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SUBJECT : BEKENU – NIAH – SUAI RECONNAISSANCE

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Report No. 35

Report on The Reconnaissance Soil Survey

of

BEKENU - NIAH - SUAI AREA

4 th DIVISION

by

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CONTENTS

I. INTRODUCTION AND SUMMARY

The Bekenu-Niah-Suai area was examined partly during the Coastal Reconnaissance[1] and the Batu Niah Surveys[2] and also by a brief examination of air photographs during 1961. The results of these surveys showed that the basins of the Sibuti, Niah and Suai rivers appeared to be suitable for agricultural development, and consequently the present area was included in the 1962 soil survey programme.

Field surveying began in early June, 1962, and was completed within six weeks by a team consisting of three Junior Agricultural Assistants, one Agricultural Assistant and one Soil Surveyor. The area surveyed during this period totals approximately 597 square miles[3]. The present report includes an additional 360 square miles of the Coastal Survey and 43 square miles surveyed at Batu Niah in previous years and supersedes information and opinions incorporated in reports on the smaller surveys since a more comprehensive and complete picture of the area is now known. Of the approximately 1000 square miles mapped an estimated 540 square miles (335,600 acres) are considered suitable for agriculture, 200 square miles (128,000 acres) marginal and 260 square miles (166,400 acres) unsuitable. The unsuitable areas mainly comprise deep peat, saline clays, podsols on terraces and hill land, limestone hills, and steeply sloping land.

The following is a summary of the soil types and their distribution. The coastline is fringed by a belt of beach sand which is extensive in the southwest and narrow in the north near the Sibuti river. The sands are leached and poor except where the water table is high and shallow peat occurs as topsoil. Behind the coastal sands are extensive deep peat swamps, largely unused and unusable. These extend inland into small valleys especially close to the larger rivers. The survey area includes the margins of the Bakong peat swamp which tongues into the surrounding hills as valley swamps. Saline alluvium only occurs in small pockets near river mouths whereas the riverine alluvium, although not usually occurring in extensive tracts, covers a large aggregate area. Riverine and former estuarine soils are important for agriculture at present in that they support wet padi cultivation. They could be used more intensively for 'sawah' padi and for other commercial crops with suitable soil management.

The hill soils are derived from sedimentary rocks and are typical of large parts of Sarawak. The main exception to this occurs where outcrops of calcareous sandstones and shales yield richer than normal soils, unfortunately indistinguishable in the field from the normal types. The hill land is low and on the whole not deeply dissected.

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1. Wall, J.R.D., Soil Survey Report no.43, 1961
2. Wall, J.R.D., Soil Survey Report no.36, 1961
*. For the location of these areas see location map on sheet A.
3. Areas measured by planimeter from 1:50,000 maps. Figures are therefore most accurate on flat land and least accurate on the most rugged dissected land where errors exceeding 100% are possible.

The hill areas that at present appear most favourable for development coincide generally with the occurrence of the shaley Sibuti, Setap and Tangap geological formations. They comprise low hills with moderate slopes interspersed with normally dry alluvium having a minimum of peat development.

The survey was effected by methods that are now standard for reconnaissance soil surveys in this country[1]. The transferring of the complicated photo data to the base sheets compiled by the Land and Survey Department proved difficult since the sheets provide little topographic data. Moreover the minor detail, such as small streams, that is relied on to find the correct photograph positions on the map is not reliable in many parts due to the method of map compilation. Errors in the drawing of soil boundaries are therefore likely to occur and soil association boundaries and acreages should be treated with reserve both for the reasons stated above and for those mentioned in the footnote on page 1. Large areas have not been examined in the field, notably the 'ulu' parts that are difficult to reach and the more rugged unusable terrain. This is permissible in reconnaissance surveying and is overcome by the methods of interpolation and extrapolation[1]. The margins of the Bakong swamp in particular have only been visited at two places but rather than leave out this important boundary to cultivable land it was decided to map the remaining parts roughly from air photographs, also the limits of the better agricultural land in the upper Sibuti, Niah and Suai rivers. In the 'ulu' Suai there still remains unmapped land that is thought to be suitable for agriculture.

Altogether more than 300 soil samples were collected for analysis in the Soils Laboratory. Field surveying was carried out in 14 pre-selected sample areas and along 260 miles of paths and cut rentises.

GENERAL CHARACTER OF THE AREA

1. GEOLOGY[2,3] The whole area is underlain by sedimentary formations of middle to late Tertiary age. These formations are covered by Quaternary alluvium in the many small inland valleys and by peat-covered alluvium in the extensive coastal and Sg. Bakong swamps.

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1 Limitations and uses of reconnaissance surveys are explained in the departmental External Circular no.2

For details see

2 Wilford, G.E. (1960). The Geology and Mineral Resources of Brunei and Adjacent Parts of Sarawak: Brit. Borneo Geol. Mem. 10, 1960.

3 Haile, N.S. (1962). The Geology and Mineral Resources of the Suai-Baram Area, North Sarawak: Brit. Borneo Geol. Mem. 13, 1962.

The rocks are predominantly fine textured. Soft fine sandstones occurring as thick beds are predominant in the Lambir and Belait Formations in the north and east, while generally thinner beds of fine sandstone alternating with few shale beds constitute the Nyalau Formation. Shales and sandy shales are the main rock types in the Sibuti and Tangap Formations which out-crop mainly north of Sg. Niah. The Setap Formation comprises shales with impersistent fine sandstones and sandy shales. Calcareous strata are common in the Sibuti and Tangap Formations.

The regional strike lies southwest-northeast with the younger formations interfingering into the older formations of the south. To the east and southeast are a series of gently folded synclines dominated by shales between which the sandstones of the Nyalau formation are folded more strongly as anticlines. Dips do not exceed 30° except in the northwest in the Lambir Formation, and in the Nyalau Formation particularly south of the Niah river. Faults are commonly but neither large displacements nor fault scarps are evident.

Low terraces occur mainly on the coast north of Tg. Bungai and between Sg. Nyalau and Btg. Suai: their alluvial material is composed of white fine to medium sands and, rarely, white clays.

.2 2. <u>TOPOGRAPHY AND DRAINAGE</u>. The two main units are the hill ranges, and the lowlying alluvial and swampy areas which broadly occupy both the northeastern edge and the coastal areas between Sg. Nyalau and Tg. Bungai.

The lowlying coastal land is fronted by a belt of beach sand between Sg. Nyalau and Tg. Bungai varying in width from less than 500 feet in the north to approximately a mile at the mouths of the Niah and Suai rivers. The surface of the ground is gently undulating corresponding to parallel series of old sand bars and lagoons, the latter being most pronounced nearest to the sea where tidal flooding is common. With increasing distance inland the land surface appears to drop slowly until the water table rests permanently at the surface and peat develops. The beach sand exists beneath deep peat swamps as much as 8 miles inland in the Suai area whereas at Tg. Bungai the total width of exposed and covered beachsand does not exceed 1000 feet. The sand forming the beaches is predominantly quartz and appears to have originated mainly from sandstone strata to the north forming cliffs at the coast.

The drainage pattern of these areas is rectilinear reflecting the presence of a subdued sand bar lagoon topography. In some respects artificial drainage of these areas is made easy by the natural drainage lines, but at their mouths the streams are almost invariably blocked by sand bars which continually form and thus prevent natural outflow of stream water. All minor and major river mouths are deflected southwest by longshore drift and little sand sized material reaches the sea by the main rivers at present since their gradients and load carrying capacity are low in the lower reaches.

The peat swamps lying behind the coastal beaches have developed partly on old beachsand, and partly in alluvial basins of mixed marine and riverine material. The Bakong swamp has estuarine material at the base and on the margins in one area at least. Many small peat swamps occur in valleys further inland, particularly near the larger swamps and close to the larger rivers. Their edges are continually being covered by skins of recent alluvium during floods.

Indirect evidence indicates that there is slight doming on the deeper swamps and therefore an element of surface radial drainage. Streams are only visible at the shallow margins. The wide band of alluvial clay beneath peat followed by Sg. Trus probably represents a former drainage line of Btg. Suai.

Saline alluvium is found mainly in the lower reaches of the main rivers and in lagoons between Tg. Payong and Sg. Nyalau. Areas are small and the typical meandering lagoons and creeks are poorly developed.

Riverine land occupies large acreages in the lower river basins particularly where re-entrants and salients in the surrounding hill land abound. It is also common in areas underlain by shale where parts have been eroded to the present base level and then covered by thin layers of alluvium. Large streams in these areas are not common.

The general height of the hills, although reflecting in part the underlying structure and type of rock, are primarily due to partial peneplanations probably taking place in Quaternary times[1]. These are shown by a widespread accordance of summit levels at an estimated 300 feet, and at further related levels between 5 and 50 feet above local base level.

The higher level coincides mainly with outcrops of the more competent Nyalau, Lambir and Belait Formations. No terraces have been noted at these heights. The hills forming the higher surface are now deeply dissected and scarp slopes commonly attain 60° due partly to the presence of resistant steeply dipping sandstone beds; absolute altitudes are low and amplitude of relief is less than 200 feet. Remaining as monadnocks above this surface are G. Subis (1294 feet), the Lambir hills (1525 feet), Bt. Igang and Bt. Iban. All except G. Subis which has unusual topographic features are moderately to intensely dissected groups of cuestas with an amplitude of relief of as much as 300 to 700 feet.

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1. For discussions on geomorphological developments see:

Liechti, P. et.al (1960). The Geology of Sarawak, Brunei and the Western Part of North Borneo. Brit. Borneo Geol. Bull., 3, 1960.

Wilford, G.E. (1961). The Geology and Mineral Resources of Brunei and Adjacent Parts of Sarawak. Brit. Borneo Geol. Mem., 10, (1961).

Haile, N.S. (1962). The Geology and Mineral Resources of the Suai-Baram Area, North Sarawak. Brit. Borneo Geol. Mem., 13, (1962).

The lower surfaces are most extensive in the north where the Sibuti and Tangap Formations occur. They also extend southwards, in particular along the synclinal structures fromed largely from the Setap Formation, and in the northern coastal parts on the Lambir Foration. In these areas many terraces and terrace remnants can be found. The largest terraces occurring north of Tg. Batu and between the Nyalau and Suai rivers are as much as a half square mile in area while the smaller remnants are a few hundred square feet. Terrace heights vary (heights above adjacent main valleys) and probably reflect stages in the lowering of the sea level, post depositional warping and the degree of dissection and headward erosion of the rivers. Terraces near the coast generally lie between an estimated 10 and 50 feet above sea level; with increasing distance upriver the heights of the highest terraces above local base level tend to decrease. Thus remnants in the upper Sg. Sibuti lie at an estimated 20 to 30 feet above local base level, at Batu Niah 5 and 15 feet, and in the upper Btg Suai less than 5 feet. In most of the 'ulu areas where these erosion surfaces occur the rate of base level lowering is sufficient to maintain moderately well-drained alluvium and to prevent in such places the formation of peat. Hill slopes are generally less than 30 to 35° and the amplitude of relief less than 50 feet.

The hills of the lower surfaces are dissected and separated by alluvial spreads. In many places however the alluvium is thin and barely covers underlying 'hills', and in yet other places the 'hills' barely protrude above surrounding flat land and can only be differentiated from well-drained alluvium by the presence of rock when augering. These features together with the deep alluvium in valleys possibly indicate the presence of a formerly dissected topography whose valleys were later infilled by alluvium after a rise in sea level; these are now being re-excavated following a lowering of base level in the present erosion cycle. The few small streams can hardly be responsible for the degree of dissection and the amount of alluvium now present.

The main drainage pattern in the hills is sub rectangular, caused primarily by structural features. The pattern is thus most persistent in the higher hills and least visible in the lower erosion surface where structure is barely apparent.

Almost all alluvial areas examined were said by local people to be flooded two to three times a year, particularly in the 'landas', with depths of two to twelve feet for as many as six days. The most seriously flooded areas are at Niah surrounding the limestone hills.

3. VEGETATION AND LAND USE. The coastal beaches near the main river mouths are reserved for cattle grazing, and for small scale cultivation of vegetables and coconuts which acts as a prop to the main fishing economy of the villages.

Primary forest on the peat swamps has not been cleared except at the shallower margins near the large bazaars and villages for the permanent cultivation of padi, and in more remote parts for shifting cultivation. There are no organized attempts at the drainage of shallow peat to extend cultivable land and the primary peat swamp forest is only exploited systematically for timber in the lower Btg. Suai.

The use of alluvial land is confined to the populated parts, mainly for padi production and in places for rubber, coconut and vegetables. Milled padi is exported from the Sibuti district most years. During the last war the Japanese reclaimed much alluvial land and swamp margins in the Sibuti District for swamp padi but large parts of this reclaimed land have now reverted to high secondary forest. In the 'ulu' of main and minor rivers large aggregate areas of alluvial land remain under primary Riparian forest containing large stands of 'belian'. This land could be used for intensive cultivation if it were more accessible. Much good swamp padi land is neglected, mainly due to the lack of need for extra produce and the lack of labour with which to farm more land.

The mangrove and nipah swamps are untouched except on the fringes at Sg. Kalulit (Sibuti). Here drainage of the land continues while coconut and catch crop planting proceeds.

The hill land nearest the large rivers and centres of population retain little primary forest except where steep slopes occur. In the watershed areas however large tracts of primary forest remain, unused as yet due to the distance from navigable streams. The Dipterocarp forest quality is said to be unusually good except where the more sandy Lambir, Belait, and to a lesser extent the Nyalau Formation occur. The reason for the higher forest quality probably reflects the presence of calcareous strata. The sandier formations support poor Lowland Dipterocarp to Kerangas forest while the terraces bear Kerangas forest only. Timber firms are at present working at Sg. Bakas (Sibuti) and the ulu Sg. Trus near Bt. Sepupok.

The population density over the area as a whole is low and the few main centres lie close to the rivers, the only easy means of communication and trading. Bazaars exist at Bekenu, Niah and Batu Niah. Chinese farmers at present develop land successfully for pepper, rubber and to a lesser extent tobacco in the Batu Niah - Niah and in the Bekenu-Sibuti areas. Malay (formerly Penan and Kedayan) kampongs concentrate around Bekenu, Sibuti, Kalulit, the main river mouths, downstream from Batu Niah, and downstream from Sg. Keliring on the Suai river: their occupations include smallholding, with rice, rubber and in places pepper as the main cash crop supplemented by cattle herding and fishing. Iban communities, mainly from Second and Third Divisions moved into this area between seven and twenty years ago. They now occupy upper parts of the navigable rivers except for one or two longhouses in the lower Suai and Nyalau rivers. Their livelihood depends primarily on shifting cultivation with the sale of padi, rubber, pepper, coffee and 'engkabang' for cash.

3. SOILS

3.1 1. CLASSIFICATION AND MAPPING. Reference is made in this section to the 'Field Classification of Sarawak Soils[1] in which soil associations are classified, defined and describ[ed]. Table 1 below lists the main soil associations of the present area gives their approximate acreage and divides them into three genetic groups. Many associations have been found to occur which for practical reasons cannot be mapped singly; thus the mapping units in several cases represent groups of soil associations, related by geomorphic distribution.

Some associations are considerably easier to map than others due to their occurrence on easily recognised geomorphic features or their presence beneath specific vegetation types, such as the associations occurring beneath mangrove and nipah and on the terraces. The residual soil associations are difficult to subdivide where thin, steeply dipping sandstone and shale strata occur in roughly equal proportions: they are particularly difficult to delimit where hills less than 20 feet high hide beneath primary and old secondary forest, and many small alluvial areas have unavoidably been omitted for this reason.

Table 1 (see next page)

3.2 2. SOIL ASSOCIATION DESCRIPTIONS. The main associations, their distribution, properties and agricultural uses are described in this section in the order given in the preceding table 1. Associations are grouped together below for descriptive convenience; numbers refer to the code numbers of associations as used in 'The Field Classification of Sarawak Soils'. In general the descriptions refer to the dominant type of soil found in the association, the variants occupy comparatively small areas.

3.2.A A. ORGANOGENIC SOILS

3.2.A.1 1. Anderson Association (31) —(31)

This association occurs as large deep swamps situated behind the coast from Sibuti to Sg. Nyalau, and in the Bakong river system. Smaller but equally deep valley swamps are common adjacent to the larger rivers considerable distance upstream. The association is generally sufficiently uniform over large areas to be subdivided into depth phases; Anderson 311 (3-6 feet), 312 (6-10 feet) and 313 (more than 10 feet)

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1 Andriesse, J.P. (1962). Field Classification of Sarawak Soils (1st Approximation), Technical Paper no. 1 1962.

Table 1

In order of description in para 3.2

ORIGIN		ASSOCIATION Code Number	ASSOCIATION Name	APPROXIMATE ACREAGE (nearest 100a)
ORGANOGENIC		311	Anderson 1	34,000
		312	Anderson 2	19,000
		313	Anderson 3	33,200
ALLUVIAL	MARINE	11	Tatau	1,300
		111	Igan	18,500
		12	Oya	2,300
		112	Mukah)	13,700
		113	Pendam)	
		121	Edin	4,900
		122	Kabong	1,500
		14	Miri	1,900
	RIVER-INE	211	Semilajau	5,300
		212	Malang)	53,800
		342	Samarahan)	
		34	Pantu)	
		222	Nyabor)	
	ESTUARINE	33	Rajang	5,000
RESIDUAL		44	Penrissen)	9,500*
		411	Matang)	166,700
		442	Bako)	1,300*
		444	Nyalau —)	
		457	Bekenu	167,700
		455	Merit —	154,800
		46	Bau	2,600
		461	Subis	2,000
		352	Paya Megok (alluvial)	1,500
MIXED		51 & 52		12,200
		22/31) 222/31/34)		2,700
		22/34/31/112/113		26,900
		342/455		11,300
		342/457		2,500

Corrected total is 640,800 acres. Approx. total 757,100 acres

*In addition to the combined total.

Maximum depths recorded exceeded 25 feet in several areas, even in the 'ulu' Sg. Sibuti. Since the Sg. Bakong swamp has only been examined cursorily, accurate peat depths are not known and all flat areas are mapped as mixed alluvium-peat without any reference to depths; similarly in other swamps of unknown depth.

The peat is raw, acid and little decomposed except near rivers where cultivation and a fluctuating water table allow periodic aerobic conditions. It usually consists of a dark brown to black woody accumulation of plant debris in a watery matrix and has low available nutrient levels. The base of the peat commonly contains high magnesium levels and where examined resembles estuarine muck in smell and organic content. Near rivers subject to flooding and near foothills peat swamps commonly contain lenses and skins of alluvial material. Where an alluvial topsoil exceeds a depth of twelve inches it is regarded as a subtype of the Bijat Association for example rather than of a peat.

The peat is cultivated only on the shallow margins (see soils described under B.1 and B.2 below). To have suitable drainage for most crops the water table should be lowered by draining, the acidity reduced by liming and the fertility increased by manuring. Only two known commercial crops grow satisfactorily on undrained and unmanured peat, jelutong and sago. The latter would provide cheap pig and poultry food if grown more widely.

In Appendix A. peat analyses are given under no. 1.

B. ALLUVIAL SOILS

1. Tatau (11), Igan (111) and Oya (12) Associations

These associations all have a marine origin and sandy textures. They constitute a belt of varying width along the present coastline, and in a few places near the inland margin of the peat swamps.

The Oya Association occurs as a narrow band on the coastal edge and in small areas near Sg. Niah, Sg. Trus and Btg. Suai. The soil mainly consists of very pale brown to pale yellow sands and loamy sands with the permanent water table lower than 24 inches, and is found where the higher, more dominant sand bars occur. The structure is characteristically weak and the consistence friable. These features combined with the excessive drainage give rise to podsolic profiles, and in small areas humus podsols. The B_2 horizon usually lies near to the water table and represents the downward limit of leaching and the beginning of hydromorphic conditions.

The nutrient status of the soil above the water table is invariably low except in the humic topsoil, where present, and where shell banks or coral occur in the profile: shellbanks have been noted at K. Nyalau and coral rock at Tg. Payong. A serious defect of these soils is the low cation exchange capacity and excessive drainage which implies that any fertilizers added are rapidly lost by leaching.

Cultivation of the Oya Association is not recommended unless the topsoil organic matter can be increased in order to retain nutrient supplies; mulching with moist peat may improve the exchange capacity but the acidity of the peat would then need to be reduced and the fertility level raised by manuring. Rough grazing land for goats and cattle is maintained along parts of the coast with moderate success.

The Tatau and Igan Associations cover more extensive areas, particularly behind the coast between the Niah and Nyalau rivers. The Tatau Association soils have in places a thin peat or muck topsoil with the permanent water table within 24 inches from the surface. Beneath is a light gray to dark brown sand, or sandy loam. The Igan Association only differs from this in that as much as three feet of peat or muck form the topsoil and the permanent water table is at or near the surface. The soils are leached above the water table but where the topsoil is peaty there are usually more nutrients than in the underlying sand which consists mainly of quartz and the peat can be cultivated successfully. Crops seen growing on drained and burned peat in Second Division and hence which should grow in the present area include shallow rooted annuals such as maize and vegetables and bush fruit, bananas, papaya and coconut. Drainage is necessary to lower the water table and provide root aeration and the burning releases a certain proportion of nutrients held by the organic matter. Further desirable measures are likely to include liming, and manuring with major and certain minor elements such as copper[1].

In Appendix A are analyses of typical profiles under no's. 2,3 and 4.

2 2. Mukah (112), Pendam (113)[2], Edin (121) and Kabong (122) Associations.

The Mukah and Pendam Associations are former marine alluvium occurring in coastal areas between peat swamps and surrounding hills and in the lower river basins. One sample analysed at Sg. Malang indicates their presence at the edge of the Bakong swamp. This may signify a general distribution around the whole swamp margin or that these associations occur in a few places only, the remaining alluvium being riverine. In view of the uncertainty in this particular area alluvial soils are mapped as both undifferentiated riverine and former estuarine clays. Both Associations are essentially derived from estuarine or marine clays deposited and developed under hydromorphic conditions. The Pendam Association consists of light grey to bluish grey silty clays or clays with redox mottles

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1. No actual manurial measures can be recommended for any soils since insufficient experimental crop yield/soil data is available.

2. A new, provisionally classified Association.

beneath the topsoil. The water table is generally within two feet of the surface. The Mukah Association is similar except that the clay soils do not contain mottles and as much as three feet of peat forms the topsoil. Muck horizons or lenses occur within the profile in places.

Chemically the soil is less acid than riverine alluvium and contains considerably higher levels of magnesium and calcium: high sodium levels have not been recorded and the presence of 'catclay' although occurring in the subsoil in places is not serious. Where peaty topsoils occur drainage is desirable to reduce the depth in order that contact with the underlying richer clay can be made by crop roots.

These associations are considered to be among the richest alluvial soils in Sarawak and ideal for 'sawah' padi with cash crops in the off season.

The Kabong and Edin Associations are found only in coastal parts with pronounced sand bar-lagoon topography. The Kabong Association consists of sand bars with characteristics of the Oya or Tatau Associations, and lagoons still subject to tidal flooding and hence containing saline alluvium. In the Edin Association non saline hydromorphic material fills the lagoons, in places with a peaty topsoil; the sand bars have generally given rise to Tatau Association soils.

In Appendix A are typical analyses of the Pendam and Mukah Associations under Nos. 5 and 6.

2.B.3 3. Miri Association (14)

The terraces lying principally north of Tg. Batu and between the Nyalau and Suai rivers are the land forms connected most closely with this association, which also forms a major component of the (51) and (52) Associations described under 32D below. Minor occurrences also occur in the Oya Association generally too small to map separately. The soils comprise humus podsols with a firm, well formed humus pan at depths varying between a few inches (eroded phase usually) and nine or ten feet. Textures are sands to loamy sands throughout and because of the weak structure and the loose consistence drainage is excessive above the humus pan. Leaching has removed practically all bases from the A_2 horizon and consequently the soil is unusually poor except where a humic topsoil is present.

The soil under natural conditions can only support kerangas vegetation and therefore its uses for agriculture at the present time are extremely limited.

In places can be found small areas of the Tanah Puteh Association (15) comprising acid light grey clays, poor in nutrients and derived from old marine clays.

Appendix A includes typical analyses of the Miri Association under no. 7.

4 **4. Semilajau (211) and Malang (212) Associations** (2)

The land forms associated with these soils are the well-drained river levees of main streams. Such levees can be found from the lower river reaches extending upstream to points where their widths are too small to map separately. Normally the sandier levees occur upstream among hilly land where steep gradients increase the load-carrying capacity of streams in flood. This is the general rule in the present area except that the types of rock in the vicinities of the river strongly influence levee types.

The Malang Association consists primarily of a moderately well drained brownish yellow clay loam to clay with a deep permanent water table. Black mottling is characteristic in the subsoil, also gleying which is indicative of poorer drainage conditions. The soil occupies the lower river reaches as wide levees and as higher, more substantial levees in the upper Sibuti river which drains large areas of the shaley Sibuti Formation. In addition the association is widespread in the alluvial areas of the low dissected land (~~lower erosion surfaces, see section 2.2)~~ drained for example by Sg. Setap, Sg. Genatan, Sg. Sekaloh, Sg. Kamya, Sg. Mulis and Sg. Sawai. These streams usually flood during the 'landas' season for short periods.

The nutrient content depends largely on whether the alluvium is derived from calcareous shales or not. In general the calcareous rock gives higher pH, calcium and in some instances higher magnesium levels. The exchange capacity in any case is not high but sufficiently high to retain added nutrients.

The agricultural value of the soil rates well for most annuals and bush and tree crops liking moderately well drained soils. The main detriment to cultivation is the prospect of flooding during the 'landas'.

Sandy levees are found in the upper streams, particularly where sandstone strata outcrops as in the 'ulu' Niah and Suai rivers. The Semilajau Association formed on such levees is characteristically well-drained and has a poorly developed profile. The weak structure and friable consistence give little resistance to 'landas' season flooding when large sections of levee commonly slump into the river to be washed away and redeposited downstream. Where the Semilajau Association gives way to the Malang Association downstream there are transitional areas of the Undup Association in which textures are variable. To avoid confusing the map Undup soils are split up according to their predominant texture.

The nutritionally poor Semilajau soils have little to recommend them but their favourable physical growing conditions. The low exchange capacity infers weak retention of fertilizers. The agricultural value increases however in view of the fact that the levees provide natural sites for kampongs and fruit gardens which receive considerable adventitious manuring.

Typical soil analyses are given in Appendix A, under no.'s 8 and 9.

5. Samarahan (342), Bijat (221), Nyabor (222) and Pantu(34) Associations

These associations have a riverine origin and are poorly drained. Owing to the difficulty in delimiting former estuarine from riverine soils in the field, as mentioned in subsection B4 above, somewhat arbitrary limits have been drawn on the map which probably favour in area the Pendam and Mukah Associations. The line can be checked where soil samples from the area have been analysed but in most cases this cannot be done and the line is drawn where valleys begin to debouch into large alluvial basins and swamps, where the present streams carry little flood material that could obscure old estuarine material.

It is also difficult at the map scale used to differentiate between the Associations occupying small valleys, such as the Pantu and Samarahan Associations, and the Bijat and Nyabor Associations occurring in large alluvial basins. To avoid confusion the upstream valleys, both large and small are mapped as Pantu or Samarahan Associations although it should be assumed that other soils, similar in character, do occur. Some small riverine areas are mapped as undifferentiated (Pantu) alluvium where complicated patterns exist or where the area has not been examined. In many of the hill areas are numerous small valleys that cannot be mapped at the present scale, thus the acreage of these combined soils could be enlarged at the expense of hill soil acreages.

The Bijat and Nyabor Associations extend over the larger alluvial areas. The soils comprise light grey to bluish grey hydromorphic clays, in places with peat or muck interlayers. The Nyabor Association only differs from the Bijat in that as much as three feet of peat or muck forms the topsoil. The mineral soil is acid and low in nutrients except where calcareous strata outcrop nearby. Since Samarahan Association soils are confined to the smaller valleys they probably consist of younger, less weathered material. In some minor valleys drainage becomes restricted where mainstream levees block the valley mouth. This results in the development of peat containing skins and lenses of alluvium from flooding. If the surface alluvium depth does not exceed twelve inches it is regarded as a sub type of the Anderson Association.

The riverine soils are important for agriculture despite their low fertility because of the possibility of a mixed wet padi - catch crop cultivation by suitable drainage and irrigation and because of their suitability for fish pond construction.

Analyses of typical profiles are given in Appendix A under no.'s 10 and 11.

.2.B.6 6. Rajang Association (33)

The Soils of this association are confined to estuaries, lagoons and lower parts of river where tidal incursions are felt regularly. The total acreage is not large.

The soil presents a broken surface due to the occurrence of numerous crab mounds as much as 4 feet high and 4 feet diameter at the base. The mounds consist of grey to dark grey clay or silty clay with redox mottling, and on some dried surfaces a yellow or white salt encrustation indicating potential 'catclay'. Leaching removes soluble bases from the older mounds and the soils become slightly acid. The undisturbed soil, which is not common, is alkaline and salt saturated.

That these soils can eventually be used for agriculture is shown in various parts of Sarawak where former estuarine land has been reclaimed for wet padi, coconuts, sago, vegetables etc; that is, the Rajang Association in time and under natural soil-forming processes will eventually form the Pendam and Mukah Associations. A mistake that can be made locally where resources are limited is to try and reclaim the land piecemeal and too soon, resulting in untimely salt water flooding beneath bunds via the myriad crab holes, and stunted crop growth because the soil is still too rich in certain salts and bases. The reclaiming of the inland margins of this association without excessive cost and labour can only be effected where drainage and rainwater leaching are possible and where salt-water and crab tunnelling can be controlled.

Soil analyses are given in Appendix A, under no. 12.

C. RESIDUAL SOILS

1 1. <u>Penrissen (44), Matang (441), Bako (442) and Nyalau (444) Associations</u>.

The main feature common to all these associations is their predominantly sandy parent material. As a general rule the coarser and purer the sand (quartz), the thicker the strata, the harder the cement and the gentler the dip the more the soils tend to become podsolized resembling the Bako Association. With increasing textural fineness, with softer and thinner strata and with increasing dip the more the soils resemble the red-yellow podsolics of the Nyalau Association. The Penrissen Association itself is a mixture of Matang and Bako Associations on cuesta topography where the Bako podsols occur on the dip slopes and the Matang yellow podsolics occur on the steeper scarp slopes. Because of the low mineral reserves of the parent material, all the soils are poor below the A_1 horizon.

Field textures of fine sand or very fine sand have been checked in the Soils Laboratory and in fact there are high percentages of silt and very fine sand in all the residual soils. In places this material is chemically similar to clay with a high exchange capacity, in other places it appears to be more like finely ground quartz.

The Bako Association is most extensive in the high Lambir hills where the massive sandstone beds form long dip slopes. The association also occurs in large areas of the watershed between the Sibuti and Bakong rivers where

/sandstone

sandstone beds dip gently and in the Bt. Igang, Bt. Iban and Sg. Nyalau area. Further small, more restricted localities occur on the lower, dissected hills in association with the Matang and Nyalau soils. Typical features include a depth of less than 24 inches usually, its stoniness and podsolic features. The A_0 horizon under primary forest is thick and consists of raw humus; the A_2 is pale yellow to white and can be as much as twelve inches deep, the B_2 shows accumulation of clay and humus.

The low nutrient levels infer that the soil is poor, and this can be verified by the fact that under natural conditions only 'kerangas' vegetation is supported. The agricultural value therefore rates low and cannot be increased unless considerable expense is undertaken in manuring. Despite gentle slopes the sandy texture and poor structure make the soil prone to sheet erosion once the binding roots and topsoil are removed by clearing and burning.

The Matang Association soils are not widespread. They occur mainly among the lower dissected 'sandstone' hills and on scarp slopes of higher cuestas; the soil material is part residual, part colluvial. Podsolization has occurred but to a lesser extent than in the Bako Association, resulting in mainly yellow podsolics. The soil consists mainly of pale yellow sandy loams on pale yellow sandy clay loams, in places with distinct reddish brown mottles. In some profiles a thin light grey A_2 layer can be seen beneath the topsoil. Structure is weak and the consistence friable except in the subsoil which in places tends to be poorly drained. Leaching has removed most nutrients leaving a poor soil. The steep slopes associated with the soil hinder cultivation and some form of terracing is essential for perennial crops. Shifting cultivation on both Bako and Matang soils should not be practised. (3)

The most common association developing from the finer sandstones with shale interlayers is the Nyalau Association, and these conditions occur mainly where the Nyalau Formation outcrops. The soils are red-yellow podsolics comprising yellow to pale yellow sandy loams on brownish yellow to reddish-yellow sandy clay loam or sandy clay; the sand grade is predominantly fine to medium. Soil drainage is free in the top horizons to imperfect in the subsoil and the structure and consistence become stronger and firmer with depth.

As with the other soils derived mainly from sandstone the high levels of quartz sand in the soil cause the exchange capacity, base level and base saturation to be low and the acidity to be a little higher than average. The low fertility level is only ameliorated where calcareous strata occur and the pH and calcium levels consequently rise above normal.

The agricultural value of this soil therefore is both degraded by the low fertility and enhanced by the good physical properties. Slopes are generally between 15° and 45° and since the topsoil has sandy textures and a weak structure it prone to erosion where the binding topsoil has been removed by burning or cultivation. A continually high rate of manuring would be necessary to maintain high yielding crops.

The three soil associations discussed above have in common a predominantly sandy parent material and sandy textures, moderately free drainage, and poor nutritional qualities. Management problems are therefore basically similar.

Soil Analyses of the Nyalau Association are given in Appendix A under no. 13.

2.C.2 2. Bekenu (457) and Merit (455) Associations. (4)

Where sandstone and shale beds occur in roughly equal proportions the resultant soil types depend to a large extent on the dip and thickness of the strata. Gently dipping thick beds give rise to cuesta topography in which sandstone beds underlie the dip slope while shale outcrops on the scarp slope. In other words there are broadly two soil types derived from sandstone and shale, distinct and mappable at large scales. Where however the beds are thinner and dips steeper the situation becomes complicated and the soil types less distinct. The main effect is that a hybrid soil results in addition to the more sandier and clayey extremes and these three soils in the present area occurring in a complex pattern comprise the main members of the Bekenu Association. The sandy soils have been described above, of which the Nyalau is the most common association.

The hybrid soil generally comprises a yellowish brown sandy loam to sandy clay loam A_2 horizon lying above a brownish yellow to reddish yellow sandy clay, and usually at three to four feet depth a reddish yellow clay. Sand textures are very fine and silt-sized material commonly exceeds the amount of sand and clay present. Black mottling is common in the subsoil in addition to reddish brown and light grey mottles. The depth of the sandy topsoil varies but tends to be thickest on gentle slopes which means that it is impossible to say with any degree of certainty that soil A with a sandy topsoil belongs to the Bekenu Association while soil B does not because the sandy topsoil is missing. The latter could be an eroded phase of the Bekenu Association or simply a normal Merit Association soil ~~(described later in this section)~~. Similarly, if the depth of the topsoil exceeds three feet it could be mistaken for the Nyalau Association.

The profile is moderately well drained in the rooting zone and less so in the more clayey subsoil which possesses a better structure and consistence than the topsoil. The nutrient status varies from poor, to above normal where calcareous strata occur consequently raising the pH and calcium levels. The exchange capacity and base saturation are normally both low, except in the humic topsoil.

For agricultural purposes the value of this soil is average since despite the favourable physical conditions the nutrient status is generally low. It was noticed during field work at Niah in the ulu Sg. Trus that timber extraction by tracked vehicles churns up the ground exposing

/the

the topsoil and underlying A_2 horizons. This allows unhindered sheet erosion and gullying. During cultivation and while constructing terraces on the steeper ground it is therefore advisable to disturb the ground as little as possible, especially in view of the fact that almost all the food value of the soil is retained in the organic matter of the topsoil.

The Merit Association extends over large areas in the Sg. Sibuti basin and is an important member of the Bekenu Association. Minor occurrences of other related residual associations and many small alluvial areas are also mapped with this association. The Merit soil basically consists of a yellow clay loam on a brownish to reddish yellow clay; silt-sized material is common. In the lower erosion surface areas, ~~(section 2.2)~~, the shallow soils that commonly exist have truncated profiles with mainly the yellow colour and stony textures. Variations in drainage and different levels of iron in the parent material cause reddish brown and light grey mottling in the subsoil and surface water gleying. Layers of iron coated and impregnated sandstone and shale are common in the profile in some areas while quartzose shales give rise to the Bayur Association especially south of Niah. Black mottling in the subsoil is probably associated with ferro-manganese concentrations.

The main physical properties are the heavy textures, medium to poor drainage, massive structure in field condition and the firm to very firm consistence. The variable nutrient status reflects the presence of calcareous as opposed to non calcareous shales. The latter are common and give a higher pH and calcium levels even in the most depleted A_2 horizon, while non calcareous shales remain poor in nutrients like the non calcareous sandstones. The A_2 horizon compared to other residual soils is thin and often absent.

Since the shale-derived associations generally develop on less steep hills than the Nyalau and Penrissen Associations their agricultural value in this respect is slightly enhanced. However, the need to provide a large recurrent outlay on fertilizers to maintain high yields is similar except that fertilizer loss will be less rapid than on the sandstone soil due to the higher exchange capacity. The heavier textures also infer decreased erosion hazards.

In Appendix A analyses of selected profiles are given under Nos. 14 and 15.

C.3 3. <u>Bau(46), Subis[1] (461) and Paya Megok (352) Associations</u>

These associations are influenced directly by limestone and their distribution is consequently limited to the Subis area on the Niah river and two small localities between the Niah and Suai rivers.

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1. A new Association not found in the 'Field Classification of Sarawak Soils'.

The Bau Association consists of brownish yellow tenacious clays of variable depths found mainly on the steep scree slopes of the limestone hills. The soil is unlikely to be residual from the pure limestone but may be derived from the nearby shale formations that once overlay the limestone. Limestone boulders protrude from the surface and form an uneven basal material. Although the structure is massive and the consistence very firm there are no gley spots denoting poor drainage and black, possibly ferro-manganese mottles become common in the subsoil. The high calcium and pH levels reflect the proximity of limestone and cause the base saturation to be high. The main impediment of the soil for agriculture is not so much the soil fertility as the steep slopes, stoniness and inaccessibility.

The Subis Association soils are organogenic and thus could be described in section 3.2.A above. However their occurrence is so limited and so tightly bound to the presence of limestone that they can more conveniently be described here. Two distinct types occur, acid and alkaline. Both types lie among the limestone boulders above the scree slopes and on hill tops and consist of a few inches of litter lying on as much as nine inches of humus, which is bound, interlaced and supported by a network of ramifying roots. Beneath the soil is usually a void of as much as ten to fifteen feet before limestone rock is encountered. This strange situation arises when networks of tree roots spanning large gaps between limestone boulder and pinnacles trap falling litter and produce hair roots to feed on and further bind the material. Eventually a complete humus mat forms between the boulders which traps all falling litter. The original basal material slowly humifies and is used and removed until the soil is left dangling in mid air supported by roots. The alkaline type has a pH of between 6 and 8 due mainly to high calcium levels and is confined to hill tops and the upper hill slopes above screes. The acid type is restricted to certain hill tops where leaching irretrievably removes dissolved bases beyond the reach of tree roots: the soil therefore slowly becomes more and more depleted until only 'kerangas' vegetation can be supported. Both soil types are completely unsuitable for agricultural purposes. The occurrence of guano in the Subis caves plays an important part in the economy of this area.

The Paya Megok Association comprises alluvial land underlain by limestone. The alluvium is clayey and resembles the Malang or Samarahan Associations except that the pH and calcium levels are high in patches. The land around G. Subis was used for swamp padi during the occupation by the Japanese to good effect, but the hazard of high twelve foot floods in the 'landas' diminishes the attractiveness of using this land.

2.D D. MIXED ASSOCIATIONS OF COMPLEX ORIGIN

1. (51) and (52) Associations

The associations are related to each other by mode of origin. Association 51 comprises old coastal landscapes, /now

now dissected, while 52 consists of former riverine areas now dissected. It is difficult to distinguish between the two except where obvious signs of old marine terraces exist, or where the soils include gravel, which generally indicates a riverine origin. Both types contain terraces and terrace soils which are principally humus podzols of the Miri Association. Small clayey areas of the Tanah Puteh Association, or mixed material of the Ridgeway Association also occur. The terraces were formerly more extensive but due to dissection have been replaced by alluvial valleys containing the alluvial soil association and swamps, many of them deep (see relevant subsections above). The land exposed by removal of terrace material is in places rocky, where rock platforms were carved by the sea or rivers. Elsewhere normal residual soils have developed from both sandstone and shale. In small areas white or light grey clays and sandy clays faintly mottled with reddish yellow have been noted which possibly indicates former gleying by marine or riverine waters.

The number of soils associations present are many. In some areas the dominant types are unsuitable for agriculture as at Sg. Nyalau, while in other places usable hill soils are predominant, for example north of Tg. Batu.

4. DISCUSSION AND CONCLUSIONS[1]

4.1 1. Soils.

In this area can be found representatives of most of the organic, alluvial and residual soils of Sarawak apart from those derived from igneous rock. Their distribution relative to each other and their properties and uses are broadly the same as in other parts of Sarawak except for the significant features listed below.

4.1.1 1. The scattered occurrences of calcareous strata especially north of the Niah river is reflected in a richer than normal vegetation, which can therefore be reasonably expected to give better crop growth, at least where calcium nutriton is concerned.

4.1.2 2. The unusually large areas of Mukah and Pendam Associations in the Sg. Sibuti basin. Only small areas were located with a deep peat cover. Properly exploited, these soils which are rich by Sarawak standards could support intensive agriculture.

4.1.3 3. The comparatively large areas of Tatau and Igan Associations between the Niah and Suai rivers. Although the sand is poor and the overlying peat has undesirable features such as the low pH level and poor nutritional content, these soils can be used for agriculture if suitable drainage and manurial programmes are effected.

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1. Relevant to this section in the para. 'Conclusions' in Soil Survey Report No. 43.

4.1.4 4. The residual soils in large areas are developed on low hills between which are moderately well-drained alluvial spreads with a minimum of peat. These hills although less than 50 feet and often 30 feet in height have slopes ranging from 5^{o} to 35^{o}, rarely more. The soils are in general not susceptible to erosion.

4.1.5 5. The presence of guano at Subis which is an important consideration for pepper growers of the area in particular.

4.2 2. Agriculture

The area covered by this report totals approximately 1,000 square miles. Of this amount 540 square miles (54%) are considered suitable for agriculture, 200 square miles (20%) marginal and the remaining 260 square miles (26%) unsuitable. The criteria used for this division are based on the general standards and capabilities of the whole agricultural community of the country. These qualities of course vary in different areas, communities and circumstances. Whether local conditions justify or do not justify an overruling of these divisions is at the discretion of the local officers.

The land classed as unsuitable for agriculture comprises peat more than six feet deep (Anderson Associations 2 and 3), saline alluvium (Rajang Association), podsols of the terraces (Miri Association) and the hills (Bako Association), limestone hills (Bau and Subis Associations) and steeply sloping land more than 35^{o}.

Marginal areas comprise shallow peat (Anderson Association 1.) poor beachsands (Oya Association) and poor hill soils on steep slopes between 20^{o} and 35^{o} (parts of the Penrissen, Nyalau and Bekenu Associations).

All remaining land is broadly suitable for agricultural purposes, subject to three main qualifying factors:

a) Flooding may be an impediment to cultivation in alluvial areas during the 'landas'; this must be assessed locally.

b) The hill land has been classed as suitable, unsuitable and marginal regardless of soil type on the accompanying maps by shading. These areas are only rough indications and inevitably include or omit small areas of the other classes. In the unshaded 'suitable' hill land the amplitude of relief is low and slopes are impossible to determine under primary and old secondary forests by air photograph interpretation. Field work revealed that slopes as much as 30^{o} to 35^{o} occurred, but due to the low heights these are mainly usable for agriculture.

c) The soils on the whole are not rich and most crops will require regular fertilizing.

Crops growing well in the area at present include swamp padi in the lower Sibuti basin, pepper at Bekenu, Nia

/and

and Batu Niah, rubber on residual and alluvial soils, coffee (Kope Jawa) mainly on the levees and alluvium soils of Sg. Sibuti and tobacco at Batu Niah. Vegetables are grown in small quantities around the main bazaars but this is essentially gardening not farming. The Coconut Planting Scheme encourage the cultivation of coconuts which should thrive on the Malang Association soils in particular without drainage, as would citrus and other bush fruit. Oil palm may prove successful in the areas where moderately drained alluvium and low hills occur. The main impediments for this crop are the slope of the hills, which ideally should not exceed 15° for extraction purposes, and possibly flooding of the alluvium in the wet season. As with all crops high yields can only be maintained with optimum soil conditions and it may prove economically unsound to add regularly the quantities of potash and phosphate fertilizer in particular that would probably be required for oil palm. A definite means of finding out would be to establish a series of small trial plots[1]. Rubber could be grown over most of the area if necessary, but since it is tolerant of poor growing conditions it is advisable to restrict new planting to the least valuable soils where competition with other commercial, more demanding, crops occurs.

4.3 3. <u>Communications</u>

Commerce and trade at present can only use river and sea transport. All three main river mouths have sand bars but are navigable by large Chinese launches to the main bazaars and short distances beyond. The occurrence or not of rains which provide river water and the amount of belian logs in the beds set the limit to outboard travel in the headwaters. The boundary of present cultivation can be taken as the limits of travel by small outboard plus two hours walk. Chinese launch owners hold a virtual trade monopoly and people in the Suai river in particular are subject to high buying prices.

To develop the between-river areas therefore roads are a prime requisite, not necessarily good roads but substantial mileages of all weather jeep tracks. With the planned trunk road from Miri to Sibu passing directly through the most important land and linking the upper rivers, and the building of feeder roads from the trunk road to connect main bazaars all that will be needed in addition are a number of spurs and loops to tap the more worthwhile 'ulu' areas. Several lines are included on map 1, page that could be used to good effect as the need for expansion arises. The main practical road-building difficulties to be encountered will include sm swamps and alluvial land liable to flooding. Roadstone is present in abundance at G. Subis.

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1. Alternative sites for an Agricultural Station a indicated on map 1, page .

4. Land Use

Only accessible riverine and coastal areas are used at the present time. The low total population means that there is more than sufficient land for all, in fact the population is insufficient in the Sibuti-Bekenu area to farm all the land that produced good padi yields during the Japanese occupation. Large 'ulu' areas are still under primary forest.

.5 5. Development

The factors outlined above combine to make it worthwhile studying the possibilities of development in detail. A significant point is that the attraction of this area stems not so much from the presence of good farming land, which in fact does occur in parts, but mainly from the absence of bad farming land. Thus the present area does not compare well with the Labuk valley in North Borneo where rich soils occur, but it does compare favourably with for example the Tanggi block in 3rd Division.

The areas most favourable for agricultural development are outlined on map 1 together with suggested alignment of roads to serve them. Trials of certain crops could be carried out most conveniently in either Sg. Sekaloh near Subis, or in the ulu Sg. Setap as indicated on the map since in both places the land is typical of larger areas to the south. It should be stressed that the soils are fertile only in scattered localities and that optimum crop yields cannot be maintained without optimal manuring. This, depending on crop requirements, may be expensive and the question of the relative merits of smallholdings as opposed to estates may be pertiment in the opening up of new land.

SOIL ANALYSES OF SELECTED PROFILES

Lab. No.	Depth (in.)	pH (H_2O)	P (av.) p.p.m.	P (tot) p.p.m.	C Org. %	N tot %	Exch. Cap. Me %	Tot. Bases	% Base Sat'n	Exchangeable + Soluble Me % Ca	Mg	K	Na	Mn. (av.) p.p.m.	SO_4 %
1. ANDERSON (313); S1058/61															
From the ulu Sg. Sibuti under primary peat swamp forest.															
S1058	0-10	3.6	50	388	47.81	0.44	95.8	1.90	2	0.13	.89	.66	.22	trace	N.D.
S1059	10-24	3.4	25	285	N.D.	N.D.	119.0	1.72	14	0	1.05	.67	0	"	N.D.
S1060	24-36	4.5	25	465	N.D.	N.D.	135.0	1.10	1	0.20	.56	.31	.03	14	N.D.
S1061	36-45	3.8	7	124	N.D.	N.D.	101.7	2.99	3	0.37	1.61	.95	.06	trace	N.D.
2. OYA (12); 4279/84															
From K. Niah near the most recent storm beach.															
4279	0- 5	5.9	8	N.D.	0.79	0.03	0.03	4.86	100	3.75	0.86	0.05	0.20	N.D.	N.D.
4280	5- 8	5.5	1	N.D.	0.17	trace	1.0	0.76	76	0.54	0.14	trace	0.08	N.D.	N.D.
4281	8-42A	5.9	trace	N.D.	0.4	trace	1.0	0.64	64	0.45	0.14	trace	0.05	N.D.	N.D.
4282	8-42B	6.0	trace	N.D.	0.10	trace	0.7	0.70	100	0.41	0.23	trace	0.06	N.D.	N.D.
4283	42-49½	5.5	2.0	N.D.	0.10	trace	0.6	0.54	90	0.45	nil	0.02	0.07	N.D.	N.D.
4284	49½-55+	3.5	5	N.D.	0.63	trace	3.0	1.51	50	0.72	0.68	0.04	0.07	N.D.	N.D.

3. TATAU (11); 4319/21

From near K. Nyalau on old sand bar covered by a thin layer of peat.

4319	0-3	3.3	2	N.D.	8.29	0.40	18.5	2.33	13	0.43	1.10	0.53	0.27	N.D.	N.D.
4320	3-15	3.6	2	N.D.	0.81	0.07	4.5	0.82	18	0.46	nil	0.09	0.27	N.D.	N.D.
4321	15-30+	4.4	3	N.D.	0.30	trace	2.3	0.53	23	0.41	nil	0.04	0.08	N.D.	N.D.

4. IGAN (111); 4315/16

From K. Suai: shallow peat on an old sand bar.

4315	0-15	3.3	trace	N.D.	17.50	0.72	60.3	3.58	6	0.75	2.03	0.43	0.37	N.D.	N.D.
4316	15-30+	4.4	trace	N.D.	.71	0.03	4.5	0.52	12	0.42	nil	0.03	0.07	N.D.	N.D.

5. PENDAM (113); 4354/57

From the basin alluvium behind levee soils of Sg. Setap

4354	0- 1	6	26	N.D.	N.D.	0.99	44.5	10.89	N.D.	6.37	3.23	0.87	0.43	N.D.	N.D.
4355	1-12	4.6	14	N.D.	N.D.	0.33	17.3	6.8	N.D.	3.56	2.56	0.43	0.21	N.D.	N.D.
4356	12-40	4.6	15	N.D.	N.D.	0.25	20.5	5.43	N.D.	2.97	1.98	0.32	0.16	N.D.	N.D.
4357	40+	3.7	8	N.D.	N.D.	0.21	18.0	6.28	N.D.	2.85	2.95	0.29	0.19	N.D.	N.D.

6. MUKAH (112); S1007/10

From alluvial land near Sg. Teris

S1007	0- 2	4.4	99	N.D.	23.04	0.47	46.4	16.58	36	13.20	2.90	trace	.48	60	0
S1008	2-18	4.0	9	N.D.	N.D.	N.D.	19.0	7.40	39	4.66	2.36	.22	.16	trace	0
S1009	18-28	3.8	8	N.D.	N.D.	N.D.	26.7	11.23	42	6.60	4.11	.28	.24	24	0
S1010	28-45	3.7	12	N.D.	N.D.	N.D.	55.2	16.68	30	6.70	9.26	.21	.51	26	.89

7. MIRI (14); 1330/34

From K. Nyalau on a low raised beach consisting of sand.

4330	0- 4	3.8	2	N.D.	0.91	0.02	2.8	0.44	16	0.32	nil	0.04	0.08	N.D.	N.D.
4331	4-13	4.2	trace	N.D.	0.16	trace	0.5	0.52	100	0.41	nil	0.03	0.08	N.D.	N.D.
4332	13-72A	4.7	trace	N.D.	0.14	trace	0.2	0.76	100	0.68	nil	trace	0.08	N.D.	N.D.
4333	13-72B	4.6	trace	N.D.	0.17	0.02	0.2	0.49	100	0.41	nil	trace	0.08	N.D.	N.D.
4334	72-79+	2.9	2	N.D.	2.42	0.03	14.2	1.06	7	0.82	0.14	0.02	0.08	N.D.	N.D.

8. SEMILAJAU (211); S1210/17

From the banks of Btg. Suai near Sg. Keliring

S1210	0- 5	4.6	3	N.D.	1.44	0.09	8.0	0.62	8	0.31	0.22	0.09	0	trace	N.D.
S1211	5-18	4.7	1	N.D.	N.D.	N.D.	0.9	0.18	20	0	0.15	0.03	0	trace	N.D.
S1212	18-21	4.6	trace	N.D.	N.D.	N.D.	4.1	0.06	1	trace	0	0.03	0.03	trace	N.D.
S1213	21-29	4.6	trace	N.D.	N.D.	N.D.	4.0	0.17	4	trace	0.10	0.04	trace	trace	N.D.
S1214	29-39	4.5	trace	N.D.	N.D.	N.D.	3.2	0.35	11	0.21	0.10	0.04	0	trace	N.D.
S1215	39-54	4.7	trace	N.D.	N.D.	N.D.	4.0	0.26	7	0.10	0.10	0.06	0	trace	N.D.
S1216	54-68	4.5	0	N.D.	N.D.	N.D.	7.7	0.20	3	0	0.15	0.05	0	trace	N.D.
S1217	63-83	4.6	0	N.D.	N.D.	N.D.	5.0	0.34	7	0.21	0.10	0.03	0	0	N.D.

9. MALANG (212); S1103/07

From Sg. Setap.

S1103	0-1	5.4	N.D.	35	10.58	0.88	44.3	34.14	77	25.8	7.4	0.76	0.18	N.D.	N.D.
S1104	1-22	5.0	N.D.	12	N.D.	N.D.	10.1	2.83	28	0.78	1.87	0.08	0.10	N.D.	N.D.
S1105	22-37	5.1	N.D.	12	N.D.	N.D.	16.9	2.79	17	0.46	1.99	0.10	0.24	N.D.	N.D.
~~S1106~~	37-53	5.4	N.D.	7	N.D.	N.D.	8.3	1.84	22	0.41	1.27	0.06	0.10	N.D.	N.D.
S1107	53+	5.3	N.D.	7	N.D.	N.D.	11.6	2.45	21	0.59	1.62	0.09	0.15	N.D.	N.D.

13. NYALAU (444); S1146/52

From Sg. Sekaloh, Niah.

S1146	0-2	3.9	16	327	16.53	0.30	70.2	1.12	2	.24	.42	.46	0	17	N.D.
S1147	2-4	4.3	10	219	N.D.	N.D.	18.0	.04	0	trace	trace	.04	0	0	N.D.
S1148	4-5	4.6	5	208	N.D.	N.D.	21.2	.03	0	0	0	.03	0	0	N.D.
S1149	5-20	4.7	2	178	N.D.	N.D.	7.2	trace	0	0	0	trace	0	0	N.D.
S1150	20-35	5.0	trace	188	N.D.	N.D.	5.4	trace	0	trace	0	trace	0	0	N.D.
S1151	35-48	5.3	trace	168	N.D.	N.D.	4.1	.47	11	.31	trace	.07	.09	0	N.D.
S1152	48-60+	5.5	0	189	N.D.	N.D.	5.1	.17	3	.15	trace	.02	0	trace	N.D.

14 a) BEKENU (457): S1158/63

From ulu Sg. Niah; non calcareous parent material.

S1158	0-1	4.3	13	243	2.97	0.31	17.9	1.71	10	1.04	.45	.22	0	34	N.D.
S1159	1-8	4.1	6	170	N.D.	N.D.	6.4	.17	3	.10	0	.07	0	12	N.D.
S1160	8-19	4.6	1	129	N.D.	N.D.	8.2	trace	0	trace	trace	0	0	trace	N.D.
S1161	19-32	4.6	trace	160	N.D.	N.D.	10.4	.16	2	.10	0	.06	0	trace	N.D.
S1162	32-50	4.6	trace	113	N.D.	N.D.	5.9	.50	8	0	.44	.06	0	trace	N.D.
S1163	50-74+	4.0	trace	164	N.D.	N.D.	16.9	.40	2	.11	.16	.13	0	trace	N.D.

14 b) BEKENU (457); S1267/69

From Sg. Telabit Btg. Suai; calcareous parent material.

S1267	0-15	4.5	2	223	3.84	0.16	6.7	2.39	43	1.40	1.33	.16	0	N.D.	N.D.
S1268	15-35	4.6	1	201	N.D.	N.D.	10.1	2.94	3	.57	2.24	.13	0	N.D.	N.D.
S1269	35-40+	4.7	1	276	N.D.	N.D.	11.7	6.43	55	2.29	3.96	.18	0	N.D.	N.D.

15 a) MERIT (455); S1097/1102

From Sg. Setap; calcareous parent material.

S1097	0-2½	4.9	N.D.	83	2.51	0.32	20.7	3.78	18	3.0	.29	.40	.09	N.D.	N.D.
S1098	2½-8	4.9	N.D.	24	N.D.	N.D.	17.2	3.23	19	1.60	1.30	.20	.13	N.D.	N.D.
S1099	8-18	4.7	N.D.	21	N.D.	N.D.	13.1	2.86	22	1.30	1.19	.29	.08	N.D.	N.D.
S1100	18-34	5.0	N.D.	16	N.D.	N.D.	15.7	4.04	26	2.98	.70	.18	.18	N.D.	N.D.
S1101	34-44	5.5	N.D.	trace	N.D.	N.D.	13.9	11.11	80	8.50	2.20	.20	.21	N.D.	N.D.
S1102	44-60+	5.9	N.D.	trace	N.D.	N.D.	15.1	10.51	70	7.72	2.54	.25	trace	N.D.	N.D.

b) MERIT (455); S1133/39

From Sg. Sekaloh, Sg. Niah; non calcareous parent material.

S1133	0-3	3.9	17	322	8.64	0.69	38.9	1.37	4	.11	.70	.56	0	6	N.D.
S1134	3-6	4.1	6	194	N.D.	N.D.	23.9	.20	1	0	0	.20	0	0	N.D.
S1135	6-21	4.3	1	183	N.D.	N.D.	16.9	.09	1	0	0	.09	0	trace	N.D.
S1136	21-32	4.6	1	131	N.D.	N.D.	20.6	.06	0	0	0	.06	0	trace	N.D.
S1137	32-39	4.6	trace	163	N.D.	N.D.	17.4	.30	2	.11	.11	.08	0	trace	N.D.
S1138	39-54	4.7	trace	151	N.D.	N.D.	17.5	.13	1	0	0	.11	.02	0	N.D.
S1139	54-80+	4.7	trace	130	N.D.	N.D.	16.5	.09	1	0	trace	.09	0	0	N.D.

SIBUTI - NIAH - SUAI RIVER BASINS

Scale 1:125,000 OR 1.97 MILES TO AN INCH.

N. B. This Map Supersedes the Rough Provisional Land Suitability Map of the Sibuti - Niah - Suai Area.

Soil Survey Drawing No. 80.

Base map derived from Land & Surv.
Sarawak series No.12

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Drawn by Sebli Mohd. Ap