SEMI-DETAIL SOIL SURVEY

OF

NAVONU AND NIUVUDI

CAKAUDROVE

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Department of Agriculture, Fiji :: March, 1968

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1. INTRODUCTION

1.1 The soil survey was carried out at two levels; semi-detail and reconnaissance. The original briefing instructions specified a semi-detail survey of the "F.D.C. Option Area" and the "Mark White Timber Concession Area", henceforth referred to as the Navonu area and the Nivudi area, respectively. (See map 1). In these areas the soils were described and sampled for chemical analysis at predetermined sites. The same applies to the adjacent Navonu Subdivision and Loa Subdivision, which are coconut development schemes settled by Fijian farmers.

1.2 Other areas were examined at reconnaissance level when it became apparent that the areas surveyed at semi-detail level were not large enough to provide the minimum acreage required by the Fiji Development Company for an oil palm estate. These additional areas were traversed to determine the soil groups present, the probable location of soil boundaries, and the suitability of the land in terms of slope. Field studies were augmented by the examination of aerial photographs. The areas examined in this manner were the Yalave, Valavala, Drekeniwai and Natewa Bay areas.

1.3 Six weeks' field work were devoted to the semi-detail survey whilst the remaining areas were completed within three.

1.4 To avoid confusion, the semi-detail soil survey is treated in the main body of the report whilst the reconnaissance areas are dealt with in appendix V.

1.5 The survey was prompted by the wish to evaluate the area for oil palm development. The temptation to produce a simple map showing suitability for oil palm only has been resisted. Such interpretative maps are ephemeral bearing in mind likely changes in the agricultural arts and the cultural environment. A soil map has been produced in the hope that the survey will not become obsolete should oil palm not live up to expectations. Further, the author is of the opinion that insufficient experimental data are available, as yet, in the Fiji environment (as opposed to the Malayan environment, for example) to justify the categorical statements involved in the drawing of such an interpretative map.

1.6 The project area was mapped by Twyford & Wright in their reconnaissance soil survey of the Fiji Islands. A discussion of the use made of this work is in appendix IV.

2. DESCRIPTION OF THE PROJECT AREA

2.1 Location: The area of the survey included the catchment of the Upper Navonu Creek and its tributaries upstream of its intersection with Lomaloma Creek, the catchment of the Vuniyaro Creek (Upper Buca River) and of the Wailevukoloa Creek, all in the Natewa Peninsula, Vanua Levu. Hilly and mountainous areas in which the majority of slopes exceeded 20° from the horizontal were excluded from the survey and are blank on the soil maps.

2.2 Accessibility: Access to the area is facilitated by the main east to west motor road (Hibiscus Highway) which serves the Natewa Peninsula. It runs through the project area from Loa village in the east, climbing over the watershed of the Navonu and Wailevukoloa Creeks to run parallel to the Navonu valley for five miles. Access to the Nivudi area is by the unsurfaced, private, timber mill road which leaves the Hibiscus Highway at the Navonu Oil Palm Trial Area and climbs over 500 feet within the distance of less than a mile to cross the Navonu - Vuniyaro watershed at 850 feet. Aerial photographs suggest that the road could be re-routed to eliminate the steepest gradients, particularly between the Navonu flats and the watershed.

2.3 Climate : The project area falls into the "Lowland Climate with a weak dry season and high rainfall" category of Twyford and Wright. The mean annual temperature is ca.77°F and the mean annual rainfall 80 to 130 inches.

2.3.1 It is probable that minimum temperatures are lower in the Nivudi area than in Navonu and that rainfall figures are higher. Although the climatic variations throughout the project area are too small to be of pedologic significance, they may be of agronomic import.

2.4 Present Land Use: The Navonu valley south of the river has been subdivided recently into thirty seven 20 to 30 acre holdings for the planting of coconuts and cocoa by Fijians. The subdivision was laid out before the services of the Department of Agriculture land use planning unit became available, and a large number of the blocks have less than the minimum of cultivable land originally deemed necessary for economic survival. The estimate in the 1967 'Stewart Report' of an area of 1300 acres suitable for planting for oil palm within the subdivision is too optimistic - see Appendix I.

2.4.1 In the absence of a local market for cash crops there is little short term economic incentive for the farmers to remain in residence on their blocks, separated from the more convivial village life. Some farmers, however, are clearly well established.

2.4.2 The Loa Subdivision is in the basin of the Wailevukoloa Creek and its tributaries. Whilst in the Navonu Subdivision many of the blocks have at least a small amount of cultivable land for coconuts, here the majority of the blocks are uncultivable. The Department of Agriculture is aware of the problems on these subdivisions and is awaiting a decision on the proposed oil palm project before deciding on the agricultural future of the subdivisions.

2.4.3 With the exception of the oil palm trials plot, the F.D.C. Option Area is uncultivated and under forest.

2.4.4 The Nivudi area was only recently opened by the timber mill road. It is uncultivated and is densely forested. White Enterprises have a logging concession in the area. Only a fraction of it, probably less than 10%, has been exploited.

2.4.5 The Stewart Report gave the impression that the Mark White Area (Nivudi) was separate from the proposed Buca River Subdivision. They are in fact one and the same area.

3. PHYSIOGRAPHY

3.1 The Vuniyaro and Navonu Creeks and tributaries are both elevated, mature river systems. The Navonu, after draining a relatively undulating landscape 300 to 400 feet above sea level, tumbles over the spectacular Tavitavi Falls at the western edge of the project area and drains into Natewa Bay. The Vuniyaro, likewise, drains an area of relatively mature relief 600 to 700 feet above sea level before passing over the Koronikaivasi Falls and draining into Buca Bay.

3.2 There are hydro-electric power possibilities in both falls.

3.3 The break in longitudinal profiles is the result of a geologically recent uplift of the peninsula. The soils in the broad upper valleys are more mature and infertile than those at lower elevations below the falls because undisturbed "in situ" weathering has been continuing for a longer period in the upper valleys.

3.4 The discontinuity in the logitudinal profile of the Wailevukoloa Creek is about 450 feet above sea level. The slopes immediately below this are steep and irregular. Above the discontinuity the ground levels out for a short distance before sloping steeply up to the watershed. The relatively short distance from the source to the coastal plain has resulted in a telescoping of the soil toposequence and a relatively small area of cultivable land above the coastal plain.

4. GEOLOGY

4.1 Soil Parent Material: The most important soil parent material is basic andesite. Pyroxene and feldspar are the essential mineral constituents with subordinate amounts of magnetite, olivine and zeolite. Basic andesite breccias are encountered very frequently. They are thought to be of fluviatile origin. They have a clastic, non-welded matrix. Compared with the andesite, the andesitic breccias are weathered comparatively rapidly. Where high, upstanding relief occurs in the project area, the country rock is invariably andesite proper.

5. SOIL SURVEY

5.1 Soil Survey Method: In the Navonu area the problem of accurate location of sample sites under the continuous tree canopy was overcome by cutting a trace network at 880 yard intervals. Soil pits were dug at the intersection points of the traces and pedological horizons sampled for chemical analyses.

5.1.1 In the Nivudi area navigation was facilitated by the narrow valleys whose intersections are clearly visible on the 1 : 24,000 aerial photographs. Here the soils were sampled at each pedological horizon using a 3 x 44 inches Jarrett post hole auger. Care was taken to avoid contamination of auger samples.

5.1.2 Of the 89 soil profiles described in full 19 were soil pit profiles. Soil samples were collected from 63 sites in all.

6. SOILS

6.1 The Soils of the Project Area: The soils are best described in terms of a "toposequence". With the exception of topography, soil forming factors are reasonably uniform. On the rolling land the soils are uniform in most places; those on the hilly land are more varied, some being rather similar to the soils on the rolling land and others less well developed; and those on the steep land are still more varied and lack well developed horizons. Physical and chemical properties of the soil show a marked progression through the toposequence.

7. DESCRIPTION OF MAPPING UNITS

7.1 Lithosols: As their name implies, they are stony soils. Although they are associated with steep slopes, they are sometimes found on gently sloping relief below steep slopes.

7.1.1 The associated vegetation is forest with Waciwaci (Sterculia vitiensis) the dominant tree species. In places Bamboo becomes dominant.

7.1.2 These are characteristically shallow, and depth to rock is less than 20 inches. Where the 'R' horizon is deeper than 20 inches, the soil is classified as a Latosolic soil. The shallow A horizon is dark brown, loamy, and contains large amounts of coarse material.

7.1.3 Example, profile 79 : Shallow pit; vegetation, Bamboo; slope, complex 5° to 15°; stoniness, class 4 (U.S.D.A), andesitic boulders.

A 1 horizon : 0 to 9 inches, dark brown (10YR 3/3) sandy loam; weak fine granular structure; friable; many angular medium andesitic stones.

R horizon : 9 inches below surface.

For analyses, see appendix II.

7.1.4 The chemical analyses of these soils show them to be of the highest fertility. In practice, however, agricultural exploitation would be difficult due to their stoniness and steep slopes.

7.1.5 Lithosols are not extensive in the project area. The largest area mapped is in the Nubunuito valley in the far north. The valley is overshadowed by a steep, in places sheer, rocky outcrop beneath which boulders and stones have accumulated.

7.2 Latosolic soils: These are brown loams and clay loams with a clay subsoil intermediate in the toposequence between the Lithosols and the Humic Latosols into which they grade downslope. They are associated with steep slopes and the foothills of high, dissected ground, particularly along the southern boundary of the project area. Latosolic soils are less weathered than the Humic Latosols.

7.2.1 They normally carry forest in which Dawa (Pometia pinnata) and Solato (Laportea vitiensis) are common constituents. When cleared, reed (Miscanthus floridulis) colonises them.

7.2.2 Slopes are mostly between 15° and 20° and over, but may be less in small areas.

7.2.3 Example, profile 030: Soil pit, 60 inches deep; altitude, 600 feet; 8° slope, summit of ridge, convex; vegetation, margin of recently cleared forest, Solato and Sourgrass (Paspalum conjugatum).

A 1 horizon : 0 to 9 inches, dark brown (10YR 3/3) clay loam; weak fine subangular blocky structure; firm; few small angular basaltic fragments; boundary gradual.

C 1 horizon : 9 to 42 inches, dark yellowish brown (10YR 4/4) silty clay loam; weak coarse subangular blocky structure; friable; many medium-sized basaltic stones showing spheroidal decomposition.

C 2 horizon : 42 to 60 inches, light olive brown (2.5Y 5/4) clay loam; structureless, massive; occasional basalt fragments contained within more weathered parent material.

For analyses, see appendix II.

7.2.4 Mean values of the A1 and C1 horizons for six representative profiles:

	pH($CaCl_2$)	ppm T/P_2O_5	ppm Av/P_2O_5	Exch cations Ca	Mg	K	m.e.% C.E.C	BS%
A1	5.7	1054	41	14.8	7.72	0.25	62.30	38
C1	5.3	331	18	10.6	7.68	0.09	55.80	33

Of the cultivable soils the Latosolic group is the most fertile. Reaction is neutral. Total phosphate figures are medium in the surface soil. Although available phosphate levels are almost twice as high as the levels in the other soil groups, they are still very low from the agricultural standpoint. Available potash levels appear to be medium in the surface soil and very low in the subsoil. As the soil skeleton is only partially weathered, exchangeable cations are relatively high.

7.2.5 Drainage and moisture retention characteristics: Due to their topographical position and their textural characters, these soils are freely draining and tend to dry out more rapidly than the Humic Latosols. This is probably the reason why they do not readily revert to forest after clearing. Coconut palms on these soils show chlorotic features during dry weather.

7.3 Humic Latosols: These are red and reddish brown clay soils.[1] Those soils in the project area with hues of 5YR, 2.5YR and 10R in the B2 and C horizons have been included in this group. The colour characteristics were found to be closely associated with a set of identifiable chemical characteristics with only two exceptions.

7.3.1 In the project area Humic Latosols were associated with the more gently sloping land. The soils are deep and rarely contain subsurface stony material in the A or B horizons. Humic Latosols have been subjected to weathering over a relatively long period and thus they show less influence of the parent material and tend to be in better equilibrium with the complex of environmental factors.

7.3.2 In general the Humic Latosols are forested and support economically exploitable Dakua (Agathis vitiensis) and other species. In places, however, particularly on residual hills, the forest thins out, and Nokonoko (Casuarina nodiflora) becomes the dominant tree species. The open canopy permits scrubby undergrowth to colonise the forest floor. These infertile patches may be considered quasi-talasiga[2] soils. Rooting depth between individual trees in the forest is confined to the top 8 inches of the soil.

7.3.3 The original soil classification based on field characteristics distinguished between Humic Latosols with scattered stones on the surface and hues less red than 2.5YR, and Humic Latosols with no stony material on the surface and hues redder than 5YR. Subsequent analyses of chemical data suggested that the subdivision was not justifiable, and it was abandoned.

7.3.4 Overall slope angles rarely exceed 15°, but slumps and collapse features associated with drainage lines often complicate the slope pattern.

1. Of 22 soil profiles of this group, 16 showed a significant increase in clay with depth suggesting an argillic horizon resulting from the illuviation of clay particles down the profile. In the Navonu area the silt fraction increased significantly with depth. In three of the pits the following increases were observed:

Site 105 ins.	c	si	s	Site 108 ins.	c	si	s	Site 102 ins.	c	si	s
0-8	46	20	34	0-9	52	20	28	0-7	40	24	36
8-30	6	62	32	9-36	46	32	22	7-30	54	22	24
30-70	6	90	4	36-72	26	48	26	30-70	2	78	20

2. Talasiga, "sun-burnt" land, Fijian term for very infertile red soil.

7.3.5 Example, I profile 102 : Soil pit 70 inches deep; slope 5°, convex; vegetation secondary forest, Makita (Paranari laurina) dominant tree species.

O1 horizon	:	1 to 0 inches, forest litter.
A1 horizon	:	0 to 7 inches, dark reddish brown (2.5YR 3/4) clay; weak fine subangular blocky to weak medium granular structure; firm; gradual boundary.
B21 horizon	:	7 to 30 inches, reddish brown (2.5YR 4/4) clay; structureless, but with "platy" cleavage; firm; diffuse boundary.
B22 horizon	:	30 to 70 inches, weak red (10R 4/2) silt loam; structureless; firm; roots nil.

For analyses, see appendix II.

7.3.6 Example II:
A further example is given below to illustrate a Humic Latosol associated with bench features below and above slopes on which Latosolic soils occur. These soils are characteristically of higher C.E.C. and pH and of moderate BS %. Their occurence is limited, and they are of academic rather than practical interest.

Profile 035	:	Soil pit 72 inches deep; slope 14°, convex; vegetation, Solato, Sour Grass, Mile-a-minute (Mikania micrantha), and Lantana (Lantana camara).
A1 horizon	:	0 to 3 inches, yellowish red (5YR 4/6) silty clay loam; weak fine granular structure; firm; slightly sticky; gradual boundary.
B21 horizon	:	3 to 23 inches, red (2.5YR 5/6) clay; structureless; firm; sticky; 4 inches diameter sandy spots mark remains of weathered stones; abrupt boundary.
B22b horizon	:	23 to 33 inches, reddish brown (5YR 4/4) clay; structureless; firm; sticky; clear boundary (chemical data confirm this as being a buried A1 horizon caused by landslip from above).
B23 horizon	:	33 to 50 inches, red (2.5YR 4/6) clay; structureless, firm; sticky; solitary weathered 4 inch diameter stone; boundary gradual.
C1 horizon	:	50 to 70 inches, brown (7.5YR 4/4) clay loam; structureless; firm; slightly sticky.

For analyses, see appendix II.

7.3.7 Mean values of the A1 and B2 horizons for 22 representative profiles:

	pH($CaCl_2$)	ppm T/P_2O_5	ppm Av/P_2O_5	Ca	Mg	K	C.E.C	BS %
A1	3.9	896	24	2.08	0.81	0.16	23.59	16
B2	3.9	601	9	0.86	0.34	0.05	20.26	9

Chemical analyses show these soils to be at far end of the fertility scale; pH levels, total P_2O_5, and available P_2O_5 are very low. Available potash is very low (although not as low as in the alluvial and gley soils). Humic Latosols have the lowest base saturation percentage of the soil groups described in the project area.

7.3.8 Drainage and moisture retention characteristics: The surface horizon of a Humic Latosol is well drained due to the good surface soil structure and concomitant high infiltration capacity. Most of the rainfall is absorbed and not lost in run-off. Due to the less permeable nature of the subsoil this moisture is retained in the soil until given up to the atmosphere by transpiring plants. The passage of heavy machinery can cause compaction and loss of good structure, causing excessive run-off and erosion.

7.4 Alluvial soils: These soils are deep, stratified, with little profile development, some accumulated organic matter, and a wide range of internal drainage from poor to good. The parent material is riverine deposits derived from basalt, andesite and andesitic breccia. Textures range from stony loam to clay. Structures are usually blocky, or columnar, and less commonly granular. Soil colours may be noticeably reddish brown in older alluvium and dark brown in more recent soils. Alluvial soils are associated with flat ground, i.e. less than 5^{o} slopes.

7.4.1 Vegetation: In the Nivudi area the alluvial flats are forested. The canopy is lower and more uniform than on the interfluves. Makita is the most common species and is frequently found in dense groves in association with Niuniu (Goniosperma vitiense). The more useful timber species, Dakua, Yasi Yasi (Syzygium effusum) and Dakua Salusalu (Podocarpus vitiensis), are present in small numbers, but are not so well developed on the alluvium as on the higher ground. In the Navonu area most of the vegetation on the flats is clearly secondary, and Bamboo is prolific.

7.4.2 Example 1, profile 90: Auger examination to 44 inches; vegetation, forest, Makita dominant; slope, less than 2^{o}.

A1 horizon : 0 to 8 inches, dark yellowish brown (10YR 3/4) loam; moderate medium blocky structure; friable; roots plentiful; boundary gradual.

C1 horizon : 8 to 26 inches, brown (7.5YR 4/4) silt loam, probably structureless; diffuse boundary.

C2 horizon : 26 to 44 inches, yellowish red (5YR 4/6) clay loam; probably structureless.

For analyses, see appendix II.

7.4.3 A further example is given to illustrate the wide range of field characteristics of the Alluvial soils.

Example II, profile 117: Pit 72 inches deep; slope less than 2^{o}; vegetation, Makita and Bamboo.

A1 horizon : 0 to 8 inches, dark brown (10YR 3/3) silty clay loam; weak medium blocky structure; friable; many rounded small stones; gradual boundary; roots abundant.

C1 horizon : 8 to 36 inches, dark yellowish brown (10YR 4/4) stony clay loam; structureless; very firm; many rounded small, partly weathered stones; roots plentiful; boundary diffuse.

C2 horizon : 36 to 72 inches, brown (7.5YR 5/4) clay loam; structureless; very firm; stony material crumbles under light pressure; roots few.

It is interesting to note that roots penetrate to more than 6 feet below the surface in this example (compare the Humic Latosols).

7.4.4 Mean values of the A1 and C1 horizons for 12 representative profiles:

	pH($CaCl_2$)	ppm T/P_2O_5	ppm Av/P_2O_5	Ca	Mg	K	C.E.C.	BS %
A1	4.1	1078	27	4.92	2.90	0.12	31.22	25
C1	4.0	764	14	2.04	2.00	0.03	28.04	14

Many of the Alluvial soils, particularly in the Nivudi area [1], were old Alluvial soils. In other words, they have long been above the present level of the local flood plain and long since ceased to receive supplies of unweathered parent material during floods. This accounts for the relative maturity and infertility of the soils. It is possible that the relative poverty of the forest on the alluvial flats is a reflection of this infertility. The average levels of potash in the surface and subsoil horizons were even lower than the average figure for Humic Latosols. (The difference in levels may not be statistically significant). The surface soil pH values were moderately to strongly acid; T/P_2O_5 low; available P_2O_5 very low; available potash low. The extremely low exchangeable bases (i.e. Ca and Mg) are evidence of the senility of these soils whose parent materials were rich in these minerals (c.f. the levels shown in 7.1.3 or 7.2.4 for Lithosols and Latosolic soils).

7.4.6 Drainage characteristics : The Alluvial soils mapped in this group are generally well drained. The water table during the wetter periods will rarely rise closer to the surface than 36 inches [2]. Due to their position in the landscape and their textural characteristics the Alluvial soils are likely to remain moist throughout the year.

7.5 Gley soils: These are alluvial soils of fine texture in which the water table remains close to the surface during the greater part of the year. They characteristically show a ferric(rust stained) horizon close to the surface above a gley horizon of predominantly gray colours. Where the water table is permanently close to the surface, the ferric mottled horizon may be absent.

7.5.1 The Gley soils are particularly common in the Navonu area and are associated with dwarf Makita forest and open sedge land.

7.5.2 Example, profile 100: Soil pit 60 inches deep; vegetation, dwarf Makita forest.

A1 horizon	:	0 to 7 inches, dark grayish brown (10YR 4/2 loam; mottles nil; moderate medium granular; firm; roots plentiful; boundary clear.
A2 horizon	:	7 to 15 inches, dark grayish brown(highly variegated 10YR 3/1, 10YR 4/2, 2.5Y 5/2 with few, fine, faint ferric mottles) clay; structureless; firm; solitary 1.5 inch diameter rounded pebble; roots few; clear boundary.

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1. pH($CaCl_2$) Navonu Alluvial soils 4.5 to 5.5
   Nivudi " " 3.5 to 4.0

2. Where patches of poorly drained land are extensive enough to be identified on aerial photographs, they have been mapped as Gley soils. However, small areas of Gley soils, too small to be identifiable on aerial photographs, have been mapped in the Alluvial group.

Cg horizon : 15 inches to 60 inches and deeper, olive gray (2.5Y 5/2), with common, medium distinct, strong brown(7.5YR 5/8) mottles, clay; slightly sticky.

Water table at 40 inches below surface on 29/11/67. Probable highest level of water table 7 inches.

7.5.3 Mean values of A1, A2, A3, and C1, and C2 horizons for 4 representative profiles:

		ppm	ppm	Exch cations m.e.%				
	$pH(CaCl_2)$	T/P_2O_5	Av/P_2O_5	Ca	Mg	K	C.E.C.	BS %
A1 A2 A3	4.8	946	24	9.08	5.98	0.10	26.36	38
C1 C2	5.13	616	15	7.76	6.82	0.03	21.20	36

In terms of exchangeable bases the Gley soils are second only to the Lithosols and the Latosolic soils. Available phosphate and potash levels are very low, however. The Gley soils in the Navonu area are neutral in reaction. The only example observed in Nivudi (see site 95, appendix II) is of much lower base status. Thus the relatively high mean horizon values above are a reflection of the particular sampling of gley soils within the project area, rather than a reflection of their inherent properties over the whole area.

7.6 Organic Soils (b): These have developed in patches where the water table lies at the soil surface during much of the year.

7.6.1 The headstreams of the Nubuniuto Creek have been captured by the Lovewaqa river which has a confluence with the Vuniyaro below the head of the Koronikaivasi gorge. The Nubuniuto valley is now drained by a misfit stream characterised by a small discharge in relation to grade. A forty acre swamp has developed and is increasing in area, stretching across the floor of the valley and along it for half a mile.

7.6.2 There is no detailed information on the Organic soils of the project area. The areas concerned are small, and it was felt that investigation of swamp substratum, involving special equipment, was outside the province of the semi-detail soil survey.

7.7 The mean values (for A1 horizons only) discussed in paragraphs 7.2.4, 7.3.7, 7.4.4 and 7.5.3 are plotted below so that a visual comparison may be made of some of the chemical properties of the four main soil groups. The upper and lower limits of the seven columns represent the highest and lowest levels exhibited by each characteristic in the soils of the project area.

8. SLOPE CLASSIFICATION

8.1 The project area has been divided into three slope categories. See map 3. Class I land has single slopes up to 5° from the horizontal (9 per cent) and is synonymous with the alluvial bottom lands.

8.2. Class II land has single slopes from 5° to 12° (21 per cent) and short, complex slopes up to 8° (14 per cent). This takes in some of the Humic Latosols and a smaller area of Latosolic soils.

8.3 Class III land has slopes in excess of 12° and less than 20° (26 per cent). Complex short slopes are in excess of 8° and in places exceed 20° over short distances. These lands include the balance of the Humic Latosols, Latosolic soils and Lithosols.

9. SOIL AND SLOPE CLASSIFICATION IN RELATION TO POSSIBLE AGRICULTURAL USE.

9.1 Humic Latosols[1]: In view of their low fertility, cultivation of Humic Latosols in slope Class III is likely to prove uneconomic. The original briefing instructions specified the mapping of land with slopes less than 20°. For this reason slope Class III lands have been included on the map. As previously stated, areas with slopes above 12° are characterised by slumps and collapse features which result in a complex slope pattern in which short slopes exceed 20° even when the overall slope is no more than 15°.

9.2 Agriculture on Humic Latosols in slope Class II will remain an economically marginal activity unless a high income yielding tree crop can be grown that will justify the application of high cost fertilizers. It is likely that oil palm will fall into this category, although it is important to recognise that the fertility of these soils is lower than those of the Navonu Oil Palm Trials Plot.

9.2.1 Chemical analyses of the soils at the Vunilagi Estate oil palm trials plot are shown at the end of appendix II. It is noticeable that the chemical characteristics of this soil are rather unlike those of the humic latosols of the project area. They are only slightly acid and have a moderately high BS % and in this respect are comparable with the Latosolic soils. Available P_2O_5 was much lower than any of the 154 soils analysed in the course of the survey. Available potash was also very low which may well explain the fall off in bunch production which has been observed in recent years. The reason for the anomolous chemical characteristics of this soil in relation to the humic latosols in the project area is obscure.

9.2.2 Judging by the coconut palms growing elsewhere in the Natewa Peninsula on Humic Latosols, the indiscriminate planting of coconuts on these soils should not be encouraged. For example, 20 year old palms on a soil with the following chemical characteristics had a diameter (breast height) of 10 inches tapering to 5 inches at 25 feet, with only seven healthy leaves and no fruit.

	pH($CaCl_2$)	ppm T/P_2O_5	ppm Av/P_2O_5	Exch cations m.e.% Ca	Mg	K	Na	C.E.C	BS%
A1	3.9	789	13	3.96	0.55	0.08	0.33	19.80	25
C1	3.9	416	8	1.21	0.20	0.03	0.59	19.69	10

If these analyses are plotted on the diagram in paragraph 7.7, it will be found that levels fall below the mean of the original 22 Humic Latosols.

A more fertile Humic Latosol (e.g. profile 049, paragraph 7.3.6) may well support worthwhile coconuts palms. One is faced with a soil that appears uniform, judging by field characters alone, and about which it is difficult to assess agricultural potential. Usually the only clue as to fertility levels is the type of vegetation present. On "virgin" soils Nokonoko may or may not be present as an indicator of low fertility. Qato Moce (Dicranopteris linearis), Nuqanuqa (Decaspermum fruticosum) and Boiboida (Geniostoma vitiense) are usually present on infertile sites. In the absence of obvious plant indicators, however, it is difficult to make an extempore decision without running the risk of giving unreliable advice. Where laboratory information is not available, planting of coconuts on Humic Latosols should be discouraged.

1. The above comments presuppose that fertilizing of coconuts on marginal soils is uneconomic although this has not been proven conclusively.

9.2.3 The above paragraph also applies to cocoa and banana production. As no experience has been gained in the area with livestock production on these soils, no objective comments on their suitability for pastures can be made.

9.2.4 N % figures for the A1 horizon of Humic Latosols under forest were uniformally high, as would be expected. It would appear that the establishment of a leguminous cover crop at an early stage in the clearing operation is imperative if nitrogen levels are to be maintained for the benefit of oil palm. After clearing of the forest, nitrogen levels will inevitably fall.

9.2.5 The high infiltration capacity of Humic Latosols coupled with their good moisture retention properties should favour oil palm provided the soil nutrient problems are resolved.

9.2.6 The deep soil makes terracing on long slopes a feasible undertaking, particularly in the southern part of the Nivudi area.

9.3 Lithosols(1): Due to their shallow stony nature Lithosols are considered unsuitable for oil palm and other tree crops which require good rooting depths. They are suitable for small scale vegetable cultivation.

9.4 Latosolic soils(2): Due to the high surfacial run-off and concomitant low moisture infiltration, shallow Latosolic soils are probably unsuitable for year round oil palm bunch production. However, run-off could be reduced by a cover crop, and in view of their relatively good fertility it may prove economic to plant oil palm for harvesting during part of the year, only.

9.4.1 Despite the seasonal chlorotic features observed on palm fronds Latosolic soils are considered suitable for coconuts. Palms showed a good girth and well developed crowns and nuts. It is often possible to plant long slopes in excess of 20^{o}, but intercropping with tavioca should be avoided. Complete loss of the 8 to 10 inch deep A1 horizon was observed in several places in the Loa subdivisions where tavioca was cultivated on steeply sloping Latosolic soils.

9.4.2 On the intermediate slopes (i.e. Class II), bananas and cocoa appear to do reasonably well, although no yield figures are available.

9.5 The Alluvial soils(4) in the project area are only slightly higher in overall fertility than the Humic Latosols, and in respect of potash they are lower. They are generally flat (i.e. Class I) and have favourable moisture characteristics. Provided adequate attention is paid to the deficiences listed, particularly in the Nivudi area, they must be considered suitable for a good range of agricultural activities. In terms of oil palm the Alluvial soils should be excellent, for, with the exception of the nutrient requirements, oil palm should have all demands satisfied; a deep loamy soil, rich in humus, with a well developed structure, a loose friable consistency and no impervious layers in the subsoil. Drainage is good, and at the same time a continuous moisture supply is available in view of the topographical position. In theory the acidity should not in itself prove debilitating provided nutrient levels are maintained with fertilizers.

9.5.1 Garden cultivation of the Alluvial soils close to the timber mill in Nivudi has produced clear evidence of infertility in the second year following clearing. Crops and weeds showed strong indications of potash deficiency in November 1967. On a subsequent visit in February 1968 these deficiences were less in evidence. Analysis of potash levels revealed the low figure of 0.10 a.e.% of K in the top 44 inches. This is the average figure for K levels in Alluvial soils in the Nivudi area.

9.6 Gley soils: Following the successful draining and cultivation of the low lying land at the Navonu Oil Palm Trials Plot, there can be little doubt as to the suitability of these soils for palm oil production.

9.6.1 The high yields obtained appear to be a strong denial of the conventional wisdom that oil palm cannot tolerate a permanently high water table (Werkhoven, Oil Palm, Green Bulletin). On the site examined at the Navonu experiment the water table appears to fluctuate between 28 inches and 9 inches below the surface, and this must be considered high by most standards. In these circumstances, however, the textural characteristics of the soil facilitate good root aeration.

Profile 112	:	Soil pit 48 inches deep, Navonu O/P experiment.
Al horizon	:	0 to 9 inches, yellowish red (5YR 4/8) silt loam; mottles nil; moderate medium granular; firm few rounded small stones; boundary gradual and irregular.
Cg horizon	:	9 to 48 inches and deeper, grayish brown (2.5Y 5/2) stony, sandy clay with 30% distinct ferric mottles, passing to olive gray (5Y 5/2) with few ferric mottles at depth of ca 30 inches. Many rounded pebbles 1 inch to 2½ inches in diameter (andesitic).

Water table at 28 inches below the soil surface. Observation following a fairly dry period on 4/12/67.

It is recommended that in the draining of less coarsely textured Gley soils for oil palm every effort should be made to lower the water table to a depth of 3 feet below the soil surface during the rainy periods of the year. As Gley soils are not usually forested, land clearing costs will be minimal.

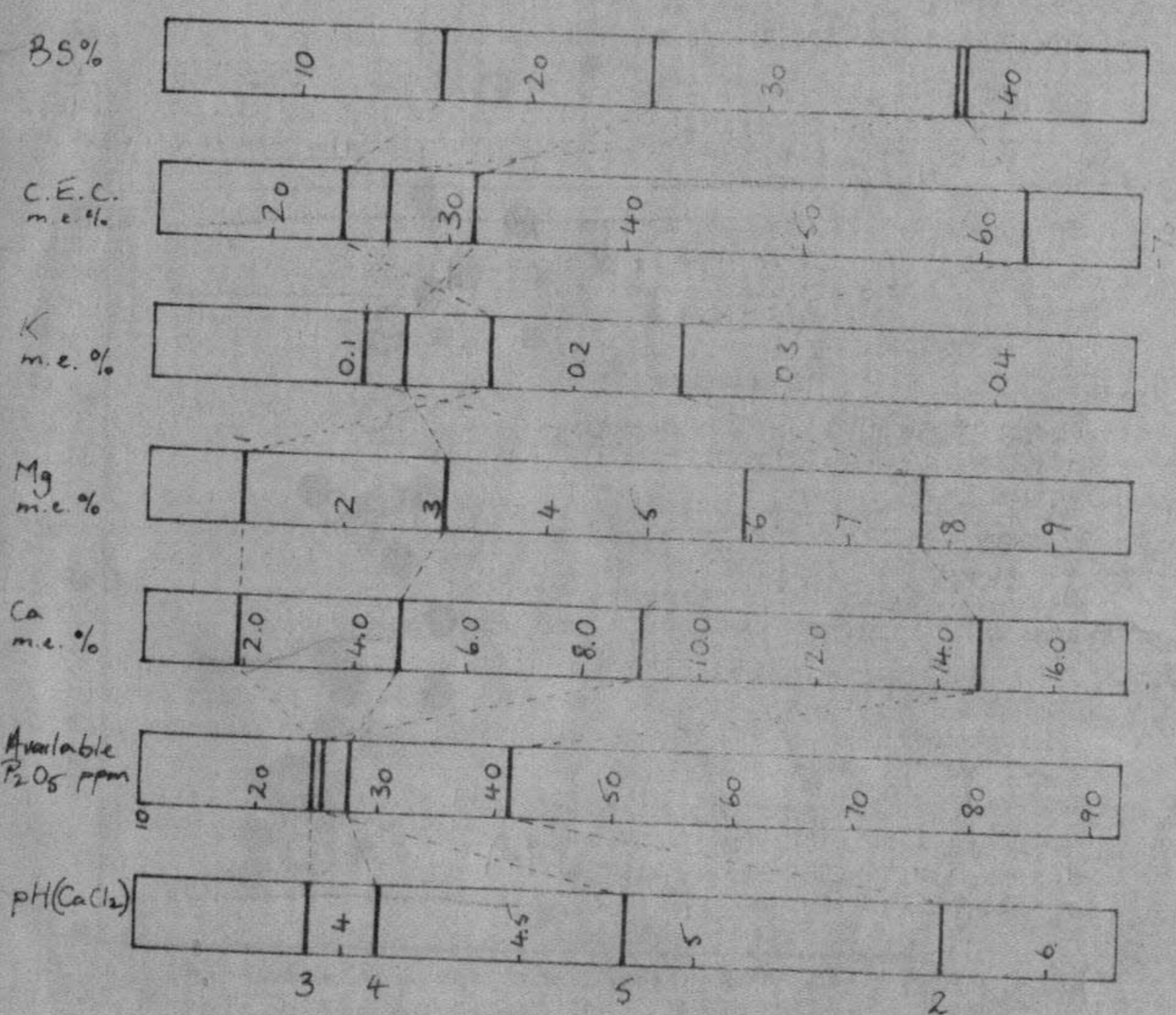
9.6.2 Bananas require at least 3 feet of unmottled soil below the surface. This implies that during the wettest part of the year the water table should not approach closer than 3 feet to the surface.

9.6.3 The base exchange complex of Gley Soils in the Navonu area is dominated by Magnesium and Calcium which is likely to be antagonistic to the take up of Potassium. Heavy applications of potassic fertilizer are recommended.

9.7 Organic soils: Deep peaty soils with a loose upper layer are unsuitable for tree crops as they cannot provide sufficient anchorage for the supporting root system. Shallow peat soils overlying a drained clay may be more suitable.

10. FERTILIZERS

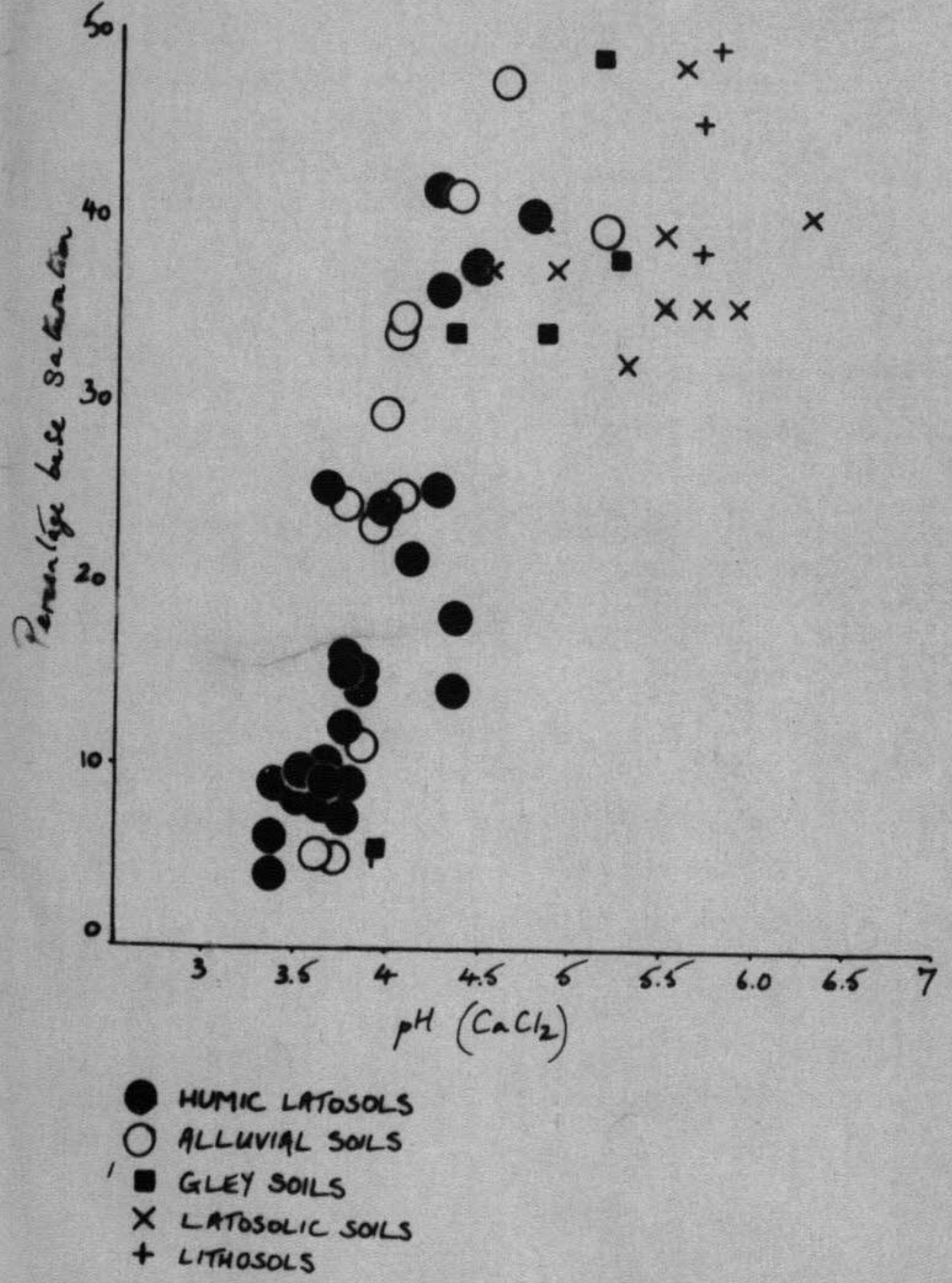
10.1 In the absence of crop response data for the soils in the project area any fertilizer recommendation will be arbitrary in the first place. However, using the available soil chemical data it should be possible to make a reasonable estimate of crop needs. On the basis of results from chemical analyses of leaves and statistical data from crop performance it should be possible to improve fertilizer treatments. Then at the final stage the feasibility of improving fertility for economic cropping on each soil group may be defined. Judging by the low nutrient levels exhibited by most of the soils in the project area, the success of any scheme will depend on high inputs of the right fertilizers.



7.7 Mean values for A1 horizons

3 = Humic Latosols
4 = Alluvial Soils
5 = Gley Soils
2 = Latosols

Fig. 7.7.1 The relationship between pH and base saturation expressed as a scatter diagram.



11. IMPLICATIONS OF RESULTS IN RELATION TO PROPOSED F.D.C.PROJECT.

11.1 On the basis of the limited information he had at the time, Stewart estimated the acreage of plantable oil palm land to be as follows :

Navonu	2,500 to 2,800
Nivudi	1,200
Buca River Subdivision	1,000
Navonu Subdivision	1,300
Other subdivisions	1,500

These areas have been surveyed, and by reference to appendix I it will be seen that the undeveloped areas with potential for oil palm are smaller, more scattered and less fertile than originally anticipated.

11.2 It is clear that if returns are to be maximised, development must take place on fertile land. However, the amount of fertile land considered to be available is small, and a reappraisal of what is meant by "available" may be necessary. In the selection of areas for the semi-detailed soil survey it has been presumed that presently occupied land (alienated and native land)was not available, despite the great interest on the part of the owners as an alternative crop to coconuts.

11.3 In the Fijian community development effort is at present being concentrated on the planting of coconuts on previously undeveloped, marginal land with the result that attention is being diverted from the unintensively used, but fertile, communal land.

11.4 If oil palm - the income from which is said to be so much higher than that from coconuts - is to be established, it would seem logical to return to the core area rather than extend the use of marginal land still further.

APPENDIX I.

1.1 F.D.C. Option Area, Navonu.

Latosolic Soils	46	Slope Class I	680
Humic Latosols	1184	II	1000
Alluvial Soils	439	III	232
Gley Soils	333		
	2002 acres		1912 acres

Forest 1300 acres

1.2 Niuvudi

Lithosols	64	Slope Class I	786
Humic Latosols	1385	II	1154
Alluvial Soils	754	III	299
Organic Soils	45		
	2248 acres		2239 acres

Forest 2180 acres

1.3 Navonu Subdivision

Latosolic Soils	500	Slope Class I	427
Humic Latosols	565	II	617
Alluvial Soils	198	III	429
Gley Soils	160		
	1423 acres		1473 acres

Cultivated Area 600 acres : Forest 800 acres

N.B.

The difference between the Soil totals and Slope Class totals is due to mapping error. The 90 acre discrepancy in the F.D.C. Option area is embarrassing but there was no time to investigate the cause of it.

36.emt

Chemical Analyses of Soil Samples

	Site No.	Samp. No.	Location	Slope Class	Depth ins.	Appearance	pH ($CaCl_2$)	T/N%	Org C%	C/N	T/P_2O_5	Available P_2O_5	Exchangeable Cations m.e.%				C.E.C.	BS%
											p. p. m.		Ca	Mg	K	Na	m.e.%	
1.1	LITHOSOLS																	
	5	008	Loa	III	0-20	v.dk.br.l.	5.70	0.31	3.5	11	892	68	18.48	5.72	0.55	0.36	66.0	38
	12	019	Loa	III	0-9	black l.	5.80	0.45	7.4	16	1588	109	28.64	7.10	0.98	0.38	75.48	49
	79	074	Nivudi	III	0-9	dk.br.sl.	5.70	0.64	6.74	11	2256	112	22.80	6.61	0.39	0.44	67.26	45
1.2	LATOSOLIC SOILS																	
	8	010 011	Loa	III	0-10 10-24	v.dk.br.cl. br.c.	5.50 5.60	0.38 0.05	5.08 0.72	13 14	1521 370	45 13	14.30 10.98	10.34 10.30	0.19 0.03	0.48 0.46	64.90 58.80	39 37
	13	020 021	Loa	II	0-8 8-25	v.dk.br.l. br.c.	5.70 5.50	0.36 0.11	4.81 1.80	13 16	1378 453	46 32	14.65 10.34	8.88 7.81	0.17 0.08	0.40 0.41	69.37 59.40	35 31
	15	022 023	Loa	II	0-8 8-14	dk.br.cl. r.br.c.	4.55 4.80	0.32 0.10	4.41 1.75	14 18	1103 574	40 22	5.85 4.92	4.75 7.38	0.86 0.86	0.23 0.26	31.86 28.89	37 46
	21	026 027	Loa	II	0-15 15-24	v.dk.br.l. br.c.	5.50 5.30	0.24 0.10	3.28 1.52	14 15	1416 545	41 32	14.74 10.56	5.06 3.96	0.09 0.04	0.32 0.40	57.20 42.35	35 35
	24	030	Loa	II	0-15	dk.br.cl.	4.90	0.40	4.89	12	1610	45	8.94	5.89	0.56	0.29	41.96	37
	27	031 032	Navonu	III	0-8 8-24	dk.br.cl. y.r.c.	5.60 4.60	0.38 0.06	5.67 1.50	15 25	579 269	27 19	11.23 4.80	7.56 8.61	0.16 0.02	0.38 0.41	39.96 38.15	48 36
	30	037 038 039	Loa	III	0-9 9-42 42-60	dk.br.cl. br.sicl. ol.br.cl.	5.90 5.70 5.90	0.22 0.04 0.02	2.89 1.45 1.12	13 36 56	1010 312 264	45 27 77	17.00 13.93 19.69	7.30 7.02 7.06	0.26 0.05 0.02	0.55 0.73 1.28	72.40 63.72 56.17	35 34 50

Site No.	Samp. No.	Location	Slope Class	Depth ins.	Appearance	pH ($CaCl_2$)	T/N%	Org C%	C/N	T/P_2O_5	Available P_2O_5	Exchangeable Cations m.e.%				C.E.C.	BS%
										p. p. m.		Ca	Mg	K	Na	m.e.%	
34	047	Navonu Sbd.	III	0-10	dk.gr.br.cl.	6.30	0.35	3.52	10	1469	63	18.04	5.83	0.54	0.81	63.25	40
	048			10-32	br.cl.	5.60	0.08	1.06	13	449	9	12.10	4.80	0.08	0.74	52.32	34
104	133	F.D.C. Option Area	III	0-7	v.dk.gr.br. scl.	5.30	0.28	3.53	13	370	23	13.54	6.44	0.18	0.24	63.83	32
				7-36	br.cl.	5.00	0.06	0.78	13	133	13	10.58	7.56	0.03	0.41	62.64	30
HUMIC LATOSOLS																	
33	045	Navonu Sbd.	II	0-10	dk.r.br.c.	4.40	0.29	4.23	15	911	22	2.01	0.95	0.15	0.36	24.38	14
	046			10-30	dk.r.br.sic.	4.25	0.09	1.57	17	347	4	1.05	0.21	0.02	0.22	15.75	10
35	049	Navonu Sbd.	III	0-3	y.r.sicl.	4.80	0.33	3.99	12	1020	45	5.50	5.39	1.19	0.32	30.80	40
	050			3-23	r.c.	4.50	0.13	1.41	11	489	9	3.24	4.10	0.21	0.32	24.84	32
	051			23-33	r.br.c.	5.05	0.17	2.81	17	1328	18	5.56	6.31	0.07	0.36	30.49	40
	052			33-50		4.90	0.05	1.13	23	579	18	5.62	3.89	0.11	0.35	28.62	35
73	060	Nivudi	III	0-10	y.r.cl.	3.70	0.40	6.08	15	884	59	0.98	0.11	0.17	0.33	16.89	9
	061			10-44	y.r.c.	3.90	0.10	1.97	20	540	19	0.44	0.11	0.02	0.31	13.62	6
74	062	Nivudi	II	0-12	y.r.cl.	3.90	0.24	4.26	18	1144	31	1.50	0.43	0.10	0.32	13.38	18
	063			12-44	y.r.c.	3.90	0.09	2.59	29	876	4	0.43	0.11	0.01	0.22	12.42	6
75	064	Nivudi	II	0-12	dk.y.br.scl.	4.00	0.40	4.99	12	1248	36	3.71	1.74	0.22	0.34	25.61	24
	065			12-44	br. sil.	3.90	0.07	0.86	12	824	9	1.08	0.11	0.04	0.46	14.58	12
76	066	Nivudi	II	0-12	dk.r.br.cl.	4.15	0.33	5.04	15	1230	19	3.85	0.99	0.11	0.35	25.30	21
	067			12-30	r.br.c.	3.75	0.10	1.62	16	636	13	1.33	0.22	0.06	0.34	20.53	9
	068			30-48	r.b.cl.	3.70	0.40	1.09	27	549	28	0.89	0.11	0.07	0.34	23.86	6

Site No.	Samp. No.	Location	Slope Class	Depth ins.	Appearance	pH ($CaCl_2$)	T/N%	Org C%	C/N	T/P_2O_5	Available P_2O_5	Exchangeable Cations m.e.%				C.E.C.	BS%
										p. p. m.		Ca	Mg	K	Na	m.e.%	
77	069 070	Nivudi	II	0-12 12-44	dk.r.br.scl. dk.r.br.sic	3.90 3.90	0.24 0.05	4.81 1.34	20 27	919 613	45 4	2.40 0.76	0.22 0.11	0.13 0.11	0.29 0.26	20.16 15.26	15 8
81	078 079	Nivudi	III	0-12 12-36	dk.r.br.cl. r.br.sic	3.90 3.85	0.25 0.06	3.34 1.70	13 28	1064 832	23 40	1.96 0.65	0.65 0.22	0.10 0.03	0.33 0.32	21.25 16.35	14 7
82	080 081	Nivudi	II	0-10 10-44	br. cl. str.br.cl.	3.75 3.95	0.32 0.05	5.53 0.78	17 16	1610 1442	40 18	1.09 0.43	0.11 0.11	0.10 0.02	0.29 0.37	18.53 19.44	9 5
83	082 083	Nivudi	II	0-10 10-44	br. l. r.br.sil.	4.50 4.15	0.44 0.11	4.76 1.33	11 12	2362 1549	27 9	6.05 1.39	2.38 0.58	0.18 0.03	0.28 0.26	23.76 13.92	37 16
85	086 087 088	Nivudi	I	0-8 8-25 25-48	dk.r.br.l. dk.r.br.scl. weak r.sil.	3.40 3.75 3.90	0.03 0.11 0.03	9.86 1.82 0.64	? 16 21	824 395 264	36 4 trace	1.51 trace 0.54	0.22 trace trace	0.31 0.11 0.02	0.32 0.29 0.33	37.80 14.31 17.65	6 3 5
86	089 090 091	Nivudi	III	0-8 8-26 26-44	dk.r.br.cl. y.r.cl. r. c.	3.80 3.90 3.80	0.26 0.12 0.06	5.11 2.00 0.74	20 17 12	1144 809 568	27 13 18	1.28 0.53 0.95	0.21 0.11 0.11	0.14 0.04 0.04	0.35 0.28 0.54	22.47 18.55 16.96	9 5 10
89	096 097	Nivudi	III	0-8 8-44	br. cl. y.r.cl.	4.30 3.90	0.27 0.07	4.14 1.30	15 19	1351 893	19 12	3.36 0.42	0.53 0.21	0.12 0.02	0.26 0.28	16.80 16.12	25 6
91	101 102	Nivudi	III	0-10 10-44	b. cl. y.r.cl.	3.80 3.85	0.25 0.08	4.00 1.29	16 16	1044 763	18 9	0.86 0.54	0.11 0.21	0.13 0.06	0.35 0.40	21.94 21.40	7 6
92	103 104	Nivudi	II	0-10 10-44	br.scl. y.r.sil.	3.80 3.90	0.25 0.09	3.46 1.71	14 19	811 573	9 4	1.62 0.43	0.54 0.11	0.08 0.03	0.27 0.48	18.36 19.26	14 5
93	105 106	Nivudi	II	0-10 10-44	d.r.br.scl. r.br.c.	3.80 3.80	0.30 0.07	5.16 1.29	17 18	1069 669	18 9	1.19 0.64	0.32 0.11	0.14 0.05	0.29 0.29	27.54 29.43	7 4

Site No.	Samp. No.	Location	Slope Class	Depth ins.	Appearance	pH ($CaCl_2$)	T/N%	Org C%	C/N	T/P_2O_5	Available P_2O_5	Exchangeable Cations m.e.% Ca	Mg	K	Na	C.E.C. m.e.%	BS%
										p. p. m.							
94	107	Nivudi	II	0-20	r.br.cl.	3.85	0.33	4.81	15	927	13	0.95	0.11	0.16	0.45	14.70	11
	108			20-44	y.r.c.	3.90	0.07	1.59	23	669	6	0.42	0.11	0.03	0.25	14.84	5
96	112	Nivudi	II	0-12	y.r.scl.	3.80	0.16	3.22	20	573	9	0.97	0.11	0.08	0.31	20.52	7
	113			12-24	r. c.	3.75	0.07	1.29	18	453	trace	0.54	0.54	0.02	0.27	19.26	7
	114			24-36	r.c.	3.75	0.05	0.85	17	453	trace	0.32	0.11	0.02	0.22	20.33	3
97	115	Nivudi	II	0-12	d.r.br.sl.	3.40	0.49	9.77	20	927	18	2.16	2.05	0.13	0.44	51.84	9
	116			12-24	y.r.cl.	3.65	0.20	4.80	24	717	13	0.64	0.21	0.04	0.16	25.15	4
	117			24-36	r.cl.	3.70	0.14	2.99	21	669	9	0.32	trace	0.04	0.33	24.08	3
102	127	F.D.C. Option Area	II	0-7	d.r.br.c.	4.35	0.45	5.60	12	911	27	4.66	2.97	0.24	0.45	23.32	36
	128			7-30	r.br.c.	3.90	0.18	2.05	11	652	8	1.68	1.26	0.03	0.27	32.55	10
	129			30-70	Weak r.sil	3.85	0.03	0.76	25	216	8	0.63	0.11	0.01	0.44	15.23	8
105	135	F.D.C. Option Area	II	0-8	d.r.br.c.	4.30	0.34	3.42	10	520	18	2.94	2.94	0.15	0.47	15.75	41
	136			8-30	d.r.br.sil.	4.20	0.10	0.48	5	218	trace	2.65	1.38	0.01	0.47	17.49	26
	137			30-72	r.br.sl.	3.70	0.03	1.31	44	173	trace	1.05	0.84	0.01	0.44	34.65	7
108	144	F.D.C. Option Area	III	0-9	y.r.c.	3.40	0.25	4.16	17	173	18	0.74	0.11	0.12	0.20	31.50	4
	145			9-36	y.r.c.	4.30	0.12	1.70	14	437	8	0.74	0.53	0.05	0.47	26.50	7
	146			36-72	y.r.l.	3.50	0.04	0.58	15	393	8	0.64	0.21	0.01	0.39	28.60	4
109	147	F.D.C. Option Area	III	0-8	y.r.c.	3.70	0.31	3.36	11	782	19	3.38	2.29	0.33	0.47	25.62	25
	148			8-24	r.c.	3.85	0.08	2.24	28	485	4	0.75	0.64	0.18	0.32	32.64	6
	149			24-72	w.r.c.	3.80	0.03	0.81	27	353	4	0,43	0.11	0.03	0.49	24.61	4
110	150	F.D.C. Option Area	III	0-8	r.br.c.	3.80	0.29	3.56	12	716	22	1.07	0.43	0.13	0.27	15.52	12
	151			8-24	y.r.cl.	3.80	0.07	1.17	17	264	trace	0.64	0.32	0.04	0.40	18.19	8
	152			24-60	y.r.sil.	3.90	0.04	0.81	20	220	trace	0.54	0.21	0.03	0.42	30.50	4

14

Site No.	Samp. No.	Location	Slope Class	Depth ins.	Appearance	pH ($CaCl_2$)	T/N%	Org C%	C/N	T/P_2O5	Available P_2O5	Exchangeable Cations m.e.%				C.E.C.	BS%
										p. p. m.		Ca	Mg	K	Na	m.e.%	
111	153	F.D.C. Option Area	II	0-10	dk.r.br.cl.	3.80	0.31	5.78	19	767	22	2.78	0.86	0.19	0.47	28.36	15
	154			10-44	dk.r.c.	3.95	0.28	4.11	15	574	22	2.57	0.75	0.17	0.43	31.57	12
A L L U V I A L S O I L S																	
*32	043	Navonu Sbd.	I	0-12	v.dk.gr.br.l.	5.20	0.30	4.78	16	892	32	9.46	6.93	0.08	0.68	43.45	39
	044			12-26	br.cl.	4.70	0.08	2.71	34	360	19	5.67	7.41	0.03	0.45	46.32	29
71	054	Nivudi	I	0-10	dk.br.c.	3.80	0.37	4.92	13	630	36	0.55	0.33	0.11	0.37	29.70	5
	055			10-24	dk.y.br.c.	3.75	0.15	2.42	16	545	4	0.11	0.11	0.03	0.34	31.90	2
	056			24-44	y.br.sil.	4.00	0.07	0.86	12	274	4	0.22	0.11	0.04	0.28	21.64	3
72	057	Nivudi	I	0-10	dk.br.cl.	3.90	0.54	6.67	12	1029	37	1.55	0.89	0.21	0.27	27.19	11
	058			10-24	y.br.cl.	3.80	0.10	1.86	19	554	13	0.34	0.34	0.03	0.26	21.84	4
	059			24-44	y.br.l.	3.70	0.05	0.61	12	457	9	0.56	0.11	0.03	0.30	21.64	5
78	071	Nivudi	I	0-12	d.br.cl.	4.00	0.28	2.83	10	1241	37	5.11	1.33	0.11	0.34	23.86	29
	072			12-24	d.r.br.cl.	3.90	0.05	1.38	28	696	19	2.69	1.57	0.03	0.32	26.32	17
	073			24-44	d.r.br.cl.	4.00	0.04	0.25	6	579	25	2.81	3.51	0.02	0.35	38.61	18
80	075	Nivudi	I	0-12	dk.r.br.l.	3.80	0.14	2.69	19	1093	28	3.81	2.24	0.07	0.32	26.88	24
	076			12-24	r.br.cl.	3.80	0.09	0.83	9	1066	24	1.04	0.69	0.01	0.25	22.42	9
	077			24-44	r.br.cl.	3.85	0.06	1.15	19	1144	41	0.90	1.57	0.02	0.38	21.28	13
84	084	Nivudi	I	0-8	dk.br.sl.	3.70	0.51	7.84	15	2272	56	1.12	trace	0.17	0.56	34.16	5
	085			8-44	br.sil.	3.80	0.09	1.36	15	1219	19	0.33	0.11	0.02	0.25	16.35	4
87	092	Nivudi	I	0-8	r.br.cl.	3.95	0.30	3.49	12	936	19	2.29	2.07	0.10	0.55	21.80	23
	093			8-44	r.br.sil.	3.90	0.09	0.86	10	839	9	0.99	0.88	0.07	0.55	26.40	9

* Recent alluvium

Site No.	Samp. No.	Location	Slope Class	Depth ins.	Appearance	pH (CaCl2)	T/N%	Org C%	C/N	T/P205	Available P205	Exchangeable Cations m.e.%				C.E.C.	BS%
										p.p.m.		Ca	Mg	K	Na	m.e.%	
88	094	Nivudi	I	0-10	dk.br.l.	4.40	0.33	3.71	11	1123	19	8.58	4.40	0.11	0.73	33.55	41
	095			10-24	r.br.cl.	3.90	0.09	1.18	13	789	19	5.28	3.08	0.04	0.70	42.90	21
90	98	Nivudi	I	0-8	dk.y.br.l.	4.10	0.49	5.24	11	962	19	7.17	3.70	0.16	0.40	45.92	25
	99			8-26	br.sil.	3.95	0.07	0.65	9	619	9	0.76	0.54	0.02	0.32	27.54	6
	100			26-44	r.br.cl.	3.95	0.11	0.98	9	549	4	1.89	1.11	0.03	0.57	24.98	14
98	118	Nivudi (oil palm plot	I	0-12	br.scl.	4.10	0.22	2.21	10	1145	19	5.00	2.78	0.22	0.30	24.98	33
	119			12-24	r.br.sil.	3.90	0.07	1.10	16	859	19	1.33	1.33	0.03	0.26	23.87	12
	120			24-36	r.br.sl.	3.85	0.05	0.66	13	811	18	0.88	1.54	0.04	0.44	25.30	11
* 101	124	F.D.C. Option Area	I	0-7	r.br.scl.	4.10	0.14	1.87	13	859	9	3.41	6.82	0.17	0.31	31.35	34
	125			7-25	dk.r.br.cl.	4.55	0.13	10.83	83	962	4	4.82	7.62	0.03	0.26	27.44	46
	126			25-72	dk.r.br.scl.	5.20	0.05	0.61	12	1176	36	4.18	6.82	0.02	0.26	24.75	46
* 103	130	F.D.C. Option Area	I	0-6	br. cl.	4.65	0.35	5.23	15	760	18	11.02	3.60	0.16	0.31	31.80	47
	131			6-36	y.r.sil.	3.80	0.10	1.24	12	671	9	1.08	0.54	0.01	0.45	23.22	9
	132			36-66	y.r.cl.	3.65	0.07	0.58	8	525	4	0.53	0.74	0.01	0.48	28.62	6
7.5						G L E Y S O I L S											
10	014	Loa	I	0-5	dk.br.c.	5.25	0.26	3.87	15	884	23	12.21	7.85	0.25	0.47	54.50	38
	015			5-18	dk.greensh gr. c.	5.30	0.21	4.02	19	630	36	12.32	10.34	0.07	0.48	55.00	42
	016			18-30	greenish gr c.w.t.at 6in	6.00	0.07	1.47	21	370	28	10.98	9.18	0.04	0.56	57.68	36
100	121	Navonu	I	0-7	dk.gr.br.l.	5.10	0.45	4.38	10	1118	23	10.56	6.38	0.12	0.59	35.75	49
	122			7-15	dk.gr.c.motts	4.30	0.09	1.33	15	330	4	4.62	6.60	0.01	0.33	34.65	33
	123			15-60	olive gr.c. motts.	4.90	0.03	0.66	22	289	trace	5.06	6.27	0.02	0.59	41.80	29

* Recent Alluvial Soil.

Site No.	Samp. No.	Location	Slope Class	Depth ins.	Appearance	pH ($CaCl_2$)	T/N%	Org C%	C/N	T/P_2O_5	Available P_2O_5	Exchangeable Cations m. e. %				C.E.C.	BS%
										p. p. m.		Ca	Mg	K	Na	m.e.%	
106	138	Navonu	I	0-7	dk.gr.br.sicl	4.30	0.11	0.58	5	983	27	6.25	4.35	0.03	0.49	32.86	34
	139			7-15	gr.br.cl.motts w.t.at 24"	4.90	0.24	2.88	12	1662	55	9.48	4.91	0.03	0.28	37.06	40
107	140	Navonu	I	0-9	dk.y.br.cl.	4.80	0.23	2.65	12	1092	22	8.45	5.46	0.18	0.52	43.34	34
	141			7-14	dk.br.l.	5.40	0.11	1.06	10	928	9	9.07	4.10	0.04	0.53	25.92	53
	142			14-21	dk.gr.br.c. motts.	4.25	0.06	0.60	10	540	19	5.01	5.34	0.01	0.26	35.97	30
	143			21-51	ol.gr.c.motts w.t.45ins.	4.80	0.16	1.88	12	860	13	6.57	4.45	0.02	0.48	29.68	39
*95	109	Nivudi	I	0-6	dk.gr.scl.	3.75	0.27	5.21	19	495	9	0.55	0.33	0.09	0.26	25.07	5
	110			6-20	dk.gr.br.cl.	3.80	0.10	1.73	17	330	13	0.32	0.11	0.03	0.31	17.82	4
	111			20-44	gr.br.c.motts w.t.at 36ins	3.80	0.08	1.48	19	165	4	0.32	0.11	0.03	0.46	21.20	4
VUNILAGI ESTATE OIL PALM PLOT																	
	155			0-15		5.20	0.35	4.22	12	1035	4	7.84	3.71	0.14	0.30	27.0	44
	156			15-30		4.05	0.07	0.77	11	353	trace	2.46	2.57	0.19	0.21	24.1	22
	157			0-15		4.70	0.25	2.70	11	1113	trace	7.09	5.78	0.09	0.36	44.1	30
	158			15-30		4.80	0.05	0.68	14	549	trace	6.27	8.03	0.20	0.30	53.9	27

*Old Alluvial Gley.

Appendix II 1.6

A guide to the intepretation of chemical analyses of Fiji soils (tentative).

pH ($CaCl_2$)	
RATING	RANGE
Very Acid Soils	Less than 4.0
Moderately Acid Soils	4.0 - 5.0
Neutral Soils	5.0 - 6.9
Alkaline Soils	More than 7.0

RATING	RANGE (%)		
	TOTAL N.	ORG. C	C/N RATIO
Very low	less than 0.1	less than 2	less than 8
Low	0.1 - 0.2	2 - 4	8 - 10
Medium	0.2 - 0.5	4 - 10	10 - 15
High	0.5 - 1.0	10 - 20*	15 - 25
Very High	more than 1.0	more than 20	more than 25

RATING	RANGE (m.e.%)			
	Ca	Mg	K	Na
Very low	less than 2.0	less than 0.5	less than 0.20	less than 0.1
Low	2.0 - 5.0	0.5 - 1.3	0.20 - 0.30	0.1 - 0.3
Medium	5.0 - 10.0	1.3 - 4.0	0.30 - 0.60	0.3 - 0.6
High	10.0 - 20.0	4.0 - 11.0	0.60 - 1.20	0.6 - 2.0
Very high	more than 20.0	more than 11.0	more than 1.20	more than 2.0

<u>T/P_2O_5</u>

less than	1000 p. p. m.	=	low
between	1000 - 2000 p. p. m.	=	medium
more than	2000 p. p. m.	=	high

<u>Available P_2O_5</u>

Very low	=	less than 50 p.p.m.
Low	=	50 - 150 p.p.m.
Medium	=	150 - 300 p.p.m.
High	=	300 - 500 p.p.m.
Very High	=	more than 500 p.p.m.

APPENDIX III

1. RECONNAISSANCE AREAS

1.1 Natewa Bay West : Access to the area is obtained by the extension of the Wainagata road, a feeder of the main east to west motor road.

1.1.1 Land Use : The density of rural population to potential arable area is reported to be low, but Ward (HMSO 1965) maps it at 201 - 350 persons per square mile, an average figure for the major part of the coastal margin of Vanua Levu. There are three subdivisions of native land in the area : Kubuna, Bucalevu and Tabia. The first two mentioned have a rational layout in terms of cultivable land, being designed by the Department of Agriculture. The last mentioned was of more spontaneous origin and is not considered to be well planned; many of the blocks occupy steeply sloping land and/or infertile soils. The balance of the native land is largely taken up with communal coconut groves. These very often occupy the best land and provide the Fijians with their main source of income. There is one coconut estate in the area, Navorau, which is 663 acres large with ca 450 acres of land with slopes less than 20°. Four extended Indian families (embracing ca 70 people) cultivate 100 acres of rice on low lying alluvial land astride the motor road south of Tabia Creek.

1.1.2 Lowland Soils : Twyford and Wright mapped the alluvium in this area as Wainibuka alluvial soil (6a) and Lawaki clay loam (6b). As correctly pointed out by Twyford and Wright, there is little fall in stream gradients, and the drainage after flood tends to be slow. The soils range from permanently flooded organic soils through Gley clays and poorly drained Alluvial soils to well drained fertile loams. The poorly drained areas grade into uncultivable saline marine marsh soils. Existing agricultural activities on the poorly drained alluvium range from the intensive rice cultivation on the Indian lease to semi-wild Duruka (Saccharum edule) on the poorly maintained Fijian land. Some Fijian rice planting has been carried out on the Buca levu subdivision. Planting of coconuts on poorly drained land has recently gone ahead and has been accompanied by a marked lack of success. Most of the better drained land is under mature coconuts palms. The Alluvial and Gley soils may be considered suitable for oil palm provided the level of the water table was lowered to a depth of 36 inches below the surface during the wetter part of the year. Improvement might depend on the construction of tidal gates and associated engineering works.

1.1.3 Hilly Land : The soils on the higher ground are Nigrescent soils in the south and Humic Latosols in the north. Twyford and Wright mapped the Nigrescent soils as Delaibo (75) stony and boundery clay. Very little coarse material was observed, and they are simply dark brown clays of moderately high base status. These represent the most fertile hill soils of the area. The fact that they are cleared of forest and colonised by reed is evidence that their fertility has been appreciated in the past. These soils are reported to dry out and crack during the drier part of the year (R.F. Burness, personal communication). They are well suited to coconuts, but in the case of oil palm, bunch production may be inhibited by soil desiccation in the drier part of the year. The Humic Latosols (Nacula boundary clay (84dM), Twyford and Wright) are inferior to the above in terms of fertility. They range from very low in fertility on the foothills (especially in the area west of Nabua) to low on the intermediate slopes. They are mainly under forest of Nokonoko. According to local farmers these soils were previously considered uncultivable, but have come into use with the coconut subsidy scheme. For agricultural potential, see paragraphs 9.2 to 9.2.6.

1.1.4 Acreages of Land with Slopes less than 20°

soil groups	acres	discrete units	slope class
Alluvial soils	2.900	9	I
Saline Marine Marsh soils	500	8	I
Nigrescent soils	1.200	7	II & III
Humic Latosols	2.400	18	II & III

1.2 Drekeniwai Area : This land may be divided into 3 categories from the point of view of soils and present land use : Alluvial soils, Gley soils, and the soils of the hill margins. The Alluvial soils are well drained and highly fertile and of relatively recent origin. They are planted with mature coconuts. Copra production by the Drekeniwai village community is said to total 300 tons per annum. Most of the better drained land is on the left bank of the river. The Gley soils take up most of the land on the right bank; in places they are used for dalo production, but otherwise they remain unused. The hill land has recently been subdivided for village farmers, and a small area has been planted with coconuts. The subdivision was drawn up by the Native Land Trust Board. Most of the subdivided area is unsuitable for planting due to the steepness of slopes. The hill soils on the southern flank are moderately fertile Nigrescent soils (i.e. moderately fertile dark brown clay loams) and suitable for coconuts, but those on the northern side are Humic Latosols.

1.2.1 Acreages of Land with Slopes less than 20°.

Soil groups	acres	slope class
Alluvial soils	300	I
Gley soils	450	I
Nigrescent soils	190	II & III
Humic Latosols	60	II & III

1.2.2 A small area of undeveloped land suitable for oil palm is to be found on the southern side of the Navonu Creek just above the Tavitavi falls. It comprises approximately 20 acres of Alluvial soil and 40 acres of Humic Latosols. It is believed to belong to the village of Nakobo on the southern coast of Natewa Peninsula.

1.3 Rear of Valavala Estate, and the area between the estate boundary and the F.D.C. Option Area : The above land comprises a unit contiguous with the area of the semi-detail soil survey. It is under forest and the soil groups mapped are equivalent to those described in the main body of this report.

1.3.1 Acreages of Land with Slopes less than 20°.

<u>Valavala Estate (rear)</u>:

soil groups	acres	slope class
Humic Latosols	280	II

<u>Between Valavala Estate</u> boundary and Navonu Option Area

Alluvial soils	80	I
Humic Latosols	105	II

1.4 Kasavu and Yalave: This area was included in the reconnaissance survey for the following reasons : It is easily accessible from the main road which runs along its southern boundary; it is of gently rolling relief; and it is at present not used for agriculture. It appears that the chief constraint on its development has been the complex land tenure situation pertaining in the area. It is bounded in the north by steeply sloping ground. Above the boundary the soils are mostly Lithosols and below Latosolic soils. The latter are forest covered, moderately fertile and closely comparable to the Latosolic soils described in the main body of the report. In the east they grade into an area of infertile Humic Latosols partly colonised with the low fertility tolerant species referred to in paragraph 9.2.2. In the west the soil boundary between the Latosolic soils and another type of Latosol is less clearly defined. This Latosol, not previously observed in the project area, is a dark reddish brown soil, often reed covered, derived from andesitic colluvium and an unconsolidated gray calcareous sandstone of Upper Pliocene age over which it lies. Judging by the vegetation this soil is intermediate in fertility between the Latosolic soils and the Humic Latosols. No chemical data is available. Some of the lowlying areas of poorly drained Alluvial and Gley soils are planted with rice. Other areas are covered by dense thickets of guava.

1.4.1 Acreages of Land with Slopes less than 20°.

	acres	slope class
Latosolic soils	650	II
Latosols (series not established)	560	II
Humic Latosol	205	II
Alluvial soils & Gley soils	234	I

APPENDIX IV

I. THE RECONNAISSANCE SURVEY OF TWYFORD AND WRIGHT

1.1 These comments are concerned with only a small area of the original reconnaissance.

1.2 The soils of the project area were divided into three main groups by Twyford and Wright and thence subdivided into five geographical types :

(i)	Recent soils	- Wainibuka Alluvial soils (6a)
(ii)	Gley soils	- Narewa Clay (51)
(iii)	Humic Latosols	- Lomaiviti Clay (29c)
		- Lobau Steepland Clay (83f)
		- Nacula Steepland Clay (84c)

1.3 Recent Soils : The field characters of the Wainibuka soils described by Twyford and Wright bear a close relation to the Alluvial soils observed in the project area. (They bear little relation to those mentioned in the Stewart Report. The passage quoted from Twyford and Wright (page 337) was taken from a description of the soils of Natewa Bay alluvial flats). The nutrient levels of the sample from Drekeniwai (Table XV, page 1, Twyford and Wright), given as typical of the Wainibuka soils, are very high compared with those of the old alluvium in the area of Navonu and Nivudi. The Drekeniwai flats are recent Alluvial soils, below the Tavitavi falls. They are noticeably dark brown in the C1 and C2 horizons unlike the reddish brown old alluvium above the falls.

1.4 Gley Soils : Narewa Clay is only briefly described in the reconnaissance survey, and laboratory analyses are not available. The two surveys agree in all important respects.

1.5 Humic Latosols: The laboratory results of analyses of Lomaiviti Clay are given on page 7 of Table XV (Twyford and Wright). The sample was obtained from the "Navonu Valley".

	pH	Av/P_2O_5	Ca (m.e.%)	Mg (m.e.%)	K (m.e.%)	CEC (m.e.%)	BS%
0 to 5 inches, very dk br clay	6.05	12 ppm	30.1	17.4	0.24	76.3	62
7 to 14 inches, very dk br clay	6. 3	14 ppm	23.5	23.0	0.06	63.2	74

The properties of this soil suggest a closer relation to a Lithosol or Latosolic soil than a Humic Latosol. Why Twyford and Wright classified this soil with the Latosols is puzzling in view of their statement (p. 125) "Humic Latosols.... are red or reddish soils, usually of clay texture .. .. moderate to low C.E.C. and are moderately to strongly acid".

1.5.1 The reconnaissance map described two other Humic Latosols under the heading of steepland soils. Lobau Clay was defined (p. 322) as being derived from andesitic tuff on steep slopes and as having seven inches of reddish brown, friable clay passing sharply to 30 inches or more of red, friable clay. In fact, the Humic Latosols described in the semi-detail report have no sharp boundary between the A1 and B2 horizons and are well over 72 inches deep. The B2 horizon was not friable, but structureless and massive. No chemical analyses were given for Lobau Clay but Twyford and Wright suggested that they corresponded closely to Sote Hill Soils. In practice they proved more acid, having higher levels of acid soluble phosphate (i.e. 44 p.p.m. as opposed to 1 p.p.m.) and lower levels of exchangeable K (i.e. 0.10 as opposed to 1.19 to 0.36 m.e.%).

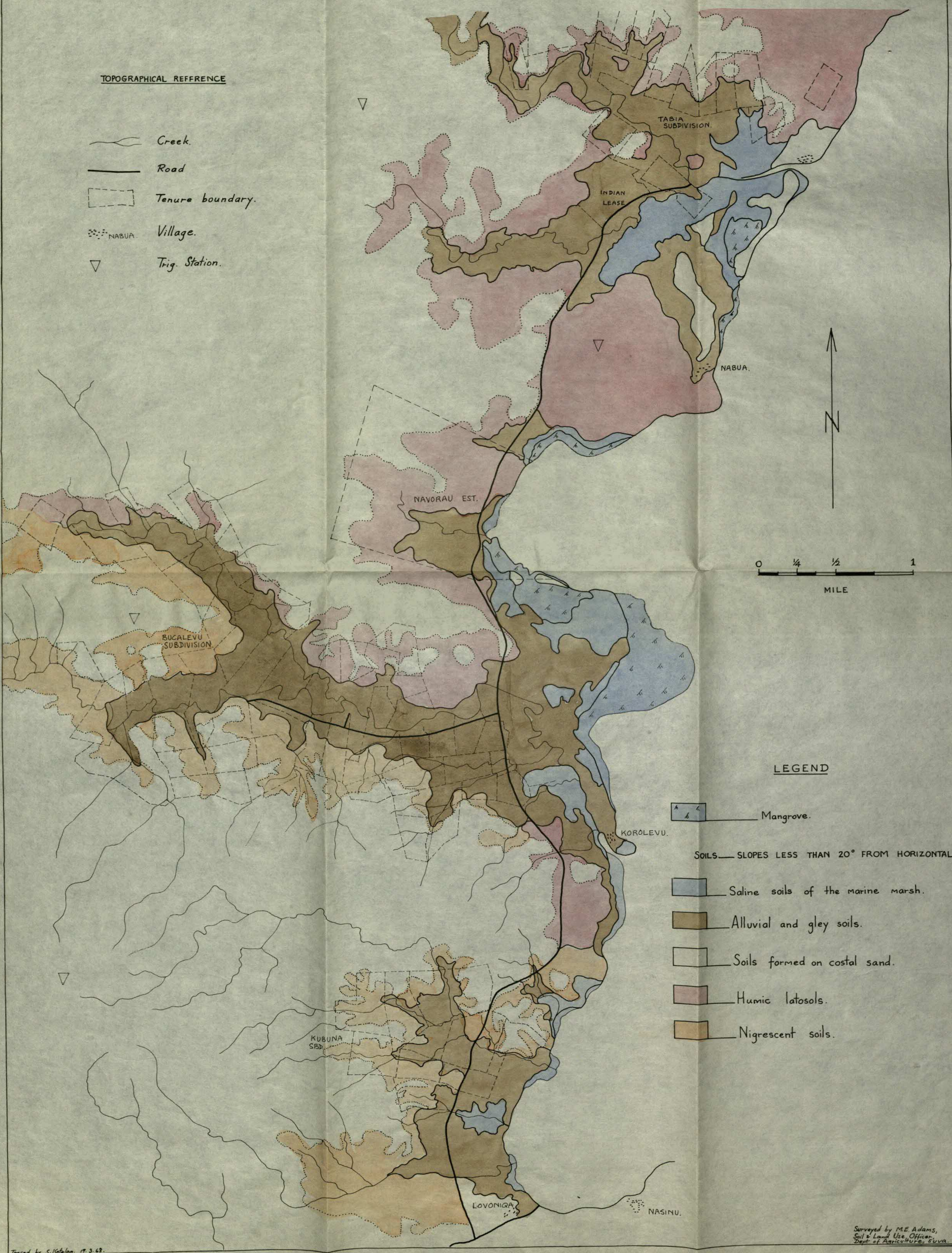
1.5.2 The Nacula Steepland Soil was defined (Twyford and Wright p.377) was a dark reddish gray friable to firm clay or a reddish brown clay over a reddish brown heavy clay with much weathered tuff. Humic Latosols similar to the above were not found in the project area during the semi-detail survey.

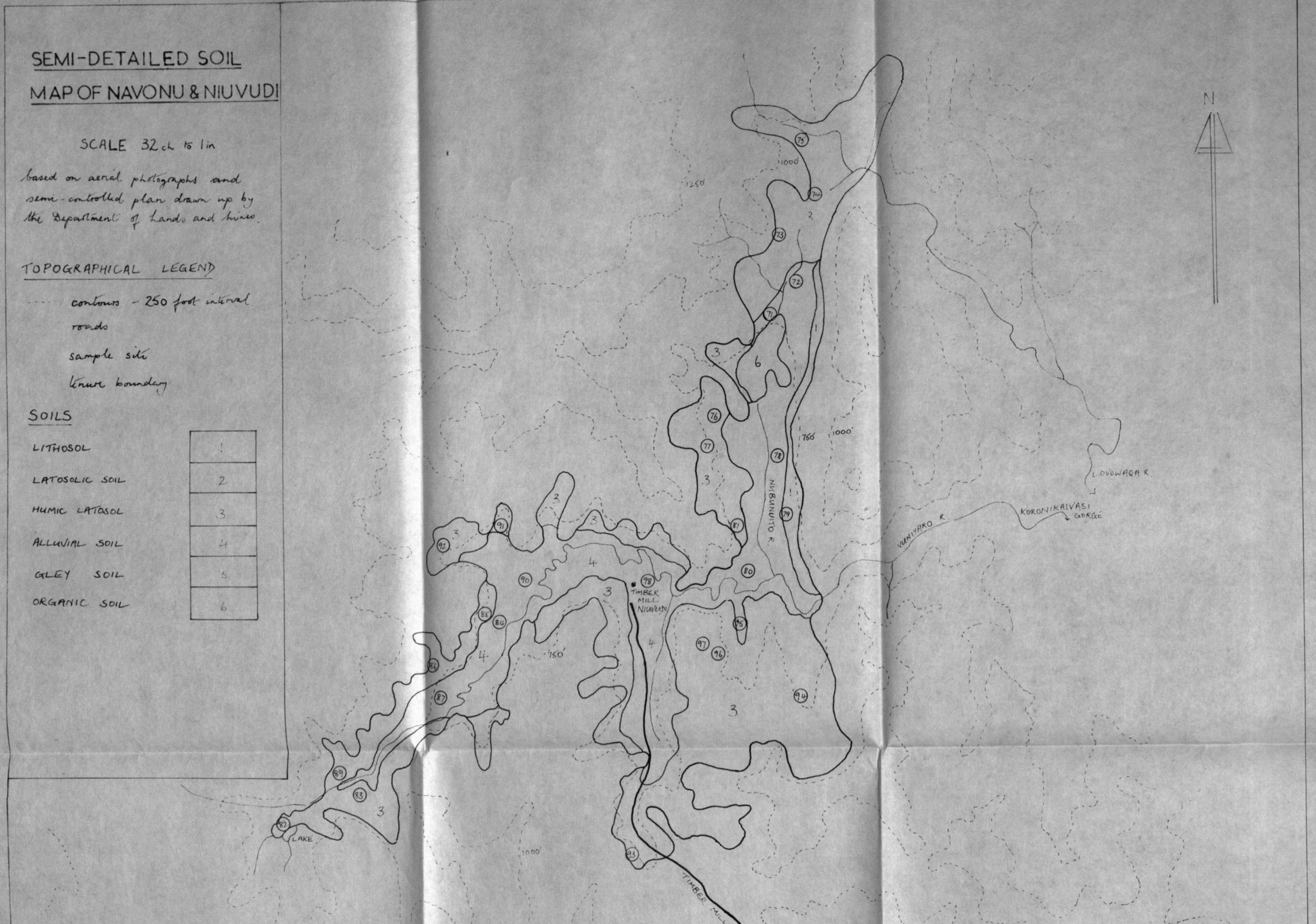
1.6 As Twyford and Wright have described a different suite of Latosols than in fact occur in the area, there were difficulties in adapting the geographical soil types of their report to fit the semi-detail work. A compromise was made by returning to the basic soil groups, Latosols, Alluvial soils, and Gley soils, and adding another sub-group, the Latosolic soils which were not previously described as being present. A fifth group - the Lithosols, was added which has been described previously in Twyford and Wright's work under another name. In the ten years since their work was completed, changes have been made in the international soil classification in order to rationalise the classification of tropical soils. In the light of this more recent work, attempts to classify the results of semi-detail soil surveys on the now outdated reconnaissance classification are bound to be unsatisfactory.

NATEWA BAY WEST

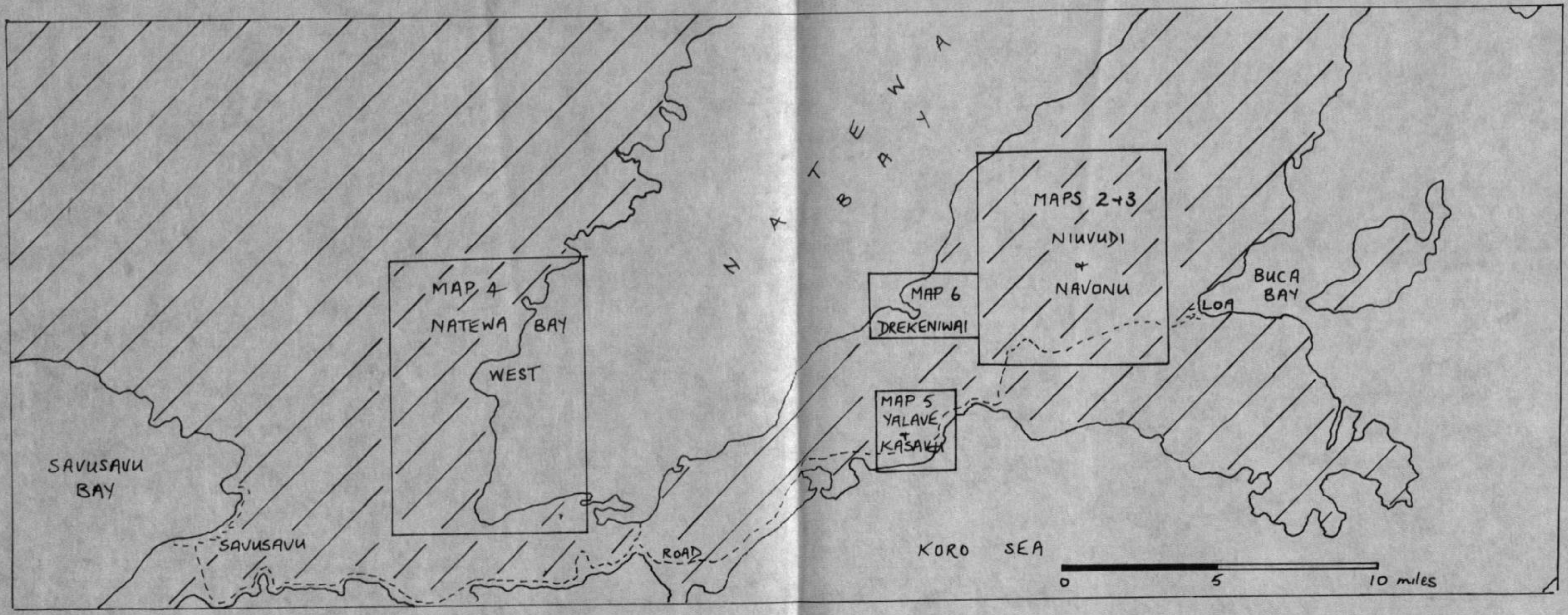
RECONNAISSANCE SOIL MAP

(Based on 1:24,000' Aerial Photographs and 1:50,000' D.O.S. Sheet.)

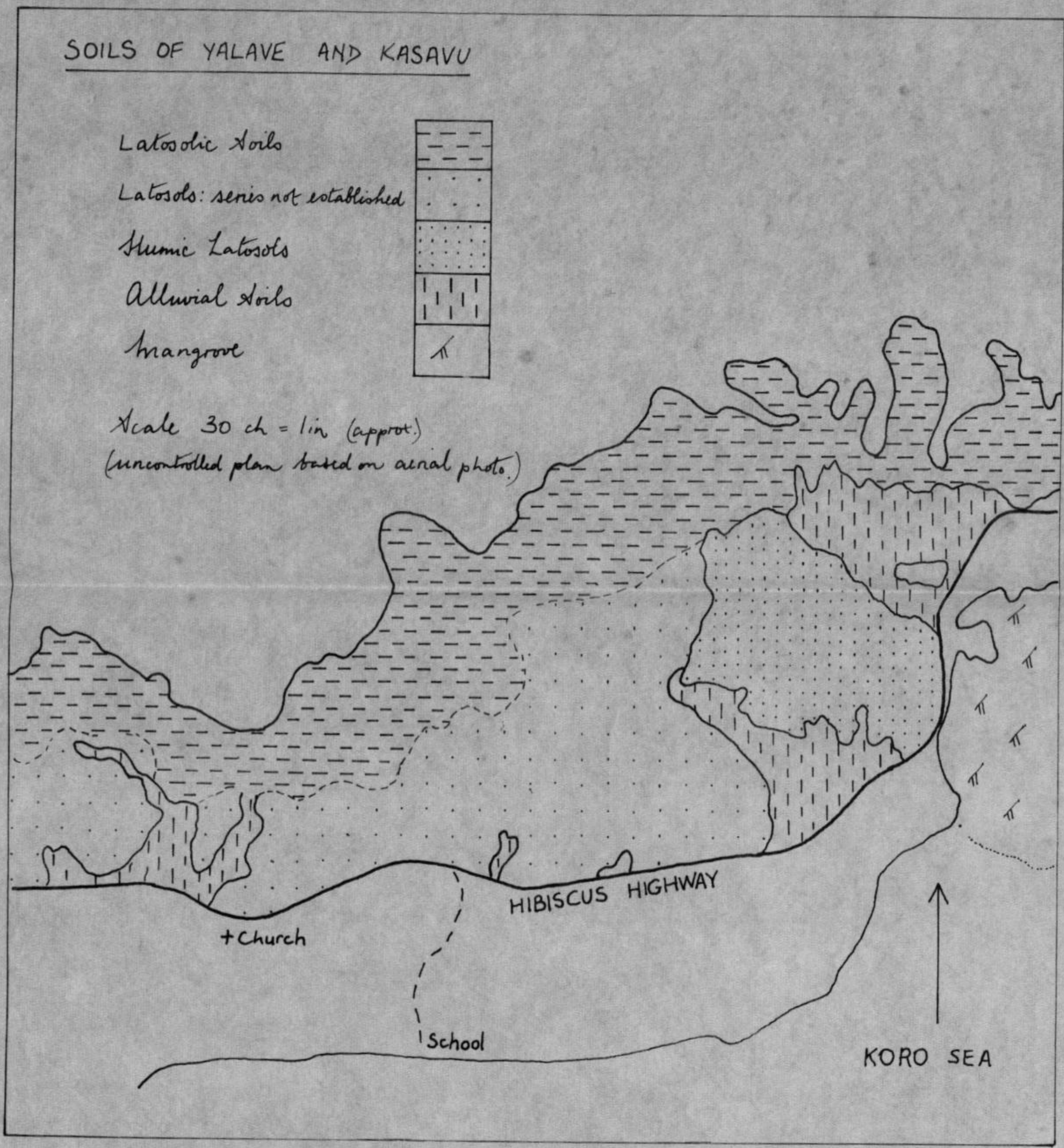



SEMI-DETAILED SOIL
MAP OF NAVONU & NIUVUDI
SCALE 32 ch to 1 in
based on aerial photographs and semi-controlled plan drawn up by the Department of Lands and Mines.
TOPOGRAPHICAL LEGEND
contours - 250 foot interval
roads
sample site
tenure boundary
SOILS
LITHOSOL 1
LATOSOLIC SOIL 2
HUMIC LATOSOL 3
ALLUVIAL SOIL 4
GLEY SOIL 5
ORGANIC SOIL 6
N
LOVOWAQA R.
KORONIKALVASI GORGE
TIMBER MILL NIUVUDI
LAKE
TIMBER MILL ROAD
VALAVALA ESTATE
CLOUD
F.D.C. BOUNDARY
OIL PALM TRIAL
F.D.C NAVONU OPTION AREA
TAVITAVI FALLS
NAKOBO LAND
NAVONU SUBDIVISION

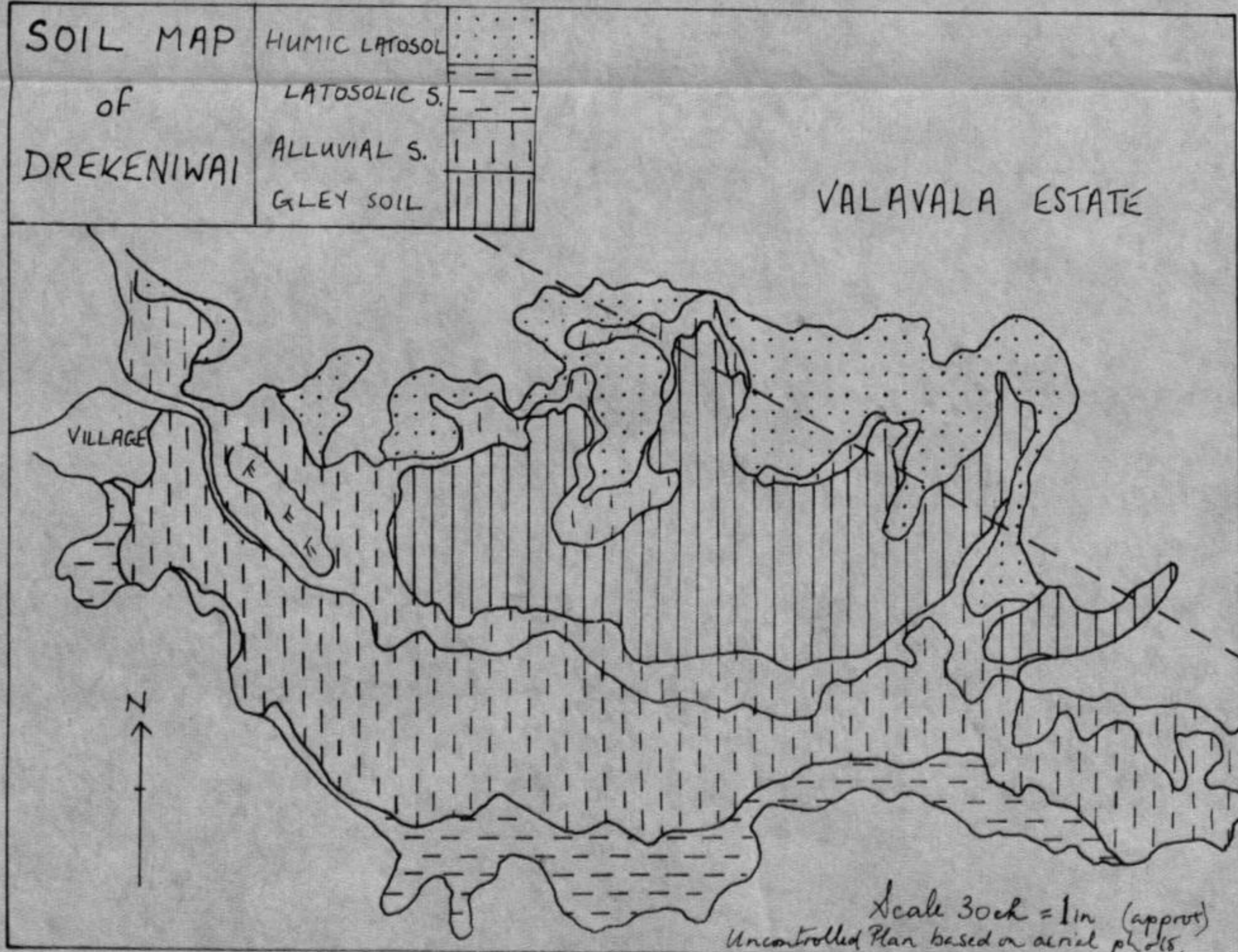
MAP 2


N A T E W A B A Y
MAPS 2+3
NIUVUDI
+
NAVONU
MAP 6
DREKENIWAI
BUCA BAY
LOA
MAP 4
NATEWA BAY
WEST
MAP 5
YALAVE
+
KASAVU
SAVUSAVU BAY
SAVUSAVU
ROAD
KORO SEA
0
5
10 miles

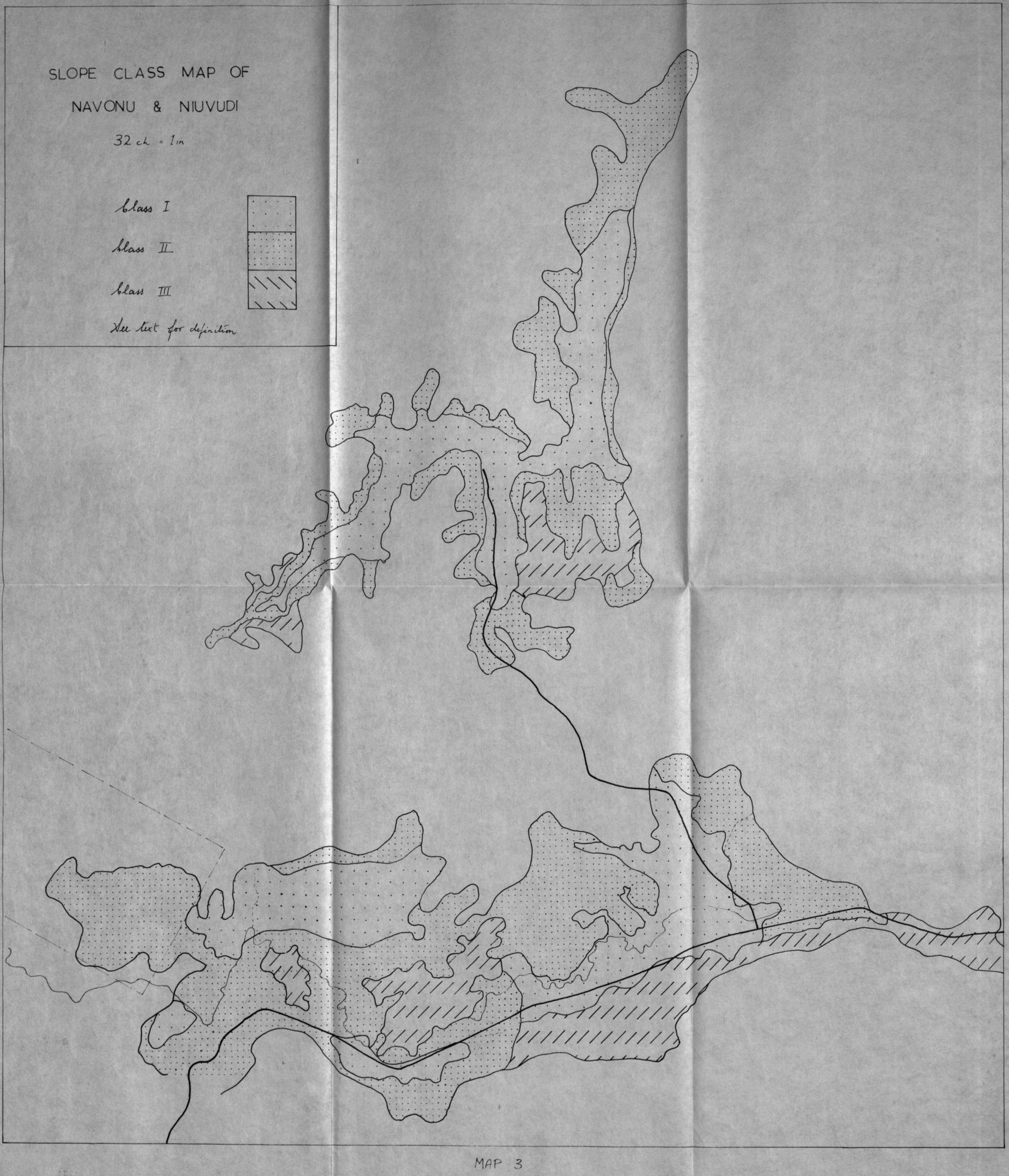
MAP 1 - KEY MAP


SOILS OF YALAVE AND KASAVU
Latosolic Soils
Latosols: series not established
Humic Latosols
Alluvial Soils
Mangrove
Scale 30 ch = 1in (approx)
(uncontrolled plan based on aerial photo)
HIBISCUS HIGHWAY
+Church
School
KORO SEA

MAP 5


SOIL MAP of DREKENIWAI
HUMIC LATOSOL
LATOSOLIC S.
ALLUVIAL S.
GLEY SOIL
VALAVALA ESTATE
VILLAGE
N
NAVONU R.
Scale 30ch = 1in (approx)
Uncontrolled Plan based on aerial photos.

MAP 6


SLOPE CLASS MAP OF
NAVONU & NIUVUDI
32 ch = 1 in
Class I
Class II
Class III
See text for definition

MAP 3