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GEOLOGICAL INVESTIGATION OF THE ROUTE OF THE KAINANTU-GOROKA ROAD, NEW GUINEA, APRIL 1966.

by

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CONTENTS

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SUMMARY

An investigation to confirm the geological feasibility of the Kainantu - Goroka road, Territory of New Guinea, was carried out in April 1966.

It was concluded that construction of the roadway to specification is geologically feasible but reservations are expressed as to the feasibility of maintaining the road as an all-weather highway on completion of construction. The occurrence of youthful topography, thick soil profiles, soft, unconsolidated sediments, and deeply weathered bedrock combine to form a major obstacle to the successful completion of the contract.

Several general recommendations, and more detailed recommendations for individual sections of the roadway, are presented in the report. Excavations should not exceed a vertical height of 20 feet, nor have a slope steeper than 1½:1, and embankments in cuts 20 feet or more deep should be benched; box-cuts should be avoided wherever possible. All traces of unstable overburden should be removed from areas to be filled before construction, and suitable steps should be taken to prevent base failure by either sinking or spreading of fills in areas of swampy ground or lake sediments. Adequate drainage should be provided along the entire length of the road.

INTRODUCTION

The second stage in the development of the Highlands Highway, Territory of New Guinea, is the construction of a new road between Kainantu and Goroka. For two-thirds of its length the proposed alignment follows the existing road with only minor deviations (Plate 1), but over the remaining distance the alignment has been entirely relocated. The first major deviation commences at Henganofi and rejoins the existing road at chainage 101,500 (feet); the second leaves the present road near the Lufa turn-off, crosses the Bena Bena River about 1½ miles upstream of the confluence of the Bena Bena and Asaro Rivers, and enters Goroka via the Asaro River Valley.

At the request of the Director, Public Works Department, Port Moresby, a geological investigation was carried out along the proposed alignment in April, 1966. The investigation was undertaken in order to confirm the geological feasibility of the proposed alignment; particular attention was paid to the problem of slope stability.

Plate 1 is a regional geological map showing the location of the existing and proposed roads. For details of the proposed alignment chainage and design, reference should be made to Territory of Papua and New Guinea Public Works Department drawings numbered 11F4/R1-1 to 11F4/R1-41 inclusive, prepared by McLean, Mackerras and Partners, chartered consulting engineers, Port Moresby.

REGIONAL GEOLOGY

The settlements of Goroka and Kainantu are both situated in intermontane basins surrounded by the ranges of the Eastern Highlands of New Guinea.

The large Goroka Valley is flanked to the north-east and north-west by the Bismarck Ranges, and to the south by the Asaro Ranges. It is drained southward by the Bena Bena and Asaro Rivers, whose waters discharge into the Gulf of Papua through the Tua and Purari Rivers. The smaller Kainantu Valley is bounded to the north and south-west by the foothills of the Bismarck Ranges and to the south by the Okapa Highlands. The Kainantu Valley is drained to the north coast of New Guinea by the Ramu River.

The oldest rocks in the area (Dow and Plane, 1965, and McMillan and Malone, 1960), consist of the Palaeozoic metamorphic complex of the Bena Bena Formation, which is unconformably overlain by a discontinuous succession of Tertiary marine sediments and volcanics. During the Pliocene, (Late Tertiary Period) the basement and the younger sediments were uplifted by a major orogeny, accompanied by vulcanism which continued into the Quaternary Period.

Active downcutting, and erosion of the sedimentary cover from the uplifted basement, commenced at the end of the Tertiary. Faulting and folding are believed to have led to the formation of the Goroka and Kainantu Valleys during the Pleistocene. Sedimentation in lakes formed in these valleys produced the Kainantu Beds* and some of the sand, silt and clay deposits which, together with the piedmont material, form the bulk of the Goroka Beds.

Subsequent downcutting by the Ramu River through the Bismarck Range and the Asaro River through the Asaro Range to a level lower than the surrounding valley floors completed the development of the present day topography.

STRATIGRAPHY

Rock Unit	Stage	Epoch	Period
Goroka Beds		Pleistocene	Quaternary
Kainantu Beds		Pleistocene*	Quaternary
Aifunka Volcanics		Pliocene ?	Tertiary
Elandora Porphyry		Pliocene ?	Tertiary
Akuna Dolerite	f1-f2	Lower Miocene	Tertiary
Daulo Volcanics	f1-f2	Lower Miocene	Tertiary
Omaura Greywacke		Lower Miocene	Tertiary
Nasananka Conglomerate		Lower Miocene	Tertiary
Bena Bena Formation			Palaeozoic ? to Mesozoic ?

*Radiocarbon dating of plant remains from near the base of the lake sediments at the site of the proposed Upper Ramu hydro-electric project, 8 miles north-east of Kainantu, give an age of 39,600 ± 2,000 years. On this dating the lake sediments are of Recent age. Confirmatory work is in progress.

Bena Bena Formation

This formation comprises green actinolite schist, quartz-muscovite schist, hornblende gneiss and rare quartzite. Except in a slide area at chainage 185,700, no fresh outcrop of Bena Bena Formation was observed along the proposed alignment. The formation is moderately to highly weathered for a considerable depth below the surface.

Nasananka Conglomerate

Rocks include pebble and boulder conglomerate, arkose, greywacke and siltstone. The only fresh outcrop observed is exposed at chainage 145,900, where moderately soft, grey, medium to coarse-grained arkosic grit is exposed in a creek bed. Although shown on Plate 1 as Omaura Greywacke the sediments exposed along the road between chainage 150,000 and the Dunantina River may belong to the Nasananka Conglomerate. The extensive weathering of the outcrops make positive identification difficult.

Omaura Greywacke

Fine to medium grained greywacke with interbeds of siltstone and shale. Fresh to moderately weathered Omaura Greywacke is exposed in the steep-sided Kafetina Gorge between chainages 163,700 and 159,500, and in the Dunantina River. Elsewhere the formation is highly weathered to a depth of 50 feet or more below the surface.

Daulo Volcanics

Light grey, fine to medium grained, hornblende-feldspar porphyry. Depth of weathering in these rocks is slight, and moderately hard, slightly to moderately weathered rock can be located 6 feet or less below the surface.

Akuna Dolerite and Elandora Porphyry

Neither the Akuna Dolerite nor the Elandora Porphyry crop out along the road alignment.

Aifunka Volcanics

These volcanics consist of fine-grained porphyritic andesitic lavas, quartz porphyry and basalt flows, dykes or sills, and andesitic tuff and agglomerate. They crop out between the Rypinka Mission Station and chainage 239,500, and are completely weathered to a considerable depth below the surface.

Kainantu Beds

Horizontally bedded cobbles and pebbles in a sand and clay matrix (conglomerate), sands, silts and clays constitute the Kainantu Beds. They are all of lacustrine origin.

Goroka Beds

The Goroka Beds consist of unstratified boulder beds, gravel, sand and clay (derived from piedmont fans originating in the valleys of the Bismarck and Asaro Ranges), and horizontally bedded pebbles, sands, silts and clays of lacustrine origin.

ENGINEERING GEOLOGY

For simplicity the engineering geology is described in sections divided by alignment chainages, starting at Kainantu.

266,000 to 250,000

Except for minor cuts and fills to widen radii, the new alignment follows the existing road across Ramu River gravel flats and the clayey gravels of the Kainantu Beds. Cuts as far as 255,400 are in stable Kainantu Beds, but over the remainder of the chainage are in slope-wash and soil which show superficial signs of soil creep on cross-slopes as flat as 5 to 10 degrees.

Very incompetent, black, silty and clayey soil is located in a swampy area between 256,600 and 255,800. Although it does not cover a very wide area, the incompetent soil may be more than 12 feet thick.

250,000 to 239,450

From 250,000 the alignment continues to follow very closely the existing road across completely weathered Aifunka Volcanics. Bedrock is not exposed, and the cuts and pavement will be formed in red to red-brown silty clay. Two samples from residual clays in existing cuts, KG01 from about 249,000 and KG02 from about 242,000, have liquid limits of 70.0 and 74.9, and plasticity indices of 34.2 and 39.3 respectively. (MH., see Appendix 1).

Although relief is slight and cross-slopes are generally less than 20 degrees (maximum 30 degrees), the area along the alignment is very prone to shallow-seated sliding of soil over firm, residual clay. Gullies which will require filling, particularly between 247,000 and 246,000, and from 243,600 to the bridge site at 239,450, contain considerable quantities of slide debris which is unstable and active.

239,450 and 223,000

Again only minor deviations are made from the existing road as the alignment cuts through low ridges of Bena Bena Formation and passes over several areas of flat, swampy ground located between the ridges.

Bena Bena Formation exposed in existing cuts, although always rippable, is predominantly only moderately weathered and quite stable. The depth of residual clay is generally only a few feet. Sample KG03, derived from predominantly gneissic rock, has a liquid limit of 70.9 and a plasticity index of 32.9 (MH); sample KG04 from predominantly schistose material at about 224,000 has a liquid limit of 37.6 and a placticity index of 10.7 (ML). Only minor slips of overburden over firm clay were observed; most of them are in gullied cross-slopes.

The swampy areas between ridges contain thick deposits of black, peaty and silty organic clays. The chief occurrences are between 233,400 and 228,400, and also from 226,000 to 224,200.

223,000 to 207,000

The new alignment follows the existing road from the start of the section as far as 216,931 (where there is a change in chainage, 216,931 becoming 220,000), at the head of the Kafetina Valley. From 216,931 the alignment deviates to the south side of the Kafetina Valley, rejoining the existing road at 207,000.

From the start of the section to 216,931 the existing road follows the top of a deeply weathered, steep-sided ridge where 10 to 15 feet of soil and overburden overlies firm, red, silty clay. Sample KG06 of residual clay from 216,931 has a liquid limit of 63.9 and a plasticity index of 20.6 (MH). The ridge has slopes of up to 40 degrees and is unstable; several slips of overburden over firm clay were observed.

Beyond 216,931 (220,000), the new alignment requires extensive side-cut and fill on slopes of up to 35 degrees, and one 60-foot deep box-cut at 218,100. There is no solid outcrop; a thick soil and overburden overlies firm, yellowish to red, residual clay, and rare exposures of moderately to highly weathered schist and gneiss. The slopes are clearly unstable, and numerous slides have occurred.

Beyond the culvert site at 212,000 the alignment crosses three slips at 210,900, 210,100 and 209,200. Each slip is sited in a bottleneck shaped gully about 250 feet wide, and slumping and soil creep is still active. Slopes all along the section are unstable, and will become active if disturbed.

207,000 to 180,500

From 207,000 the new alignment follows the existing road along the gravel river flats on the south side of the Kafetina River Valley. The section is probably one of the best along the route, and to 185,700 there will be no difficult construction problems. At 185,700 there is an extensive slip of overburden; movement has occurred along northerly dipping planes of foliation in the underlying, moderately weathered, gneiss. The lower slopes are clear of debris but on the upper third of the slope there is still a large quantity of material, lying loose, which is likely to come down with very little warning.

From 185,700 to the bridge at 180,500, meanders of the Kafetina River flow very close to the existing and new alignments, and small amounts of under-cutting have taken place at the toe of some embankments. The damage is not serious, but corrective action will be necessary.

180,500 to 163,700

Below the bridge at 180,500 the Kafetina Valley becomes more constricted than above the bridge and enters a short, but steep-sided, gorge at 163,700. The new alignment follows the existing road across cross-slopes which average between 20 and 30 degrees, and which in places are as steep as 40 degrees.

The road will be formed in highly to completely weathered Omaura Greywacke; depth of weathering is extensive, and no fresh bedrock is exposed in this section. Two samples of residual clay, taken from 176,800 (KG07), and 166,000 (KG08), have liquid limits of 40.7 and 44.7, and plasticity indices of 16.7 and 19.6 respectively (both CL). Despite the lack of outcrop, relic bedding is a common occurrence in the residual clay. The attitude of the bedding is such that the dip is outwards (south), into the valley at an average of about 35 degrees. The relic bedding planes form preferential slip planes and the slips which have taken place along the existing road can be related to this structure. One severe slip is located between 166,500 and 166,900. Not only has the slope above the cut failed, but the steep (45 degrees) slope which drops away about 150 feet vertically to the river below the road has been eroded by storm-water run-off and river encroachment at the toe.

Creeks running across the alignment into the Kafetina River are deeply incised and carry a very large volume of water after heavy rain. Construction of permanent fills in the deeply incised waterways is likely to be difficult.

163,700 to 159,600

In this section the road passes through the steep-sided Kafetina Gorge. The gorge is one of the few sections along the route where fresh, or only slightly weathered bedrock is exposed. However, the advantage gained is somewhat offset by the difficulty of working in such steep, rugged terrain.

Bedrock is fresh to slightly weathered, horizontally bedded Omaura Greywacke, consisting of fine to medium-grained beds of greywacke with thin interbeds of shale and siltstone. Although hard and strong, the rock is very fractured and may be difficult to work with explosives.

River encroachment into the toe of fill areas will be a problem if suitable corrective measures are not employed. The river is undermining the existing road at 162,000, 160,300 and 159,700.

There is little evidence of slope instability through the gorge. Vertical cuts remain as formed, and the small amount of dislodged material is of loose rock, scree and soil which has been washed from the top of vertical cuts.

159,600 to 147,000

This section takes the alignment from the end of the Kafetina Gorge to the start of the first major deviation at 147,000. Fresh bedrock is not exposed and the road will be formed in completely weathered Omaura Greywacke. A sample of residual clay (KG09), taken from 155,500, has a liquid limit of 72.6 and a plasticity index of 40.6 (CH). Apart from the first quarter of the section where some slopes are up to 30 degrees, cross-slopes are not steep, normally averaging between 15 and 20 degrees. Very few slides have occurred along the existing road. Where failure has occurred it has been in the form of movement of overburden over firm clay located about 10 feet below the surface.

147,000 to 101,500

The deviation leaves the existing road about ½ mile west of Henganofi, crosses the Dumantina River half a mile south of the present bridge, and cuts through a low saddle at the western end of Mount Trulatrulaga, before rejoining the existing road at 101,500.

From the start of the deviation to the Dumantina River crossing, the alignment will be formed on completely weathered Omaura Greywacke, and possibly some completely weathered Nasananka Conglomerate. Little evidence of landslides can be observed between 147,000 and 138,000; weathering is apparently deep, but cross-slopes are slight, averaging 10 to 15 degrees. Beyond 138,000 the increase in road gradient is accompanied by an increase in cross-slopes up to 35 degrees, and in this section small slides can be observed. From the top of the gradient at 132,000 to the Dumantina River, cross-slopes are also slight, but soil creep and shallow slides occur around the edges of numerous small gullies. Wherever failure has occurred the surface material has moved over the firm clay beneath. Relic bedding in completely weathered bedrock, and a few small outcrops of moderately weathered greywacke and siltstone, over which soil and scree has slid, are exposed in cuts in the existing road on the descent to the existing Dumantina River bridge. A sample of residual clay (KG10), taken from about 129,000, had a liquid limit of 69.4 and a plasticity index of 38.4 (CH).

From the Dumantina River crossing to the Trulatrulaga ridge, and from this ridge to the existing road at 101,500, the alignment crosses extensive areas of swampy ground. The swamps contain thick deposits of black, silty and organic clay, and are poorly drained. Gullies are filled with silty and clayey soil and scree which merge with the swampy areas. However, the higher ground is more stable; weathering is not deep, and moderately fresh siltstone (Omaura Greywacke), and hornblende - feldspar porphyry (Daulo Volcanics), occur within a few feet of the natural surface.

101,500 to 68,000

From 101,500 to the ridge at 88,700 the alignment cuts through high ground consisting of moderately soft and weathered, but strong, hornblende - feldspar porphyry. However, fill areas and the alignment between 93,000 and 90,500 are on swampy ground consisting of black, silty organic clay, and silty and clayey slope-wash material. The swampy ground is poorly drained, and where crossed by the existing road there are many signs of base failure by sinking.

Beyond 88,700 the alignment follows the existing road across the piedmont deposits and lake sediments preserved in the Goroka Basin. The piedmont gravels are quite firm and stable, but the silty layers which occur within the horizontally bedded lacustrine gravels, sands and clays make the lake deposits prone to failure. Two occurrences of lake sediments are known at the approaches to the bridge site at 81,000 and in the fill area at 78,200. A careful check should be maintained along the rest of the road in case any other lake deposits containing silty layers are uncovered during excavation.

68,000 to 51,850

The second major deviation leaves the existing road at 68,000 and crosses the Bena Bena River about 1½ miles above the confluence of the Bena Bena and Asaro Rivers.

For most of its length the road crosses lake sediments, preserved on the sides and shoulders of small valleys cut into piedmont deposits of the Goroka Beds. The lake sediments consist of horizontal pebble beds, sand, silt and clay, the thickness of which are not known. Drainage is poor, particularly in low-lying depressions, and the presence of silty and clayey layers makes the sediments prone to sliding. Soil creep and surface sliding are prominent on the small valley slopes and also on the descent from 56,100 to the Bena Bena River.

The approaches to the Bena Bena bridge are located on fill between 53,020 and 52,387, and 52,068 to 51,850. The fill on the eastern side of the bridge is across a gully before the abutment on the river bank is reached, but that on the western side is formed in the river bed. At the time of the investigation the river by-passed the bridge site and ran in a large loop through the proposed fill area on the western approach.

The depth of gravels in the river is not known, and nothing is known of the rock type beneath the gravels.

51,850 to 00

After leaving the Bena Bena bridge the alignment is westwards across a low divide into the Asaro Valley and thence almost due north to Goroka.

Lake sediments, intermingled with piedmont deposits, occur along the alignment from the bridge as far as 43,000. The lake sediments form a thin cover along the sides and shoulders of small gullies on each side of the divide between the two valleys, and will be troublesome in fill areas.

From 43,000 to 35,000 the ground is swampy, and poorly drained; black, silty and organic clays extend an unknown depth beneath the alignment. The existing track across the swampy area is impassable after heavy rain.

At 35,000 the road rises from the swampy area to a higher terrace level of the piedmont gravels and follows a well-formed existing road the rest of the way into Goroka. The gravels are well drained and stable, and no problems are foreseen in this section of the highway.

CONCLUSIONS

Construction of the Kainantu - Goroka road to specification is geologically feasible. However, unless the measures outlined in the recommendations are carried out during construction, reservations are expressed as to the feasibility of maintaining the highway as an all-weather road on completion of construction. Because of the many problems associated with the construction of a permanent roadway, the construction work will need to be closely supervised.

A combination of factors common to most of the Highland regions of New Guinea provide the major obstacle to the successful completion of the contract. These are: youthful topography, thick soil profiles, soft, unconsolidated sediments, deeply weathered bedrock, and high moisture content of the soil and rock. The stability of the steep-sided slopes is undermined by the high rainfall in the wet season (November-April, see Appendix 2). Additional problems are presented by the presence of extensive areas of low-lying, swampy ground, and unstable silt and clay lake deposits along several sections of the highway.

Both general recommendations and more detailed recommendations, for sections of the alignment, are made below. Some of the recommendations, if implemented, will lead to an increase in the cost of the project. However, if the Kainantu - Goroka road is to be constructed as an all-weather road it is considered that the cost involved in carrying out these recommendations will be less than the cost of maintaining, and probably re-establishing, sections of the road damaged by landslides which will occur in the wet season. The likely effect of a closure of the highway on the Highlands Districts must also be taken into account.

GENERAL RECOMMENDATIONS

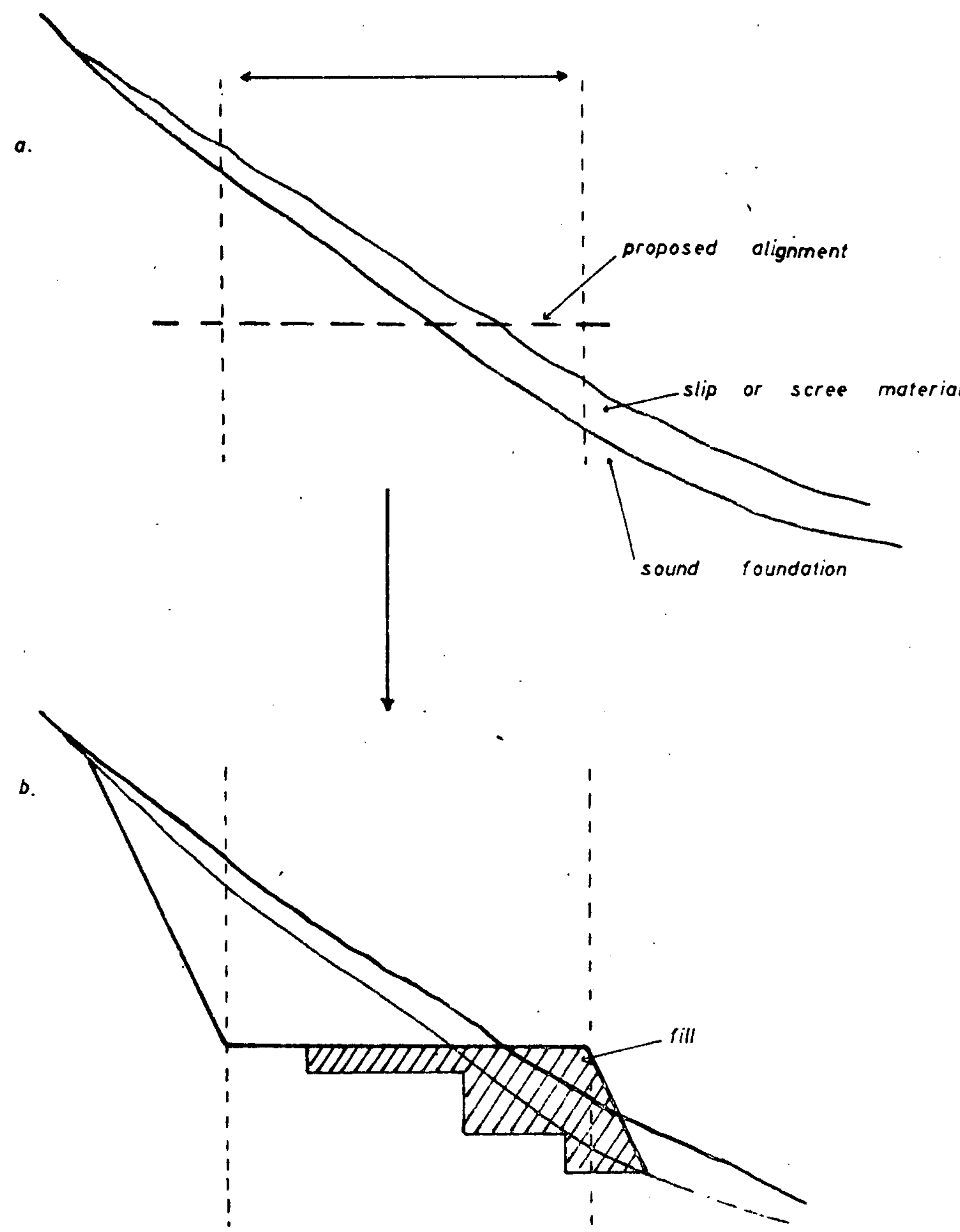
It is recommended that:

Excavations

A. Side-cut and box-cut embankments should not exceed a vertical height of 20 feet, nor have a slope steeper than 1½:1. Embankments in cuts 20 feet or more deep should be benched; the width of the berms so formed should not be less than 10 feet. Where a cross-slope is steeper than that recommended for the slope of the embankment the angle of the cross-slope should be reduced. These recommendations are aimed at preventing two types of failure:

(i) failure of the ground above the cut due to removal of support from the toe of the slope in the cut. This type of failure is the dominant cause of landslides along the existing and proposed roads. In nearly all cases there is a definite interface between overburden and firm ground; in some cases this interface corresponds to outward dipping relic bedding, and in nearly all instances is aligned roughly parallel to the surface topography. With the removal of support and, in the wet season, entry of water into the overburden and along the interface, failure occurs, and the overburden slides over the firm ground.

(ii) embankment failure. The strength of the residual clays along the alignment - resulting from cohesion and internal friction - rapidly tends towards zero when the mass becomes saturated. It can be observed that few embankments along the existing road which have a vertical height in excess of 20 feet maintain stability for long in the wet season. Any increase in the vertical height, or the slope, of an embankment over twenty feet should be made only if favourable results are obtained from fig 1



Schematic drawing of excavation for cut and fill on side slope.

Geological Office, Port Moresby 20·6·66

PNGB 55·9·4

To accompany Record 1966/161

B55/A10/33

from tri-axial tests on undisturbed samples from the site. Consideration must also be given to the influence of local geological structures.

B. Box-cuts should be avoided wherever possible; if required, they should be kept to the minimum possible depth and length, and be excavated in accordance with A., above. Clearing of slide material from a box-cut can be a slow, difficult process, and if a major failure takes place it may be impossible to clear and reform the alignment in all but the most favourable weather conditions. The disastrous effects resulting from box-cut failure have been well demonstrated at Kassam Pass.

In the event of a box-cut being necessary it is considered advisable to increase the road formation width by up to double that required, particularly in bad ground. The additional width would decrease the likelihood of road blockage if a slide does occur, and also simplify the task of re-establishing the alignment.

Fills

C. Fills incorporated with side-cuts, and fills in gullies on side-slopes, are liable to failure if placed on unstable ground, such as slide material or slopes where the overburden and soil is demonstrably slide-prone. All traces of unstable overburden must be removed from the area to be filled, and on side-slopes it is recommended that the additional precaution of benching the foundation be carried out (fig. 1). If the unstable material is not removed base failure will occur and the fill will be lost. Compaction of the fill should be strictly supervised at all stages of construction.

D. Suitable steps should be taken to prevent base failure by either sinking or spreading of fills in areas of swampy ground or lake sediment deposits.

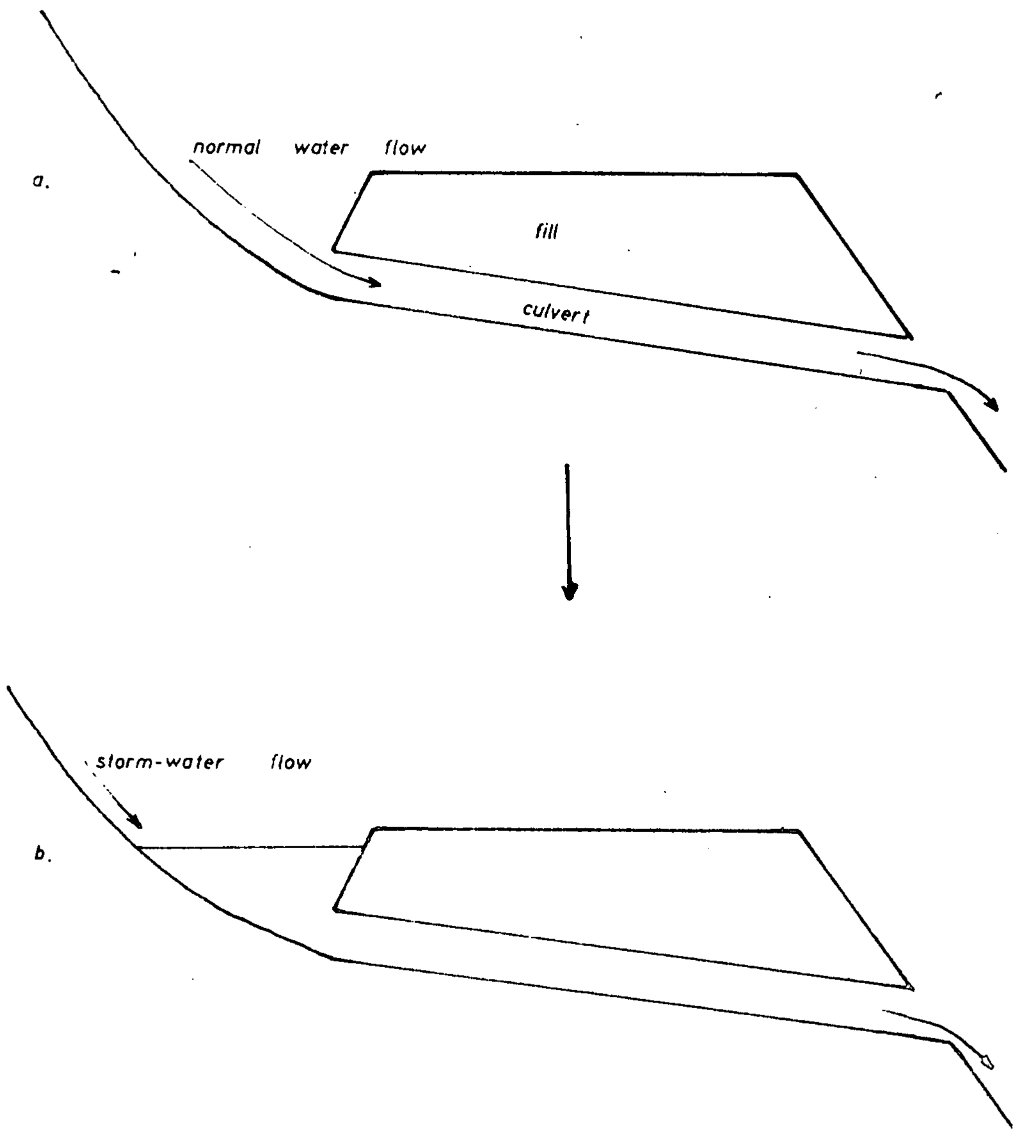
Failure by sinking is prevalent in the swampy areas along the existing road and can be expected at any location where the new alignment crosses swamps. Excavation and backfilling of the swamps will be expensive and probably impractical,so consideration should be given to pre-draining the alignment. Possibly, owing to the oversaturation or impermeability of the silty, organic clays, pre-drainage will not be possible and slow, controlled compaction may be the only alternative. In any case drainage must be provided to prevent increase in pore-water pressure during consolidation.

Fills in areas of lake sediment deposits are likely to fail by spreading of the fill, caused by silt layers within the horizontally-bedded deposits of pebbles, sand and clay. The lake sediments do not appear to be very thick and it may be economical to remove unstable material and backfill the alignment with an approved aggregate. If not, compaction of the sub-base should be carried out very slowly to ensure that there is no unacceptable increase in pore-water pressure within the silty layers.

In all areas where lake deposits and swampy ground occur, steps should be taken to determine the depth of the deposit before construction of that section commences.

Drainage

The provision of adequate drainage is one of the most important aspects in the design of the new road. Nearly all the landslides in the Highland Districts have occurred during the wet season, a fact which emphasises the part played by water in creating them. The entry of water into overburden and soil, or along preferred slip planes, reduces the cohesion and the angle of internal friction to a value below the minimum fig 2



Schematic drawing of culvert design

Geological Office Port Moresby 20·6·66

PNGB55·9·5

To accompany Record 1966/161

B55/A10/32

required for stability. Equally important is the erosive action of large volumes of uncontrolled storm-water run-off. Water should not be released on fill material.

Culverts should be designed so that storm-water run-off can be cleared as rapidly as possible. The contract design for culverts allows for a time lag such that it is possible for a head of water to build up behind the culvert (fig. 2). This increases the likelihood of the culvert becoming blocked and introduces a seepage of water into the fill. Piping, leading to the eventual failure of the fill could result, particularly if compaction of the fill during construction had not been adequate.

DETAILED RECOMMENDATIONS FOR INDIVIDUAL SECTIONS OF ROAD

266,000 to 250,000

The thickness of the silty, organic clays in the swamp area between 256,600 and 255,800, should be determined and the possibility of pre-drainage fully investigated. All traces of unstable ground should be removed from the alignment between 255,400 and the end of the section, particularly in the fill area 254,000 to 253,200.

250,000 to 239,450

The unstable slide material in the wide gully between 247,000 and 246,000 should be removed and firm ground exposed before fill is placed. The culvert outlets must be well protected against erosion by storm-water run-off. Similarly, unstable slide material will have to be removed from each of the fill areas between 243,600 and the bridge site at the end of the section. All 18-inch culverts should be replaced by culverts with a minimum diameter of 24 inches.

239,450 to 223,000

The thickness of the peaty and silty organic clays in the swamp areas between 233,400 and 228,400, and from 226,000 to 224,400, should be determined before construction commences. The feasibility of pre-drainage should also be investigated. Any ditches excavated for pre-drainage of the swamps need to be maintained as permanent drains on completion of the section. The strength and stability of the abutments for the bridges in the section must be carefully checked prior to construction.

223,000 to 207,000

Fill areas 220,150 to 219,800, 219,330 to 218,970 and 217,800 to 217,200 are located across, and on the side of a steep-sided, narrow ridge. Slopes in the area are unstable and great care will have to be taken in the excavation for, and placement of, the fills. The centre line between 220,150 and 218,970 is well to one side of the ridge crest. It is considered that it would be more satisfactory to re-align the road so that the centre line is moved back to the ridge, even though this would mean a slight reduction in the radius of the curve. The benefit gained in stability and reduction of fill would compensate the disadvantage of a slight reduction in standard.

It will be difficult to maintain stability between 216,931 (220,000), and the culvert site at 212,000. Slopes in this section are steep and clearly unstable, and the removal of support from the slopes by the cutting of batters will increase the danger of landslides. All batters will have to be benched and particular care will have to be taken to ensure that fill material is placed on firm ground - benching of the foundation will probably be required. Drainage provisions will need to be adequate and it is recommended that all culverts in the section have a minimum diameter of 36 inches (as against the 18 inches specified in the design). It is essential that all storm-water run-off be removed from embankments and pavement as rapidly as possible and is not permitted to soak into or erode fill material.

From 212,000 to 207,000 it is recommended that the alignment be relocated to a line discussed in the field with representatives of McLean, Mackerras and Partners and subsequently pegged by surveyor Janssen. The new line moves the alignment from the unstable hillside to the river flats below, and avoids passing over the active slides at 210,100 and 209,200. Fill placed at the outlets to the valleys will have to be well protected on the up-slope side by a concrete wall, and the culvert will need to have a diameter of not less than 5 feet to allow the passage of water and slurry through the fill without danger of blockage. From about 207,700 to about 208,100 the road will have to be built up from the stream bed which runs alongside the alignment in that section. Associated work will include the straightening of the stream's course and protection of the pavement with boulder rip-rap and wire mesh.

207,000 to 180,500

Very little modification of specification is required in this section. From 185,700 to the bridge at 185,500 meanders of the Kafatina River flow very close to the proposed alignment at about four points. Slight undercutting of the embankments has taken place and protection of the alignment with boulder rip-rap and mesh would be advisable. The loose overburden still present on the slip face at 185,700 will have to be cleared away; once clear the slip face can be utilised as a natural batter.

180,500 to 123,500 (Dumantina River), excluding 163,700 to 159,600 (Kafetina Gorge)

The danger common to all this section is the creation of unstable conditions by the removal of support from the hill slopes when forming side-cuts. Careful use of benching will ensure that instability is kept to a minimum. Similarly care must be taken to remove all unsound material and expose sound foundations before the placement of fill takes place. If due care and attention is given to these points, not forgetting the provision of adequate drainage, few problems are expected.

The severe slip located between 166,900 and 166,500 is best overcome by moving the alignment into the hillside. The additional earthworks required will be considerable as benching on more than one level will be necessary to maintain stability of the cross-slope. However, there is no other practical solution, and if the additional work is not carried out in the first instance failure will occur again at a later date.

163,700 to 159,600

Protection of fill from river erosion will be required at 162,000, 160,300 and 159,700. Damage to the existing road at these chainages is not great and it is considered that protection with boulder rip-rap in wire mesh will be adequate.

123,500 to 68,000

The thickness of the extensive deposits of peaty, silty and organic clays which occur in this section should be determined before construction commences, and the possibility of pre-drainage fully investigated. Cuts are not expected to provide any major problem but it will be imperative to remove all incompetent material - swamp, slopewash or lake deposit - prior to the placement of fill on cross-slopes.

68,000 to 00

The thickness of the swamp deposits and lake sediments must be determined before construction. Between 68,000 and the Bena Bena bridge lake sediments occur extensively on the sides and shoulders of small valleys cut into the piedmont deposits of the Goroka Beds. The design level calls for a considerable amount of fill on top of the lake sediments with the resultant danger of base failure by sliding. It is considered, therefore, that it will be necessary to excavate the sediments and backfill the alignment.

It will be necessary to divert the Bena Bena River to eliminate the present loop through the western approach and bring the main channel back under the projected bridge site. The task will not be difficult, and in fact, the present direction of flow can be put to good advantage. Construction of the eastern approach, the bridge, and the new channel, can be completed before the diversion is carried out. Construction of the western approach can be completed after diversion. Adequate stop-banks will be required along the western side of the new channel to ensure that the river does not revert to its former course. The abutments of the bridge will have to be firmly anchored to bedrock and well protected against river erosion.

REFERENCES

DOW, D.B., and PLANE, M.D., 1965 - The geology of the Kainantu goldfields. Bur. Min. Resour. Aust. Rep. 79.

McMILLAN, N.J., and MALONE, E.J., 1960 - The geology of the Eastern Central Highlands of New Guinea. Bur. Min. Resour. Aust. Rep. 48.

APPENDIX 1

Results of mechanical soil tests carried out by Public Works Soils Laboratory, Port Moresby.

GRADINGS (% smaller)

Sample No.	P.W.D. Lab. No.	Classif-ication*	B.S. Sieve Size					hydrometer analysis				%	%	%	Atterberg Limits		
			3/16	14	52	100	200	.04	.01	.006	.002	Sand	Silt	Clay	L.L.	P.L.	P.I.
KG01	900	MH			100	99	97	94	86	81	59	3	38	59	70.0	35.8	34.2
KG02	901	MH			100	99	98	95	81	71	53	2	45	53	74.9	35.6	39.3
KG03	902	MH				100	99	98	89	83	60	1	39	60	70.9	38.0	32.9
KG04	903	ML	100	98	96	92	84	73	44	33	16	16	68	16	37.6	26.9	10.7
KG05	904				100	98	91	79	43	29	13	9	78	13		28.8	
KG06	905	MH		100	98	96	93	84	58	32	16	7	77	16	63.9	43.3	20.6
KG07	906	CL		100	95	89	82	78	60	51	36	18	46	36	40.7	24.0	16.7
KG08	907	CL		100	99	97	91	83	59	49	31	9	60	31	44.7	25.1	19.6
KG09	908	CH				100	99	92	79	71	49	1	50	49	72.6	32.0	40.6
KG010	909	CH				100	99	89	82	79	56	1	43	56	69.4	31.0	38.4

* Classification is according to the United States Unified Soil Classification.

APPENDIX 2

Rainfall figures from gauging stations at Goroka, Henganofi and Kainantu.

GOROKA

	1965	1964	1963	1962	1961	1960	Average
January	828	1352	106	472	826	1587	862
February	1013	878	113	870	773	1529	863
March	900	1107	859	704	544	964	864
April	488	587	438	896	805	1082	716
May	482	403	198	1454	769	297	600
June	328	111	380	171	378	451	303
July	24	104	170	500	158	35	165
August	181	136	458	414	773	226	365
September	845	345	1085	377	687	85	571
October	257	166	631	736	1121	676	598
November	225	885	370	446	780	1029	622
December	1259	458	506	1637	479	1099	906
TOTAL:	6830	6532	5314	8677	8093	9060	7418

HENGANOFI

	1965	1964	1963	1962	1961	1960	Average
January	1252	1940	120	270	1148	1136	978
February	747	2205	135	1147	680	1611	1087
March	1195	1220	1098	653	1191	1239	1099
April	550	1036	255	928	704	705	696
May	297	532	97	903	587	190	434
June	155	50	340	166	401	301	235
July	46	49	230	227	120	27	116
August	132	83	171	250	654	274	261
September	670	192	844	514	522	134	446
October	106	444	1110	629	638	805	622
November	346	752	209	390	853	657	534
December	608	429	544	989	665	1026	710
TOTAL:	6104	8932	5153	7066	7963	8105	7220

KAINANTU

	1965	1964	1963	1962	1961	1960	Average
January	904	1725	99	472	1008	1770	996
February	884	1171	220	991	735	1346	891
March	1327	1029	660	898	882	1408	1034
April	637	757	575	1039	542	786	723
May	652	502	118	813	785	601	578
June		23	658	263	354	499	359
July		72	359	531	105	143	242
August		216	406	370	1264	267	505
September		417	342	774	297	125	391
October		274	957	308	971	1140	730
November		802	778	760	871	883	819
December		363	451	1299	678	855	729
TOTAL:		7351	5623	8518	8492	9823	7961

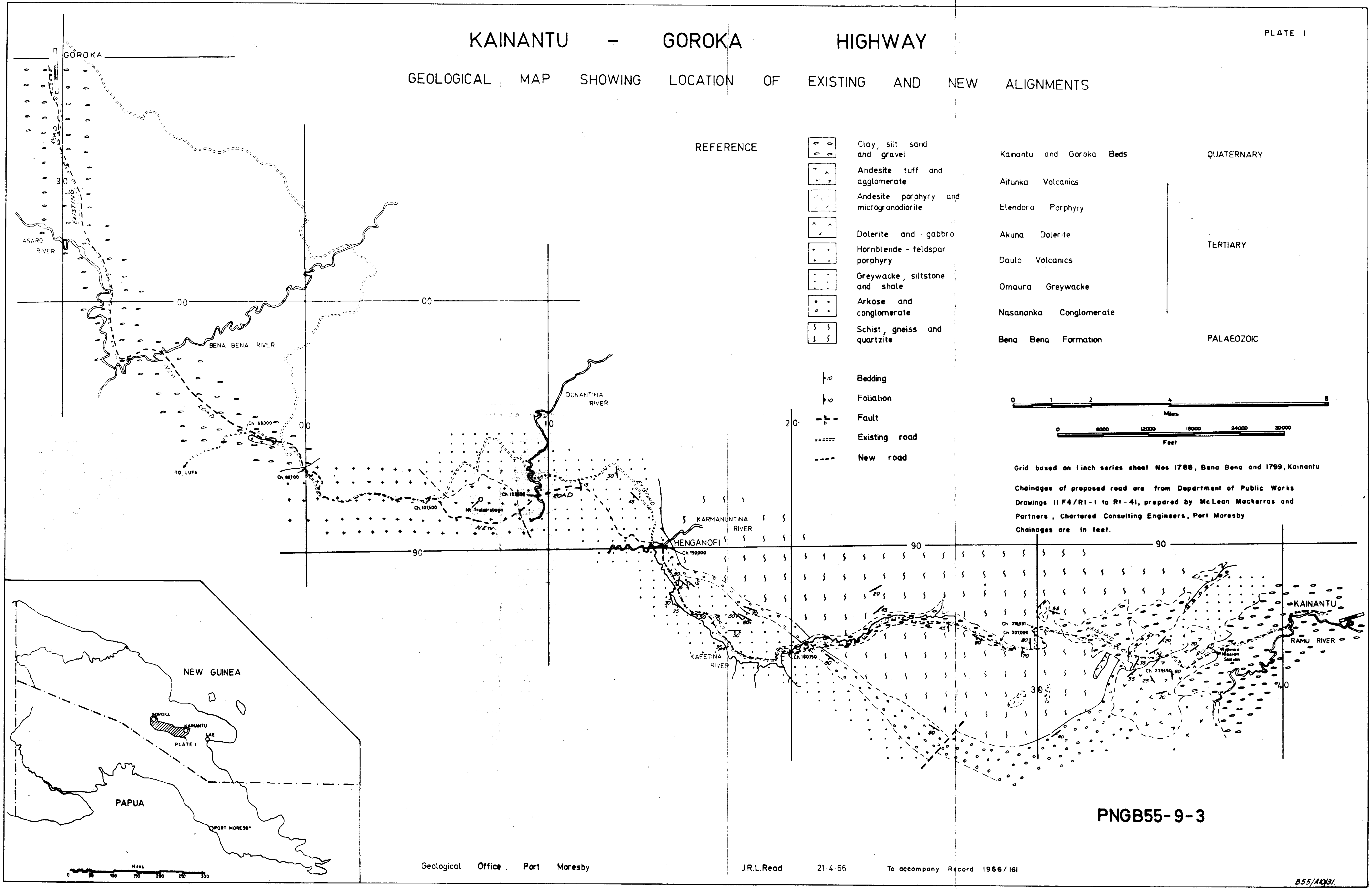


PLATE I
KAINANTU - GOROKA HIGHWAY
GEOLOGICAL MAP SHOWING LOCATION OF EXISTING AND NEW ALIGNMENTS
REFERENCE
Clay, silt sand and gravel — Kainantu and Goroka Beds — QUATERNARY
Andesite tuff and agglomerate — Aifunka Volcanics
Andesite porphyry and microgranodiorite — Elendora Porphyry
Dolerite and gabbro — Akuna Dolerite
Hornblende - feldspar porphyry — Daulo Volcanics — TERTIARY
Greywacke, siltstone and shale — Omaura Greywacke
Arkose and conglomerate — Nasananka Conglomerate
Schist, gneiss and quartzite — Bena Bena Formation — PALAEOZOIC
Bedding
Foliation
Fault
Existing road
New road
Miles
Feet
Grid based on I inch series sheet Nos 1788, Bena Bena and 1799, Kainantu
Chainages of proposed road are from Department of Public Works Drawings II F4/RI-I to RI-41, prepared by McLean Mackerras and Partners, Chartered Consulting Engineers, Port Moresby.
Chainages are in feet.
GOROKA
ASARO RIVER
BENA BENA RIVER
DUNANTINA RIVER
TO LUFA
Ch. 68000
Ch. 86700
Ch. 101500
Ch. 122550
Mt Trulacruhaga
KARMANUNTINA RIVER
HENGANOFI
Ch. 150000
KAFETINA RIVER
Ch. 180150
Ch. 216931
Ch. 207000
Ch. 235450
KAINANTU
RAMU RIVER
EXISTING
NEW ROAD
NEW GUINEA
GOROKA
KAINANTU
PLATE I
LAE
PAPUA
PORT MORESBY
PNGB55-9-3
Geological Office. Port Moresby
J.R.L. Read 21·4·66
To accompany Record 1966/161
B55/A10/31.