill land facing the South China Sea in northwest. Recent formations are young marine deposits on the coast and delta zones and are derivatives of igneous and sedimentary rocks inland. Figure-8 shows the stratigraphic succession of the Tertiary and Quaternary Periods. Figure-9 shows the distribution of geological strata by period.

The present gentle topography is formed by a repetition of sedimentation and erosion caused by repetitive precipitation and uplift. The coastal area along the South China Sea facing northwest and flat land in the watersheds of the Belait and Tutong Rivers are deposits of the Quaternary Period in the Alluvial Epoch. Peat has developed and has become low swamps.

Deposits of white silica sand soil (kerangas) sometimes emerge in small relief wavy topography below about 30 m in altitude and are particularly prominent in the western part of Daerah Tutong.

Hill land low in altitude but with considerable variations can be found in the inland parts. Hills and ridges formed on sedimentary rocks of the Quaternary Period and low swamps of deposits formed in the Quaternary Period are distributed in watersheds of minutely interwoven small and medium rivers. Roads and rivers are used for transportation in the area.

Roads are used to reach the northern part of the area and to about 4,000m northeast of Kg. Apak-Apak in the central part of the area. Rivers are used to access the banks along the Belait River in the west and near Supon Kechil in the east of the area. The southeastern part cannot be accessed by roads or rivers.

The principal road is a highway from Sungai Liang to Labi. Near Mau, there is a branch road to the east, which subsequently stretches approximately southward through the center of the survey area via Bukit Sawat. This road is a new (partially improved) road scheduled to reach Apak-Apak and Sukang via Buau in the future. If the road condition is good, the section between Apak-Apak and Buau can be accessed by vehicles at present.

There are other roads that reach the above new road merging midway between Kg. Bidang and Rambai, and passing through via Long Tadion.

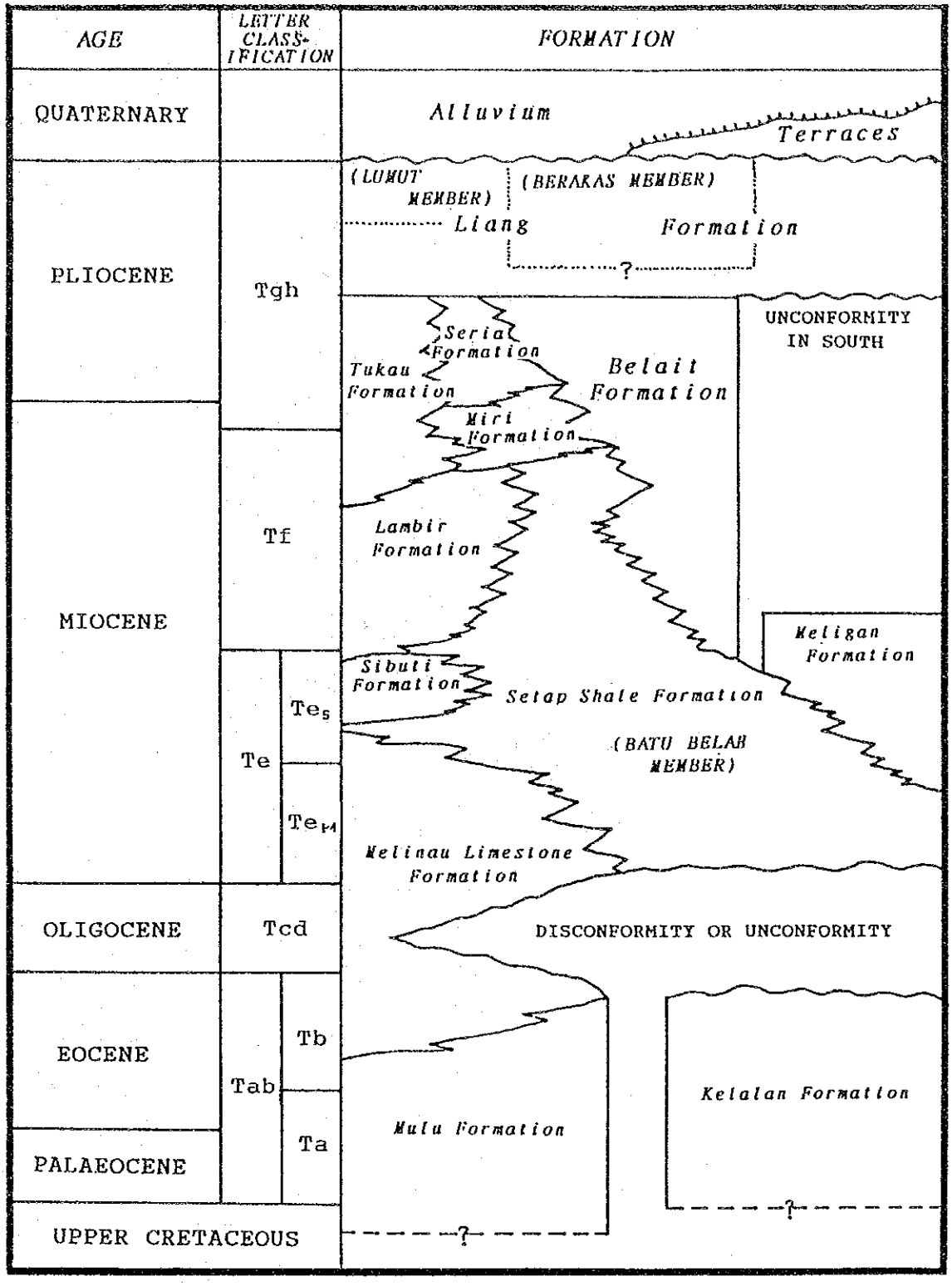


Figure-8 Stratigraphy of the Brunei area

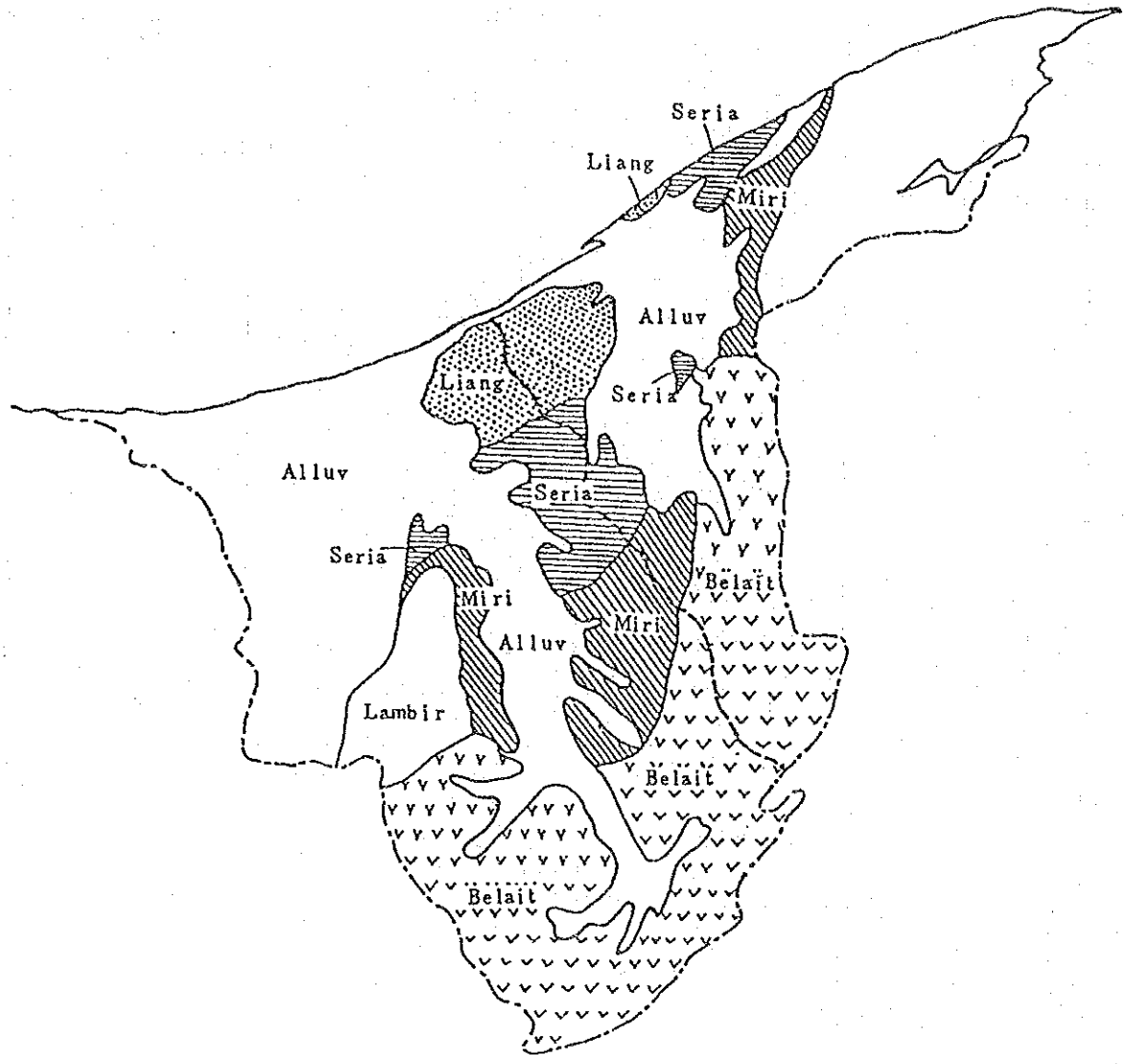


Figure-9 Geological map

The southwestern part of the survey area is accessed through the Belait River. Buau and its vicinities in the south are accessed by following the Buau River, a tributary of the Belait River, upstream. Passage through this river is difficult during the dry season due to the low water level.

Supon Kechil and its vicinities in the east were accessed by following the Tutong River upstream and the survey area was reached by land through Belabau. Kg. Bukit Sawat, Kg. Pangkalan Siong and Kg. Apak-Apak are located in order upstream along the Belait River. Kg. Kukub, Rumah Buau and other communities are located in the watersheds of the Buau River.

Kg. Pak Bidang, Kg. Pak Meligai, Kg. Long Mayan, Kg. Merangking Ulu, Kg. Sg. Singap and other communities are located along the road that ran southward from the centre of the northern part of the survey area to Kg. Bukit Sawat.

Kg. Supon Kechil is located in the east. There are nearly no communities south of it.

As listed above, the communities are concentrated along the roads in the northern part of the survey area and along the Belait River.

2. Aerial Photogrphy and Preparation of Topographic Maps

2.1. Outline of Work

2.1.1. Purpose

Aerial photography was carried out for the 350,000 ha forest area of Daerah Belait and Daerah Tutong, including the 50,000 ha area set as the Model Plantation area, for which topographic maps were subsequently produced. Surveying was conducted in accordance with the rules and specifications as set out in The Rules for Overseas Survey Work (referred to as JICA Rules hereinafter).

After due consultation with the Forestry Department and the Survey Department, Brunei Darussalam, aerial photography was subcontracted out to an Australian aerial survey firm (Kevron Aerial Surveys Pty. Ltd.), and concluded as planned. All other aerial survey works to be done in the field such as aerial signalisation, monumentation, control point survey, levelling, and field verification were conducted by the JICA Team with their Brunei counterparts. By working closely with the Brunei counterparts throughout the process, including the aerial photogrammetric mapping and cartography work done in Japan subsequently, technology transfer of photogrammetry was successfully made to the Brunei side.

2.1.2. Work Volume

Type of Work	Planned Volume	Actual Volume
Aerial signalisation/ mounumentation	16 points	20 points
Aerial photography	350,000 ha	350,000 ha
Control point survey (GPS survey)	16 points	18 points
Levelling	150 km	150 km
Field verification	50,000 ha	50,000 ha
Aerial triangulation	116 models	116 models
Plotting/editing/ drawing	50,000 ha	50,000 ha

Basides, App. Table-1 shows the principal instruments employed.

2.1.3. Meetings with the Forestry Department, the Survey Department and Sub-contractor

Meetings were held with the Forestry Department, the Survey Department and the sub-contractor to discuss how best to proceed to produce the best possible topographic map with the limited period of time.

(1) Meetings at the start of the field work

Aerial signalisation/monumentation, aerial photography, photo processing, control point survey, levelling, field verification were explained in terms of work methods, work volumes, work group organisation, and work schedules, to be followed by consultation and confirmation on such matters as selection of Brunei counterparts and items to be supplied by the Brunei side. With respect to aerial photography, agreement was reached as follows.

a. Favoured (priority) use of airport facilities for aerial survey aircraft and helicopter.

b. Assurance of safety of photographic flights in the vicinity of the Malaysian border.

c. Availability of the Survey Department's photo processing facilities for use by the JICA Team.

d. Restricted use of topographic maps and aerial photos.

e. Extension of visas for JICA Team/photographic crew members.

The map symbols and their application rules and 1/20,000 scale topographic map design were finalised and determined.

(2) Meetings upon completion of the work

The progress of the field work was reported and the dispatching of a security officer to oversee the photogrammetric mapping and cartography work expected to be done in Japan was confirmed.

2.2. Aerial Photography

2.2.1. Aerial Signalisation/Monumentation

Aerial signalisation was made of the newly established GPS points

(20 points) to make them serve as control points for aerial triangulation. Of the 20 GPS points that were signalised, 4 were monumented in concrete but the remaining 16 points were temporarily monumented due to access problems.

The work on monumentation and installation of aerial signals was started immediately after a technical briefing to the workers involved, and was to be concluded in time for the scheduled photographic flight. The signalised points were identified on the photos, excepting one, which was marred by halation.

Of the 18 GPS points that were signalised, the Descriptions of Airphoto Signals were prepared.

(1) Specifications for aerial signalisation

a. Shape: Three-leaf signal

b. Size: 60 cm x 200 cm

c. Color: Painted in white

(2) Specification for GPS point monumentation

a. Monumentation was made in accordance with official Brunei specifications as follows.

1) Reinforced concrete (diameter of 6 mm)

2) Concrete strength = 240kg/sq. cm

2.2.2. Aerial Photography

Photo taking commenced immediately after a meeting with the photographic crew to discuss procedural details. The wether was not favorable, with a prolonged spell of cloudy and rainy days during the July part of the scheduled work period, but fortunately it turned out fine in early August. After checking the photos taken, areas found to be inadequate in imagery for plotting due to cloud coverage, etc. were reflown. Aerial photography was completed with the last reflight taking place on August 10, producing complete photos covering the entire planned area. Photo processing was concluded on August 27.

The aerial photography, including reflights, covered an area of 350,000 ha, and as a result the photos were produced that were all sufficiently adequate for plotting. (See App. Table-2)

The photo orientation was produced based on the existing 1/50,000 and

1/200,000 scale topographic maps. Photo numbers and the locations they represent on the map as well as the course numbers were shown on the photo index map.

(1) Specifications for photography

Scale:	approx. 1/25,000
Photographic altitude:	approx. 4,100 m
Datum height:	approx. 100 m
Photographed area:	350,000 ha
Photographic flight course direction:	East and west
Overlap:	60% between plus 5% and minus 5%
Sidelap:	30% between plus 10% and minus 10%
Kappa:	Not more than 10 degrees
Omega, Phi:	Not more than 5 degrees
Cloud cover:	Less than 5% in successive five photos

Film: Kodak Double-X Panchromatic Aerographic Type 2405

Printing paper: Kodak Professional Paper Kodabrome II RC N2M

(2) Base airport

Photographic flights were based in Bandar Seri Begawan International Airport.

(3) Final products

Photo processing was carried out using the laboratory facilities in the Survey Department. From the processed film immediately after checking, four sets of contact prints as well as diapositive films and two-times enlarged photos as listed in App. Table-3 were produced for delivery. One set of four-times enlarged 6cm x 4cm stereoscopic spot photos with respect to the 20 signals installed were prepared to be attached to the descriptions of photo signals.

2.3. Control Point Survey

Traversing and trigonometric survey in forest areas usually involves felling of trees and poor intervisibility. The GPS survey method using satellite signal receiving units was employed for accuracy and efficiency.

2.3.1. GPS Survey

The study area has B77 and B78 close-by which are control points forming part of the national geodetic network established by the Survey Department. With these control points as given points, coordinates of the newly set up GPS survey points were determined by the broadcast ephemeris data and differential method using the Global Positioning System (GPS) survey instruments. The observation started on July 10. Three (3) 4000SL receiving units, made by Trimble of the USA, were operated for simultaneous observation. Checking of the survey results with respect to the 18 newly set up control points found that they sufficiently met the specified accuracies for horizontal positioning and elevation.

Required accuracies:

Horizontal position; plus or minus 2 ppm x distance or
plus or minus 2 cm / 10 km x distance

Elevation; plus or minus 5 ppm x distance or
plus or minus 5 cm / 10 km x distance

The type of ellipsoid on which computations were based for their geodetic coordinate system was Everest whose dimensions are 6,377,298.523 m in larger radius, 1/300.8017 in flattening, with the origin of the coordinate system at latitude 4°00'00" N. and longitude 115°00'00" E. of Greenwich.

(1) Observation

Data was taken simultaneously from 5 satellites at elevations higher than 15 degrees of elevation angle by 3 receiving units for about one hour at a time. The operating receivers were located within 50 km from each other. Small capacity power generators were used as an electric power source for the GPS units as they were being operated in the forests.

(2) Pricking

Among GPS control points, aerial signal for No. GPS 1 was not identifiable on the aerial photos due to halation so it was represented by the pricking method.

Satellite data is based originally on the WGS-84 ellipsoid and therefore all coordinate computations were initially made on WGS-84 and subsequently converted to Everest based coordinates, the national coordinate system applied in Brunei Darussalam, using geodetic station B78 as a given point.

Computations of plane coordinates were based on the Rectified Skew Orthomorphic Coordinate System.

2.3.2. Levelling

There are several national levelling routes running in the survey area. By using national bench marks located in Lamunin Village along with those set on the road between Liang and Labi, totalling 17 existing points on the two routes, minor order levelling was conducted with Wild NA2000 by direct levelling for a distance of about 150 km. Minor order bench marks were set up along the levelling route at intervals of about 1 km and pricked on two-times enlarged photos. The minor order bench marks were located at such points that are clearly identifiable on the photos so as to make them serve as control points for elevations in the 1/20,000 scale topographic map. The accurancies of the levelling survey results sufficiently met the requirement of plus or minus 5 cm times square root S (S: distance of route) for closure discrepancy.

Specifications of minor order levelling:

Staff distance;	80 m at max
Minimum unit of reading;	1 mm
Observation;	1 reading for 1 pointing
No. of two-way observation;	one in each direction

2.4. Field Verification

Topographic map information as acquired on the two-times enlarged photos was verified and checked in the field according to the map symbols and their application rules, and findings were incorporated in the photos. Administrative names and boundaries were checked on site with the Brunei counterparts. The following were reconfirmed in the survey.

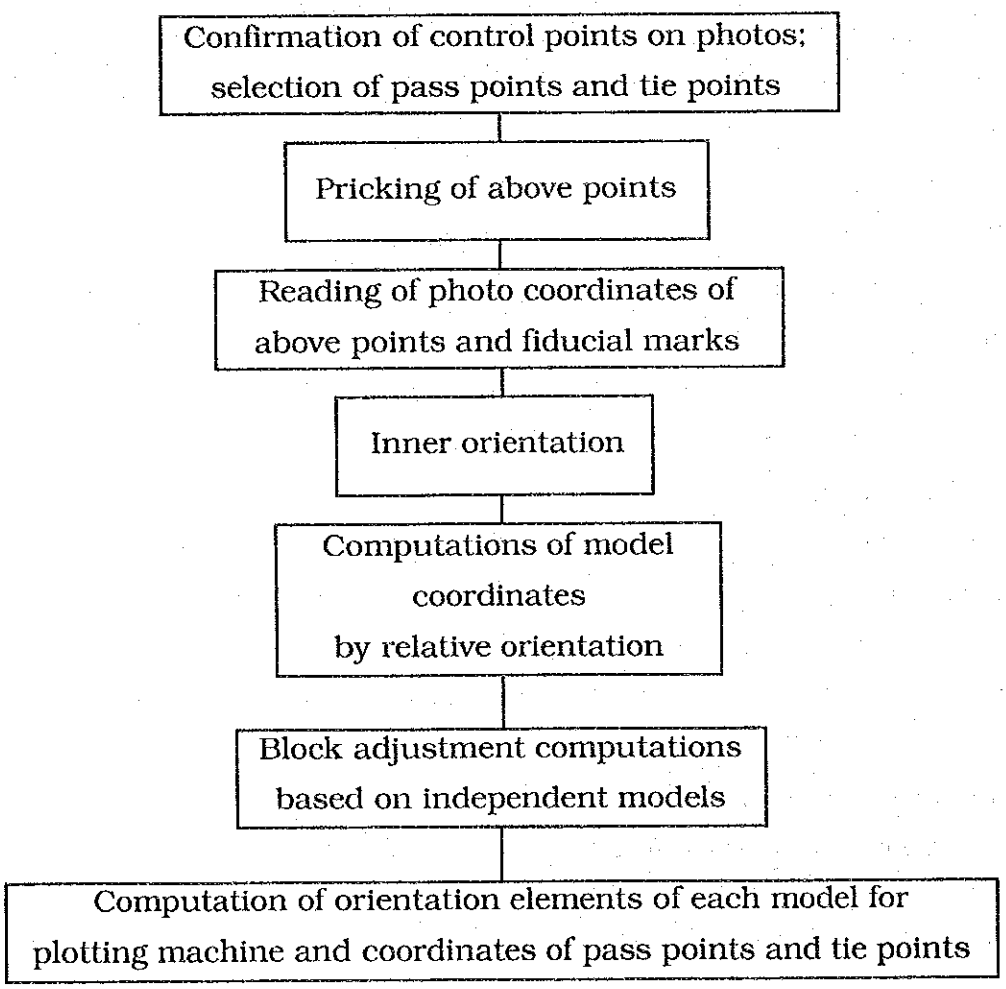
a. Application of map symbols and items to be represented,
b. Administrative names and other proper names

2.5. Preparation of Topographic Maps

2.5.1. Aerial Triangulation

Aerial triangulation was performed by analytical block adjustment computations based on independent models using the programme by the name of PAT-M43. On the basis of positive films, relevant photos and maps brought to Japan by the security officer from Brunei Darussalam on September 10, orientation elements as well as coordinates of pass points and tie points for each model of 116 models were obtained in the process schematically shown below. Computation results were found to sufficiently meet the specifications required for control points residuals of horizontal and elevation positons, and for pass points and tie points discrepancies of horizontal and elevation positions.

The work was carried out using the following procedures.



(1) Checking by plotting machine

Checking of the aerial triangulation results found that all pass points, tie points and control points met the required tolerance of 0.2mm on map for horizontal positions in X and Y. With respect to elevations, pass points, tie points, control points and minor order bench marks also met the required tolerance of 1.7m or less as specified in the JICA Rules.

2.5.2. Plotting

Based on the aerial triangulation results, the plotting manuscript was prepared according to the map symbols and other relevant specifications, following the models developed in aerial triangulation.

Specifications

Scale:	1/20,000
Area:	50,000 ha
Projection:	Rectified Skew Orthmorphic
Inner neat lines:	14 km x 20 km (70 cm x 100 cm on map) with tic marks 2 km apart on distance grids
Contour intervals:	5m for intermediate contour lines, 25m for index contour lines, and 2.5 m for half interval contour lines.

(1) Preparation of manuscript sheets

Neat lines, grid lines, control points, pass points and tie points were drawn on polyester sheet by coordinategraph.The study area was covered by five map sheets.

(2) Orientation

Relative orientation was performed using 6 pass points, while for absolute orientation, all ground survey points contained in the models were applied. Residuals of the control points in absolute orientation were within 6.0m for horizontal positions and 1.7m for elevations.

(3) Detail plotting

a. Colours of pencils used for plotting were as specified by map symbols and their application rules.

b. Houses were delineated individually as they actually appeared instead of generalization.

c. Half intermediate contour lines were shown only where contour intervals

were more than 2 cm on the map.

d. Attention was paid to ensure that the spot heights were located about 5 cm apart on the map.

e. Matching of adjacent manuscript sheets was done on a chip polyester-based sheets.

(4) Checking and modification

Operators were instructed fully on the map symbols and their application rules, detail plotting, matching of adjacent sheets, to ensure consistency and uniformity between operators.

2.5.3. Editing

From the plotting manuscipt, the editing manuscript was made by incorporating findings of the field survey and information from the existing 1/50,000 scale topographic maps. Extra care was taken to ensure consistency and uniformity between data to be represented.

(1) Editing

a. The editing manuscript was produced according to the symbols and their application rules and instructions on compilation work.

b. Representation of control points on the topographic map was made independently after all else has been shown in order to avoid omission.

c. Extra attention was paid to matching of adjacent map sheets.

(2) Checking/modification

Edited map sheets were checked for any missing data or inconsistency, and modifications, where necessary, were made.

2.5.4. Drawing

Drawing was made by a standard drafting (fair drawing) method using pens and ink. The marginal information plate as agreed with the Forestry Department and the Survey Department, was used in drawing. Tracing was done in the following order in accordance with the map symbols and their application rules as agreed with the Forestry Department and the Survey Department.

a. Elevations

b. Notations

c. Linear features
d. Building symbols
e. Houses and others
f. Landuse
g. Landuse boundaries
h. Contour lines
i. Checking/modification

Each sheet was checked and, where necessary, modified on the drawings.

2.5.5. Inspection

The 1/20,000 scale topographic map in the form of an original drawing was inspected by the Survey Technical Center of the Japan Survey Association.

2.6. Final Results

In compliance with the Brunei regulations covering topographic maps, aerial photographs, and other related materials as they are taken out of the country, the results of aerial photography and those of ground surveying including control point survey were brought to Japan accompanied by the Brunei Security Officer. The 1/20,000 scale topographic maps and related photogrammetric mapping results, as produced and completed in Japan, as well as the results of aerial photography and ground surveying previously brought from Brunei were taken back to Brunei Darussalam by the Security Officer on December 8, 1992.

Then on December 16, 1992, the survey team took back with them 6 sheets of the 1/20,000 scale original topographic map to Japan in order to make the vegetation map and the soil map. These 6 sheets of the topographic maps were returned to the Foretsry Department, Brunei Darussalam on September 4, 1993.

3. Forest Survey

3.1. Survey Design

The intention of the forest survey was to prepare current distribution maps of various forest types in more detail, based on ecological characteristics of tropical rain forests. Therefore, an emphasis was placed in classifying forest type (forest type classification) based on ecological characteristics, instead of classification by differences in stand volumes of forest stands.

An emphasis was placed on preparing forest type maps that would incorporate data of significance in selecting afforestation species and in handling forests, as well as in studying environmental conservation.

More specifically, stand volumes of each stratum (each forest type division was called a "stratum" in sample surveys) and all forest stand volumes were estimated by the stratified double sampling method.

This method was generally used in sample surveys combining both photo interpretation and field survey, in surveying forests of large areas, where sample plots for field survey sufficiently large in proportion to the survey area could not be obtained.

Forest types were basically classified by interpreting topography and stand types (canopy type, tree height and crown density) using aerial photographs in accordance with the procedures for forest type classification proposed by Anderson, and modified to suit when applied to the survey area only. The comparison between forest type classification by Anderson and of this survey is in Table-10. The minimum classification unit would be about 5ha. Sample plots (large samples) in numbers needed for individual classified forest types would be placed on aerial photographs. Average crown diameters (x_{1i}) and crown densities (x_{2i}) of large samples would be interpreted from the aerial photographs. Small samples would be sampled from these large samples and complete enumeration would be conducted at the site with the sampled small sample plots to obtain measured volumes (y_i), and photo interpretation values (x_{1i}, x_{2i}) corresponding to them. A regression formula tto obtain estimated volumes ($\hat{y}_i$) by this independent variable (x_{1i}, x_{2i}) and dependent variable (y_i) were established and volumes of large sample plots were estimated.

Table-10 Contrast between forest type classification by Anderson and of this survey

	Forest classification by Anderson		Forest classification of this survey	
	Symbols	Forest types or conditions	Symbols	Forest types or conditions
Freshwater swamp forest	2.1	Levee alluvium	2.1(1)	Levee alluvium
	2.2	Lower level alluvium	2.2(1)	Lower level alluvium
			2.2(1.EX)	— 〃 — (Exploited forest)
			2.2(1.S)	(Sparse density)
Peat swamp forest	3.1	Mixed swamp forest	3.1(1)	Mixed swamp forest Dense enen, small crowns
			3.1(1.EX)	— 〃 — (Exploited forest)
			3.1(2)	Mixed swamp forest Dense uneven, medium crowns
			3.1(2.EX)	— 〃 — (Exploited forest)
	3.2	Alan forest	3.2(2)	Mixed swamp forest Dense uneven, large emergents
			3.2(2.EX)	— 〃 — (Exploited forest)
			3.2(2.S)	(Sparse density)
	3.2/3	Transitional between 3.2 & 3.3		
	3.3	Alan bunga forest	3.3(3)	Alan bunga forest
			3.3(3.EX)	— 〃 — (Exploited forest)
	3.4	Padang alan forest		
	3.5	Padang forest	3.5(1)	Padang alan forest
Mixed dipterocarp forest	5(2)	Canopy uneven, medium or large emergent	5(2)	Dense uneven, medium or large emergents
			5(2.EX)	— 〃 — (Exploited forest)
	5(3)	Dense even canopy of medium crowns	5(3)	Dense even, medium crowns
	5(4)	Dense uneven canopy of medium and large crowns	5(4)	Dense uneven, medium and large crowns
			5(4.EX)	— 〃 — (Exploited forest)
Secondary forest	8	Generally over 25 years old	8	Generally over 25 years old
			8(S)	(Sparse density)
	9	Cleared land and cultivation	9	Forest plantation
			10	Cultivation, cleared land and village
			11	Unstocked land and land slide

Necessary and sufficient large sample plots were provided for each forest type allowing stratification and entire stand volumes to be estimated.

3.1.1. Preliminary interpretation of aerial photos

The aerial photographs were first interpreted to divide forests into forest types and to allocate large and small samples to the strata distributed inside the survey area.

Forest type classification was interpreted from aerial photographs based on three factors, namely, topography, stand type and crown density.

(1) Interpretation of topography

The distribution of each forest type was greatly affected by topographical factors. The topography of the entire survey area was of lowland, low-relief, wavy topography. Freshwater swamp forests [2] appeared in a belt shape in riparian alluvial deposit areas along rivers and valleys low in altitude, which were flooded during the rainy season. Peat swamp forests [3] were on flat lowland, lying between freshwater swamp forests and lowland hills. These areas were always in a swampy condition. Peat swamp forests were distributed in intermediate zones between freshwater swamp forests and lowland mixed Dipterocarp forests. Padang alan forest-Strata [3.5(1)] appeared in the centre of peat swamp forests and Alan bunga forest-Strata [3.3(3)] were distributed along the outer edges of them. Mixed peat swamp forest-Strata [3.1(1), 3.1(2), 3.2(2)] appeared on the furthest outside edge, adjacent to the freshwater swamp forests. Lowland mixed Dipterocarp forest-Strata [5(2)] were also distributed in fine wavy topography inland. Mixed Dipterocarp forest-Strata [5(4)] containing relatively many large-diameter trees could be found in hill land connected to lowland mixed Dipterocarp forests.

Figure-10 shows the relationship between forest types and topography.

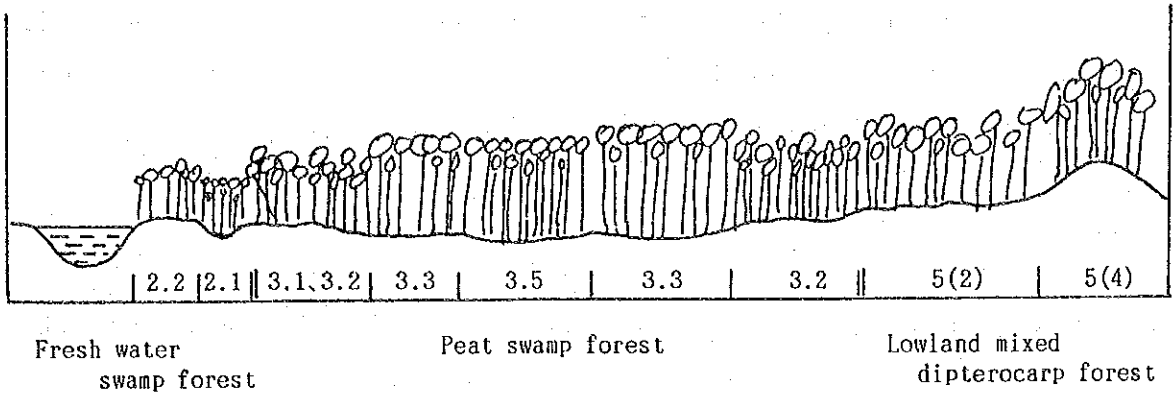


Figure-10 Relationship between forest type, configuration and topography

(2) Interpretation of forest type

Freshwater swamp forests [2], peat swamp forests [3] and lowland mixed Dipterocarp forests [5] classified by topographical interpretation, were further segmented into sections (1) to (5) according to differences in the stand types.

In photo interpretation, the factors used to interpret stand types were canopy type, crown size and tree height. These factors were used in classifying stand types.

The tone in the photos of some crowns of *Shorea* genus trees in Alan bunga forests [3.3], in peat swamp forests and in lowland mixed Dipterocarp forests [5(4)] was a relatively bright light gray compared with those of other stand types, and was easy to interpret. The photo tone could also be used in estimating humidity inside the forests. Forst stands with a high humidity, as in Padang alan forests [3.5(1)], generally appeared dark gray in aerial photos.

Figure-11 shows the discrimination criteria for forest type classification.

The characteristics in the photo interpretation of the forest types are described below.

a. Freshwater swamp forest

(a) Type 2.1:

Stand Type (1) with even height and dense canopies. Crown diameters were extremely small and tree heights were about 30m. This type was distributed in a slim belt shape on alluvial soil zones on river banks.

(b) Type 2.2:

Stand Type (1) with even-height and dense canopies as in Type 2.1. Crown diameters and tree heights were slightly larger than those for Type 2.1. This type was distributed adjacent to Type 2.1 or, in the absence of the Type 2.1. there was only Type 2.2.

b. Peat swamp forest

(a) Type 3.1 (mixed swamp forest):

Stand types were Types (1) and (2). Crown diameters of Type 2 were slightly larger than those of Type (1) and canopies of Type (2) were uneven in height. The tree heights of upper-storey trees were 30 to 40m.

(b) Type 3.2 (mixed swamp forest):

The stand type was very similar to Type 3.1 (2). Trees were tall, about 45m. Type 3.1(2) was similar to freshwater swamp forests while Type 3.2 was similar to lowland mixed Dipterocarp forests. This was the forest type in which variations were dynamic.

(c) Type 3.3 (Alan bunga forest):

The stand type was Type (3). Alan were the dominant trees and the tone was a bright light gray in the photos. Crown diameters were "medium" and were uniform and dense. The average crown diameters were "large." The heights of upper-storey trees were about 45m.

(d) Type 3.5 (Padang alan forest):

The stand type was the type which combined (1) and (3) and was treated as (1) in the survey. Alan trees which were straight and tall were dense and crown diameters were "small" or "medium." The tone of the canopies in the photos was gray.

c. Mixed Dipterocarp forest

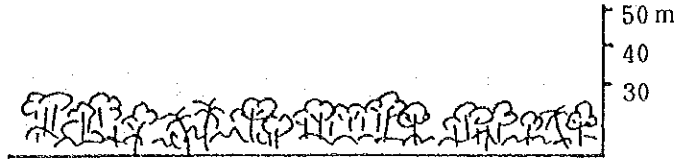
(a) Type 5(2):

The stand type was (2). Forest trees of upper-storey canopies were a mixture of "medium" and "large" crown diameters and canopies were uneven in height. In some places, canopies were sparse. In this type, the proportion of Dipterocarp species with large diameters was relatively large. Heights of upper-storey trees are 40 to 50m.

(b) Type 5(3):

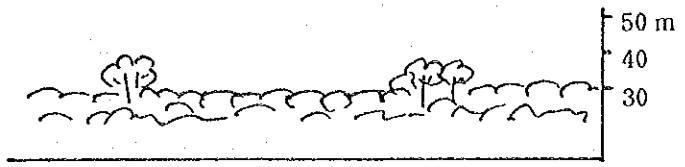
The stand type was intermediate between (3) and (4). Forest trees with medium crown diameters grew gregariously in small groups among upper-

8



Secondary Forest

(1)

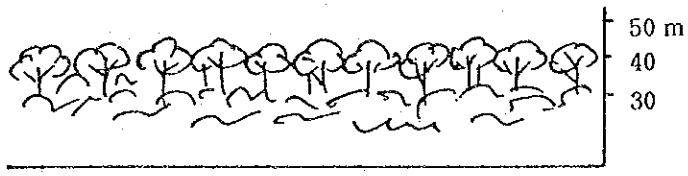


Dense even Small crowns

(2)

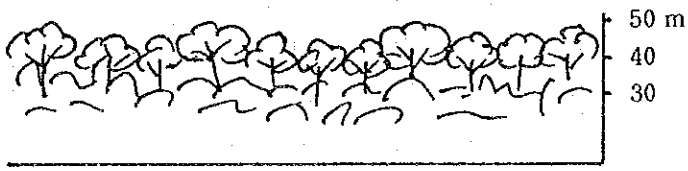
Dense uneven, Medium, Large emergents

(3)



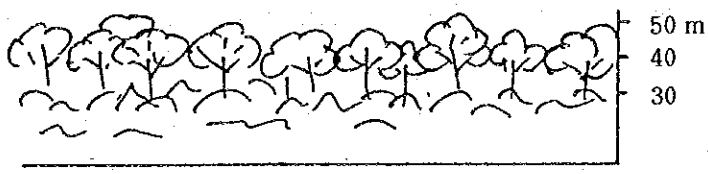
Dense even, Medium crowns

(4)



Dense uneven, Medium and large crowns

(5)



Dense uneven, Large crowns

Figure-11 Stand type

storey trees, but their canopy layers were not even as in Type (3). Crowns were rather dense and heights of upper-storey trees were 40 to 50m. This type appeared in hilly topography.

(c) Type 5(4):

The stand type was Type (4) and was distributed only in lowland hills. Crown diameters were a mixture of medium and large. Large-diameter trees were mostly Dipterocarp trees. The tone of the canopies in the photos was a slightly bright light gray. The height of upper-storey trees was about 50m.

(3) Interpretation of crown density

The crown densities of upper-storey canopies were interpreted in photos by comparing upper-storey canopies of the forest stands with the crown density rule. Table-11 shows the classification from the preliminary interpretation.

Table-11 Classification of crown desity

Crown density	Crown occupancy rate
High density	Over 90 %
Medium density	60~80 %
Sparse density	Below 50 %

3.1.2. Selection of sample plot

The stratified double sampling method was used to identify large sample plots of a required number, and sampling of a reasonable number of small sample plots from these large sample plots was performed. Field surveys were made with these small sample plots. The small sample plots were first selected bearing in mind the time constraints for taking aerial photos and for the start of the field survey. The sampling of large sample plots was performed after the field survey.

A minimum of about 30 small sample plots was believed necessary for the entire survey area, taking into consideration the forest type, survey period and access to the survey area.

The following factors were used in selecting small sample plots:

a. To decide numbers of small sample plots for individual forest types in

accordance with area proportions of the forest types.

b. To allocate at least one plot for each forest type except for those forest types whose distribution areas were extremely small.

c. To select plots which had a typical stand type of each forest type whenever possible.

d. To select as many forest types with large stand type changes.

Taking the foregoing factors into consideration, anemphasis was placed in allocating small sample plots to zones along the Belait River, and along the new road being built in the center of the survey area. This was due to the complex conditions in the watershed of the Belait River, compared to the relatively simple forest types in the watershed of the Tutong River.

3.1.3. Shapes of small sample plots

It was decided that the small sample plots should be a belt-like shape so that sample survey points could be confirmed on aerial photos and that work could be performed efficiently in the survey area.

Base lines were drawn (base line length 100m) from the survey origin in fixed directions and a width of 20m was provided on each side of the base lines to obtain belt-shaped small sample plots.

The base lines were divided into 20m segments and ten blocks of 20 x 20m each were provided on both side of the small sample plots bordering the base lines. As a rule, the base line length was decided to be 100m. It was also decided that the base line length would be reduced below 100m depending on the forest condition such as where small-diameter trees were found to be dense in secondary or other forests. In this case, the lower limit of the measured diameter breast height was reduced.

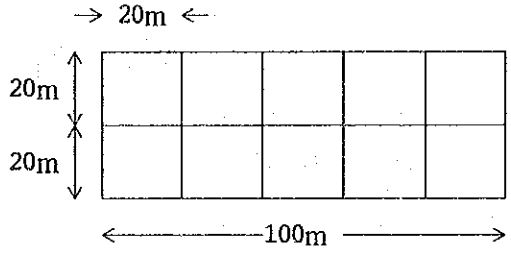


Figure-12 Shape of small sample plots

This block setting was used to measure the variations of diameter breast height, clear lengths and stock volume inside sample plots and for ease of verifying measured trees inside the sample plots.

3.1.4. Survey items

The following items were surveyed for all the sample plots:

1) Weather 2) position 3) numbers of aerial photos showing sample plots 4) base line direction 5) gradient 6) slope direction 7) crown density

The following items were surveyed in the complete enumeration of the sample plots:

1) Tree species name, 2) distinction between upper- and lower-storey trees, 3) diameter breast height, 4) tree height (clear length) and 5) crown diameter

A lower limit for the diameter breast height for trees to be measured was established to be 18cm as a rule, in accordance with the survey method used in Brunei Darussalam. The lower limit was set at 10cm if the base line length was less than 100m.

3.2. Field Survey

3.2.1. Number and positions of sample plots

Tables-12 and 13 show the numbers of sample plots by area and by forest type.

The locations of the sample plots are shown in Figure-13.

Table-12 Number of small sample plots by area

Daerah	Area	Number of small sample plots
Tutong	Ukong	3
	Watershed of Sg. Supon	2
Belait	Mau/Bukit Sawat	11
	Along the new constructed road	8
	Apak Apak	10
	Buau	4
Total		38

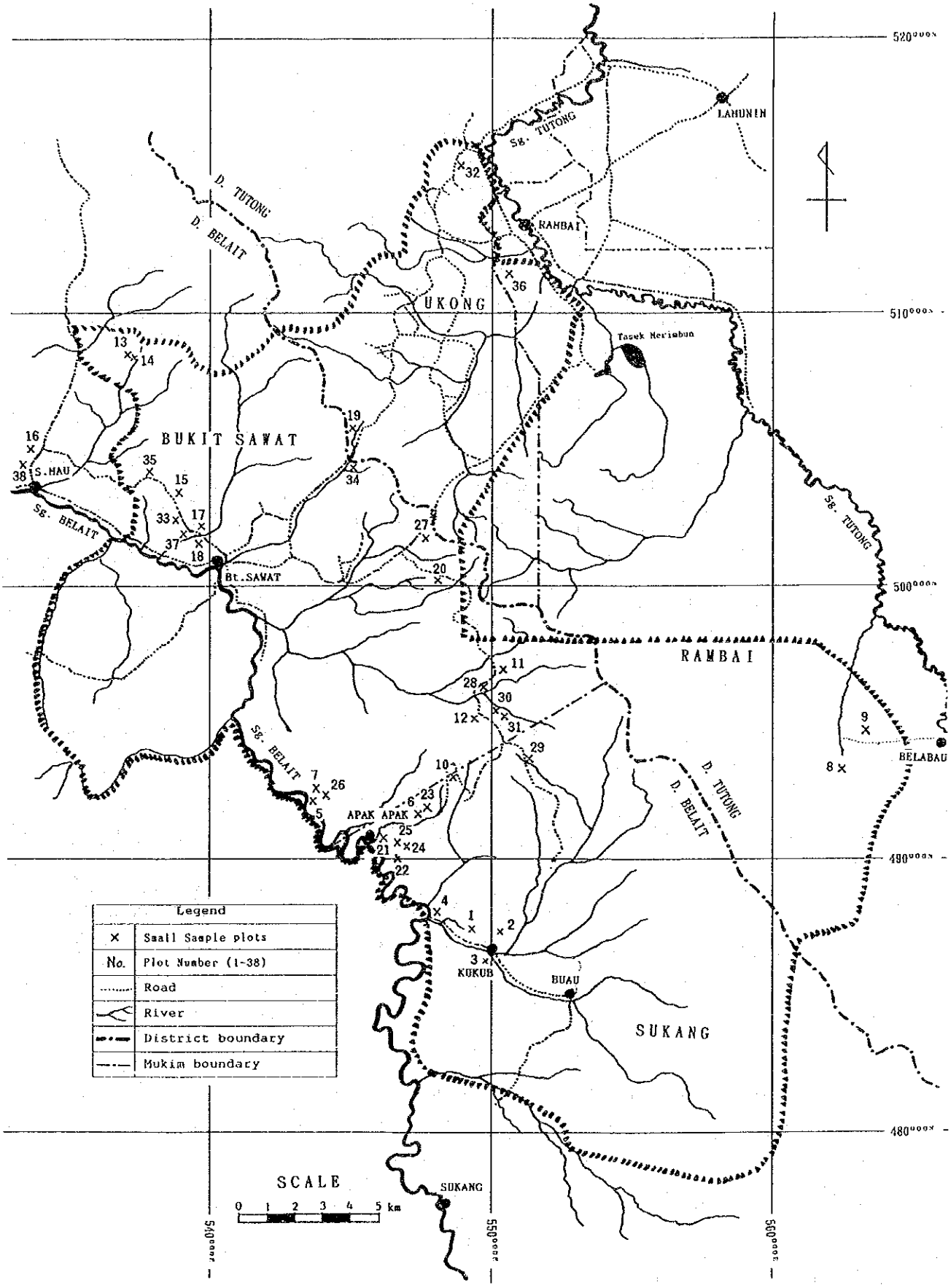


Figure-13 Location of small sample plots

Table-13 Number of small sample plots by stratum

Forest types	Stratum	Number of small sample plots
Freshwater swamp forest	2.1(1)	2
	2.2(1)	2
Peat swamp forest	3.1(1)	1
	3.1(1.EX)	1
	3.1(2)	4
	3.2(2)	5
	3.3(3)	4
	3.5(1)	2
Mixed dipterocarp forest	5(2)	7
	5(2.EX)	4
	5(4)	4
Secondary forest	8	2
Total		38

3.2.2. Preparation of stand volume tables

Stand volume tables were prepared to calculate volumes of single trees in the sample plots.

The tables were prepared using the following formula contained in the FOREST RESEARCH NOTE IN BRUNEI DARUSSALAM No. 9 (DEVELOPMENT OF FOREST INVENTORY SYSTEM IN BRUNEI DARUSSALAM --- VOLUME TABLE CONSTRUCTION ---) by Masakiyo Kawaguchi and Mansor Bin Ahmat/ Forestry Department, Brunei Darussalam and JICA Forestry Research Project Team in Negara Brunei Darussalam/July, 1988.

$\text{Log } V = a + b \cdot \text{Log } BH + c \cdot \text{Log } D$

All species a = -3.91836, b = 0.70315, c = 2.01337

Kapur bukit a = -3.35807, b = 0.91246, c = 1.52979

Keruing a = -3.72438, b = 0.16487, c = 2.32208

Seraya a = -4.78619, b = 1.31309, c = 2.05064

Other a = -4.08397, b = 0.88112, c = 1.97930

V: Volume per tree BH: Clear length

D: Diameter breast height

Using the above formula, volumes per tree (available outside bark volume) by diameter breast height and clear length were calculated for the

main individual species. This data was compiled as the stand volume tables annexed to this report. (App. Table-4) The diameter breast height was expressed in increments of 2cm within the range of 18 to 150cm, and the clear length, in increments of 2m within the range of 10 to 50m.

These stand volume tables were used in consolidating the results of the complete enumeration in the sample plots when volumes of individual stand trees were calculated. Those volumes which were not shown in the tables were calculated using the above formula. The formula for Seraya was used in calculating volumes of Meranti trees, because both of these species belong to the *Shorea* genus and their tree forms are similar.

3.2.3. Results of sample plot survey

(1) Data arrangement

The data of the 38 sample plots obtained in the sample plot surveys at the site was consolidated according to the following flowchart. Figure-14 shows the overall flow of data arrangement. The results of the data arrangement are summarised in the standard interpretation cards attached as an annex to this report as final data.

A personal computer (NEC PC-9801) and card database software (The CARD3+) were used in arranging the data.

a. Tree species identification work

The following references were used in identifying tree species as far as was possible:

1) A Check List of Brunei Trees: Hasan Bin Pukul and P. S. Ashton
2) Manual of Tropical Botany: Research Institute of Tropical Botany (1991)
3) Effective Tropical Tree Species: Tropical Agriculture Research Center, Ministry of Agriculture, Forestry and Fisheries, Japanese Government

However, the identification work was very difficult because vernacular names were different depending on the location, and one species was called by many different vernacular names. Conversely, one vernacular name was used to describe several different species. Species names of nearly all tree species could not be identified and species names are not included in the descriptions.

b. Files of complete enumeration data

The eight items to be described in the complete enumeration field-book,