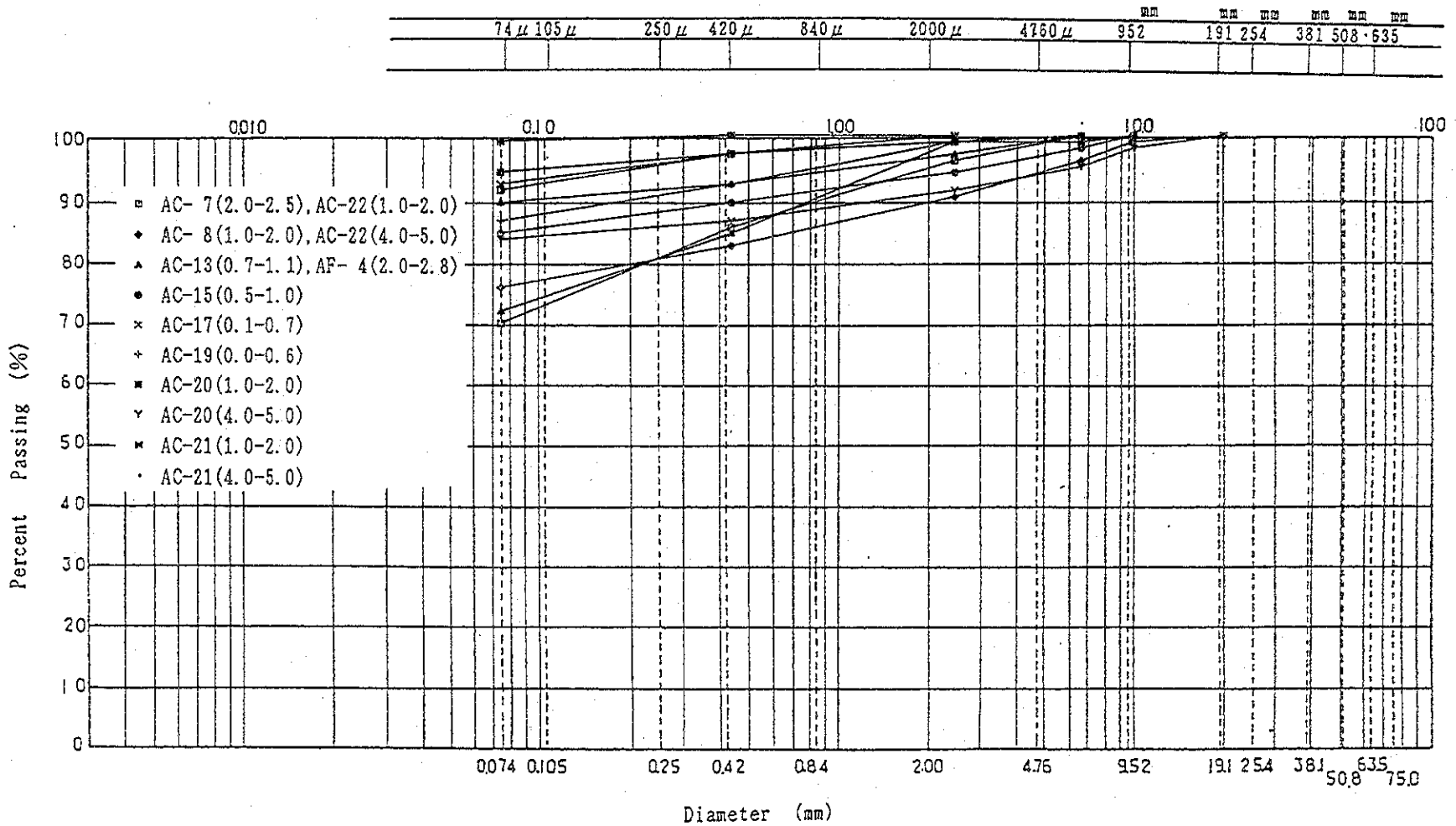

Fig. II-13 Gradation Curve (1 / 7)
(Black Cotton Soil~Weathered Pleistcene Lake Deposits)

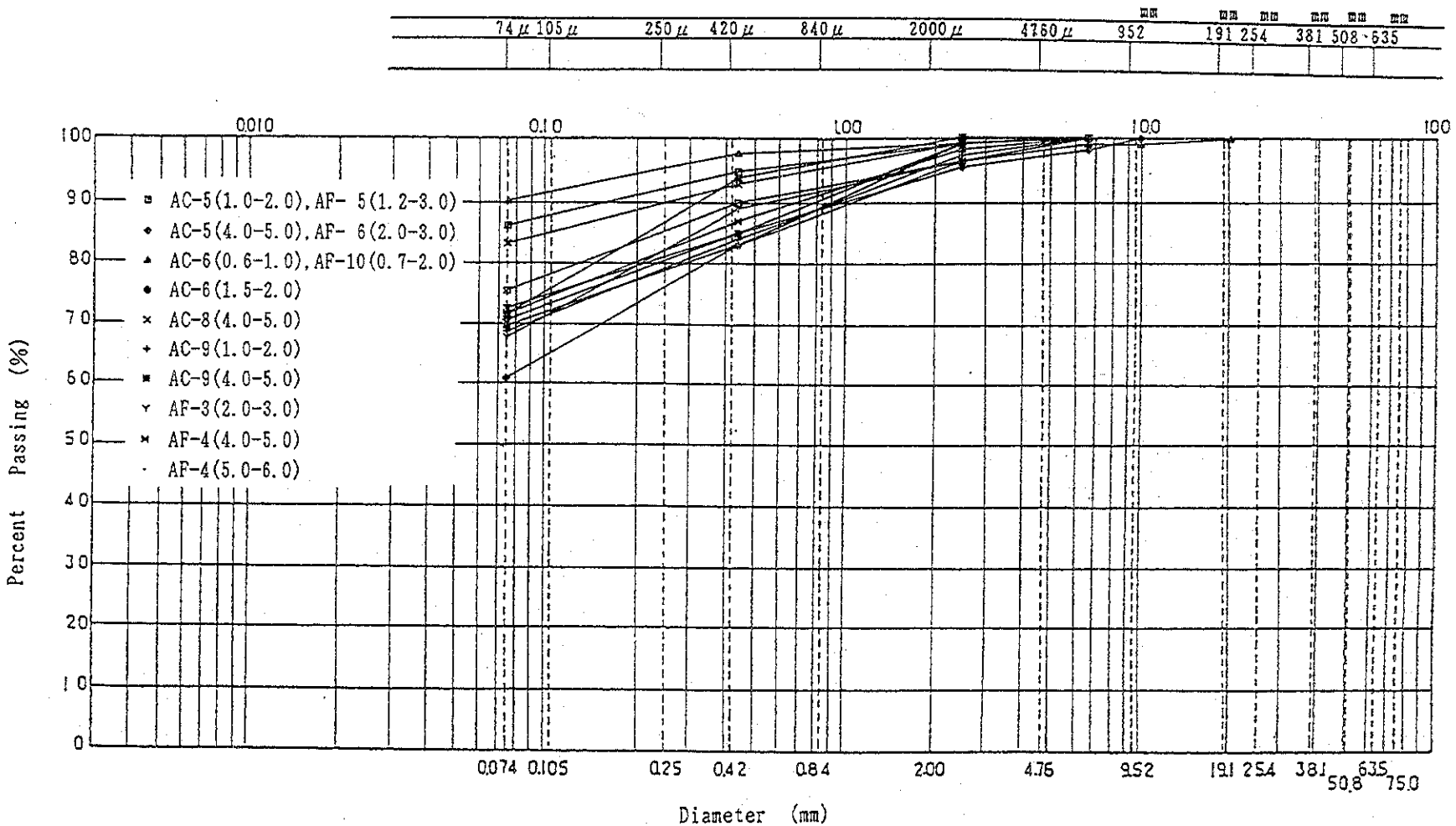

Fig. II-13 Gradation Curve (2 / 7)

(Pleistcene Lake Deposits···Tuffaceous)

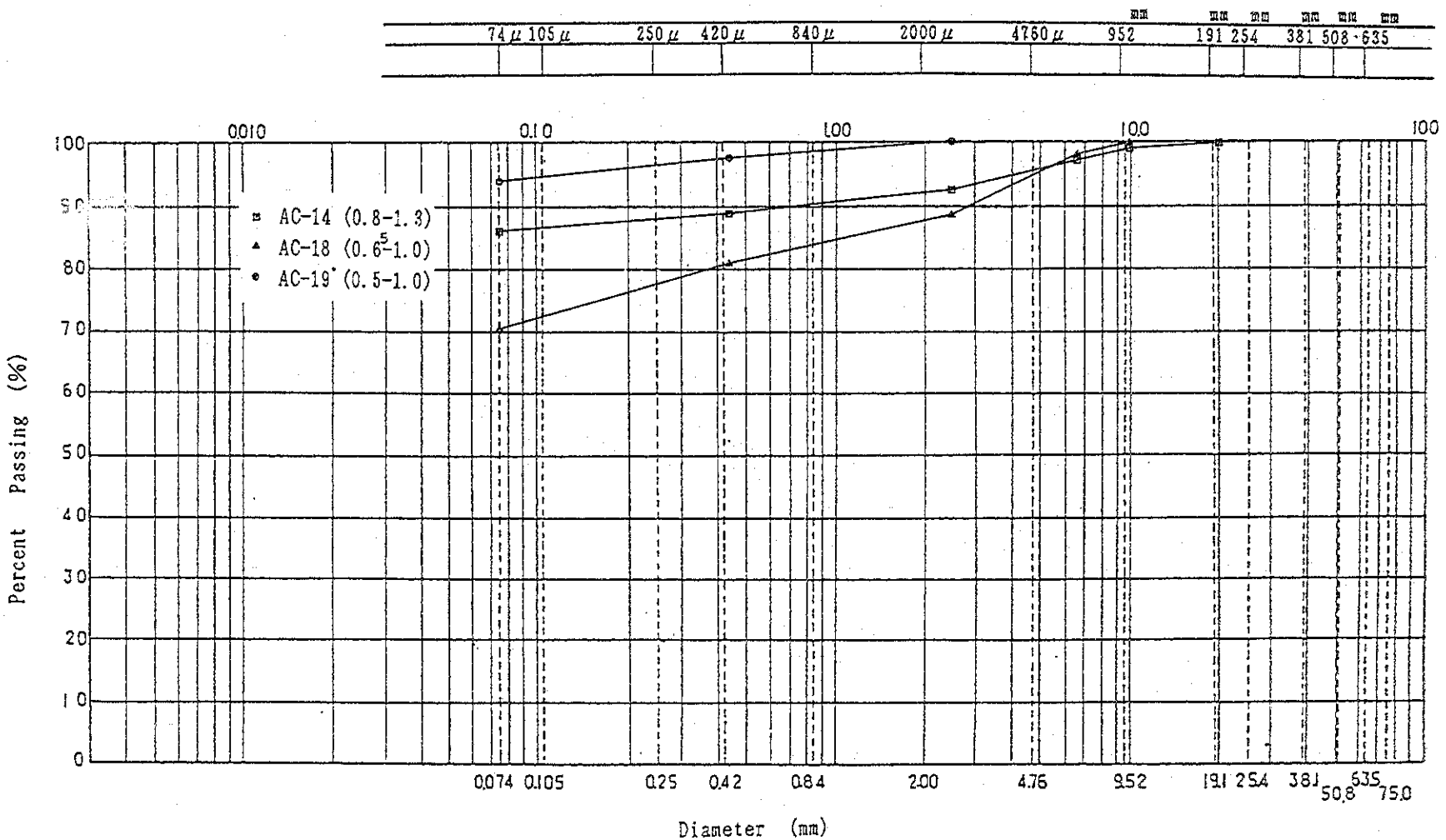

Fig. II-13 Gradation Curve (3 / 7)

(Hillwash Deposits･･･Dellivium?)

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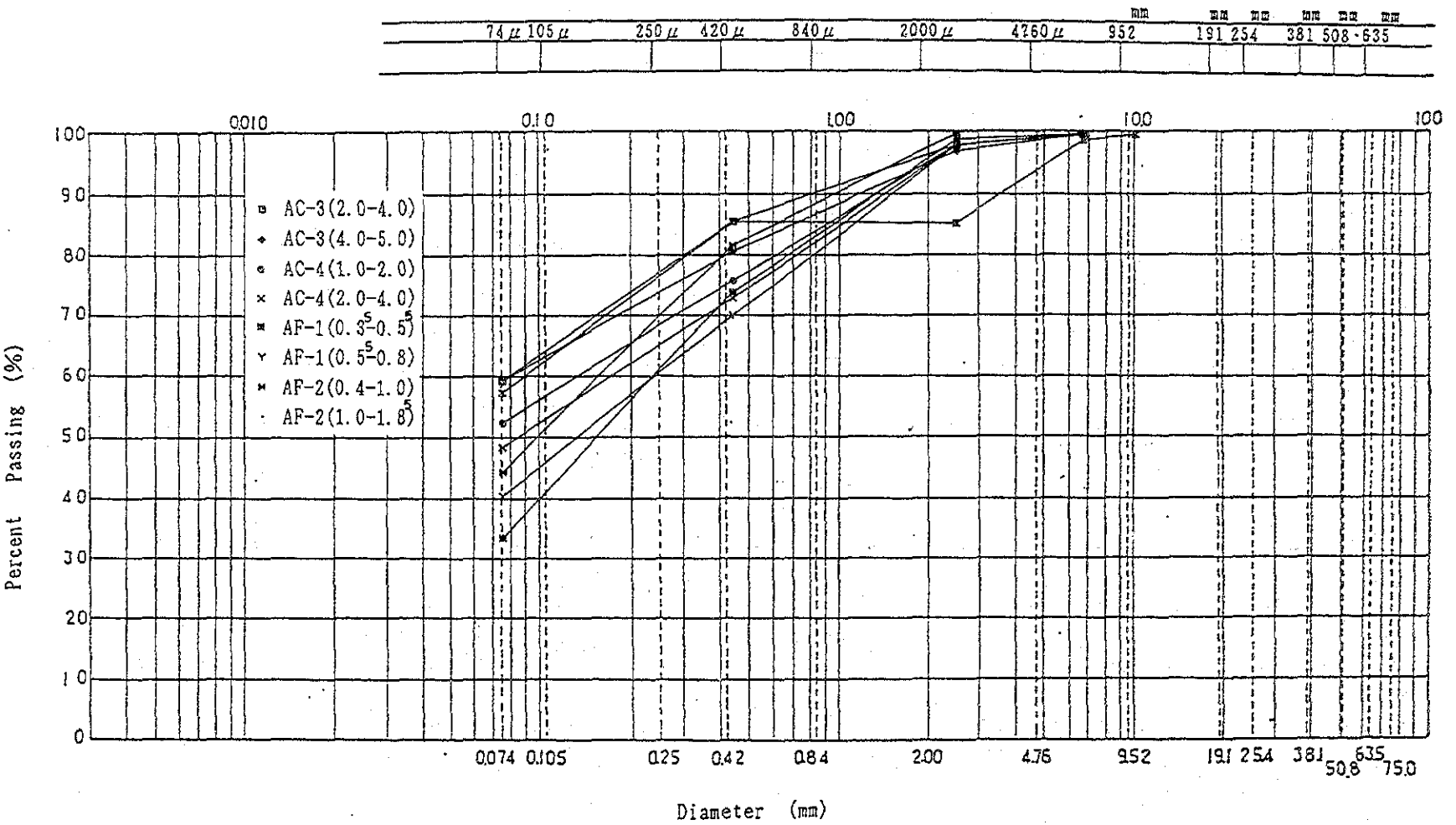

Fig. II-13 Gradation Curve (4 / 7)
(Colluvium)

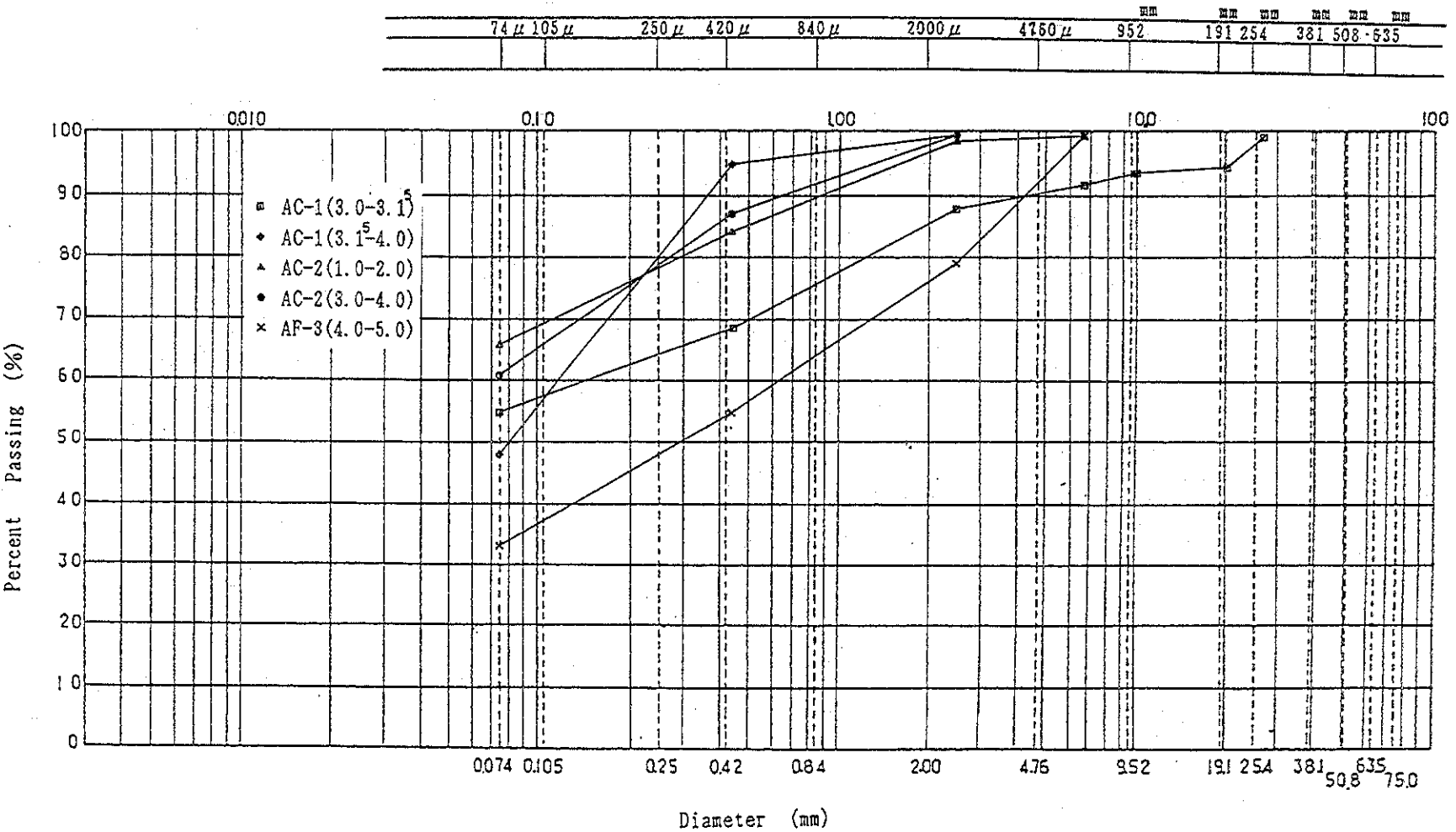

Fig. II-13 Gradation Curve (5 / 7)

(Weathered Granitic Rocks~Residial Soils)

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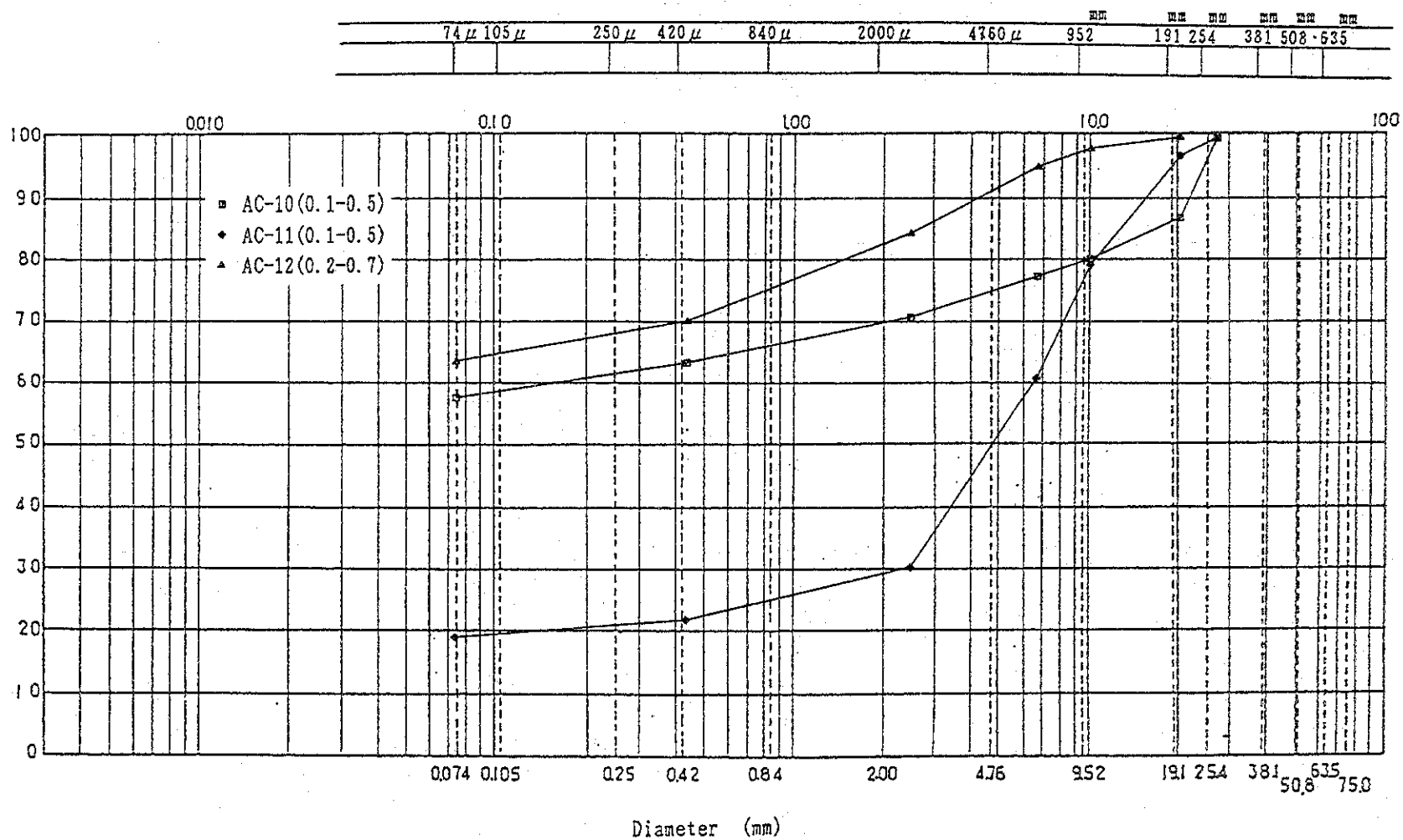

Fig. II-13 Gradation Curve (6 / 7)

(Lateritic Ironstone~Scree Deposits)

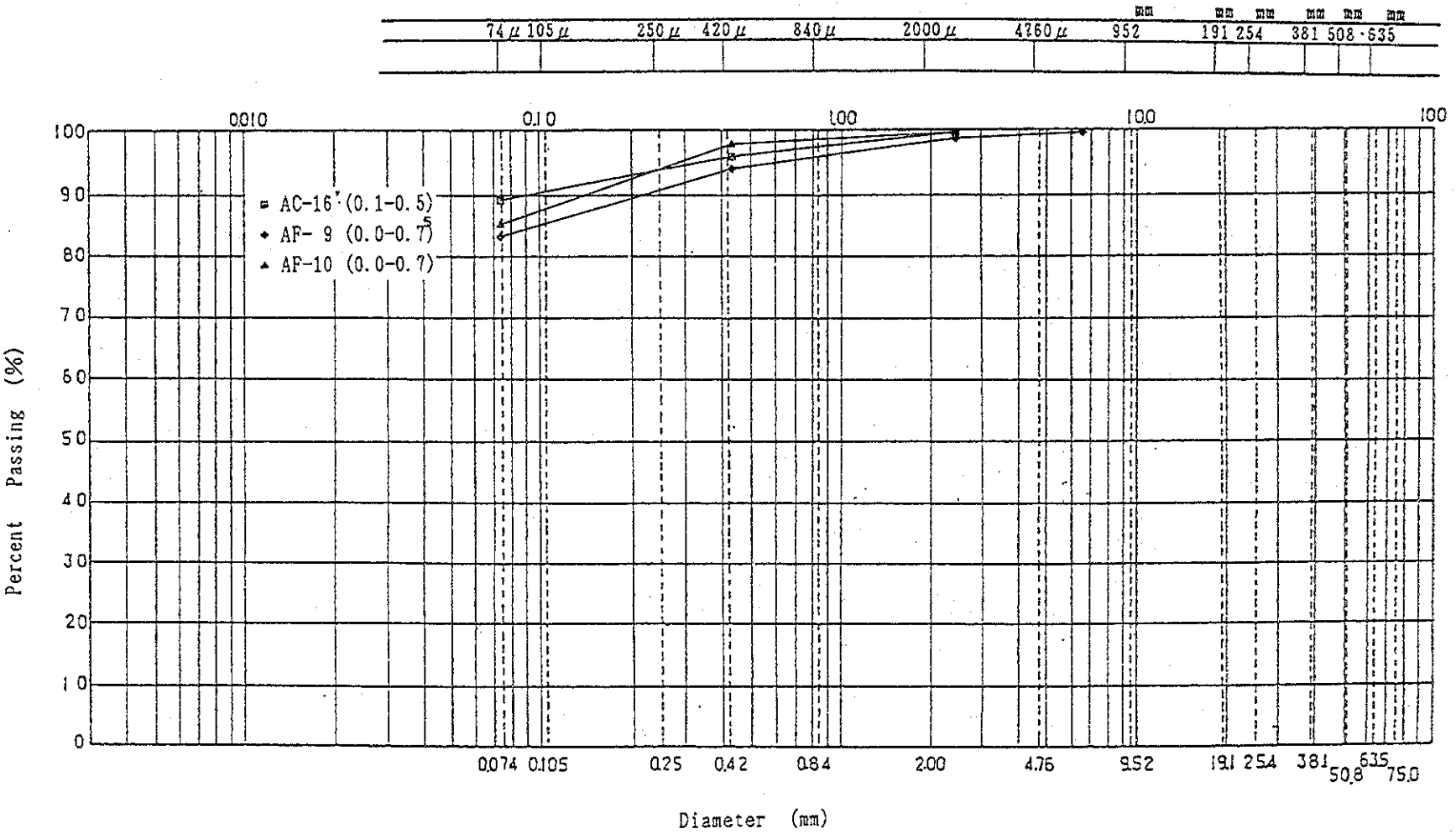

Fig. II-13 Gradation Curve (7 / 7)
(Flood Deposits)

Sample No. TP－1 (1.5～2.0 m)

In situ moisture content (Wf) 13.7 %
Specific gravity of soil grains (SG) 2.45
Amount retained on 19.1mm test sieve 0 %

Test No.	1	2	3	4	5
ρd t/m³	1.625	1.771	1.832	1.787	1.744
ω %	8.0	10.3	12.4	14.0	15.6

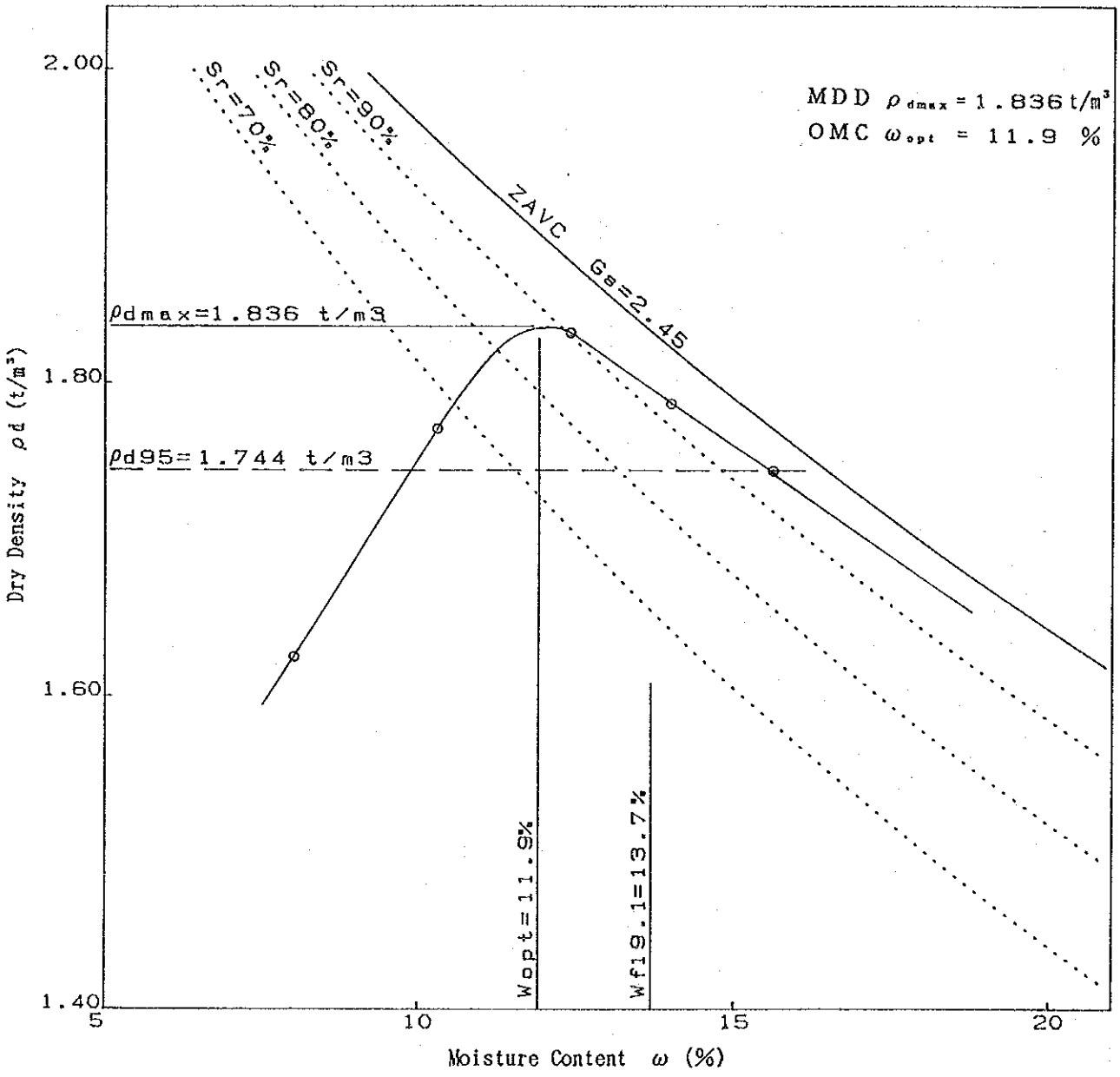

Fig. II-14 Compaction Curve (1 / 11)
Dry density／moisture content relation
(2.5kg rammer method)

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Sample No. TP－2 (2.4~3.0 m)

In situ moisture content (Wf) 5.3 %
Specific gravity of soil grains (SG) 2.30
Amount retained on 19.1mm test sieve 0 %

Test No.	1	2	3	4	5
ρd t/m³	1.565	1.616	1.651	1.610	1.558
ω %	11.4	12.8	15.4	17.3	19.4

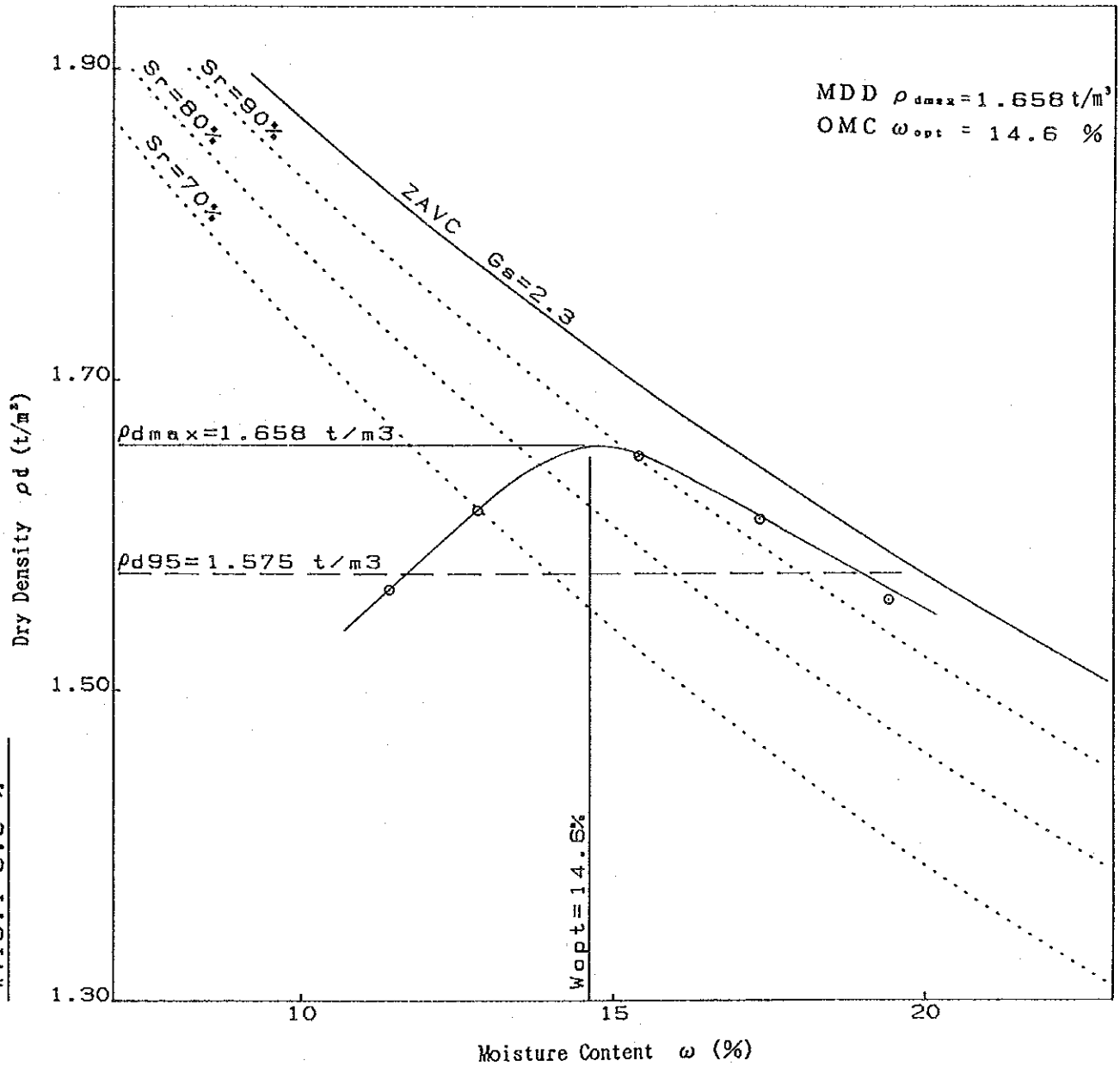

Fig. II-14 Compaction Curve (2 / 11)
Dry density／moisture content relation
(2.5kg rammer method)

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Sample No. TP－3 (1.5～2.0 m)

In situ moisture content (Wf) 8.0 %
Specific gravity of soil grains (SG) 2.15
Amount retained on 19.1mm test sieve 0 %

Test No.	1	2	3	4	5
ρd t/m³	1.190	1.209	1.307	1.317	1.290
ω %	21.3	22.6	25.0	26.5	28.7

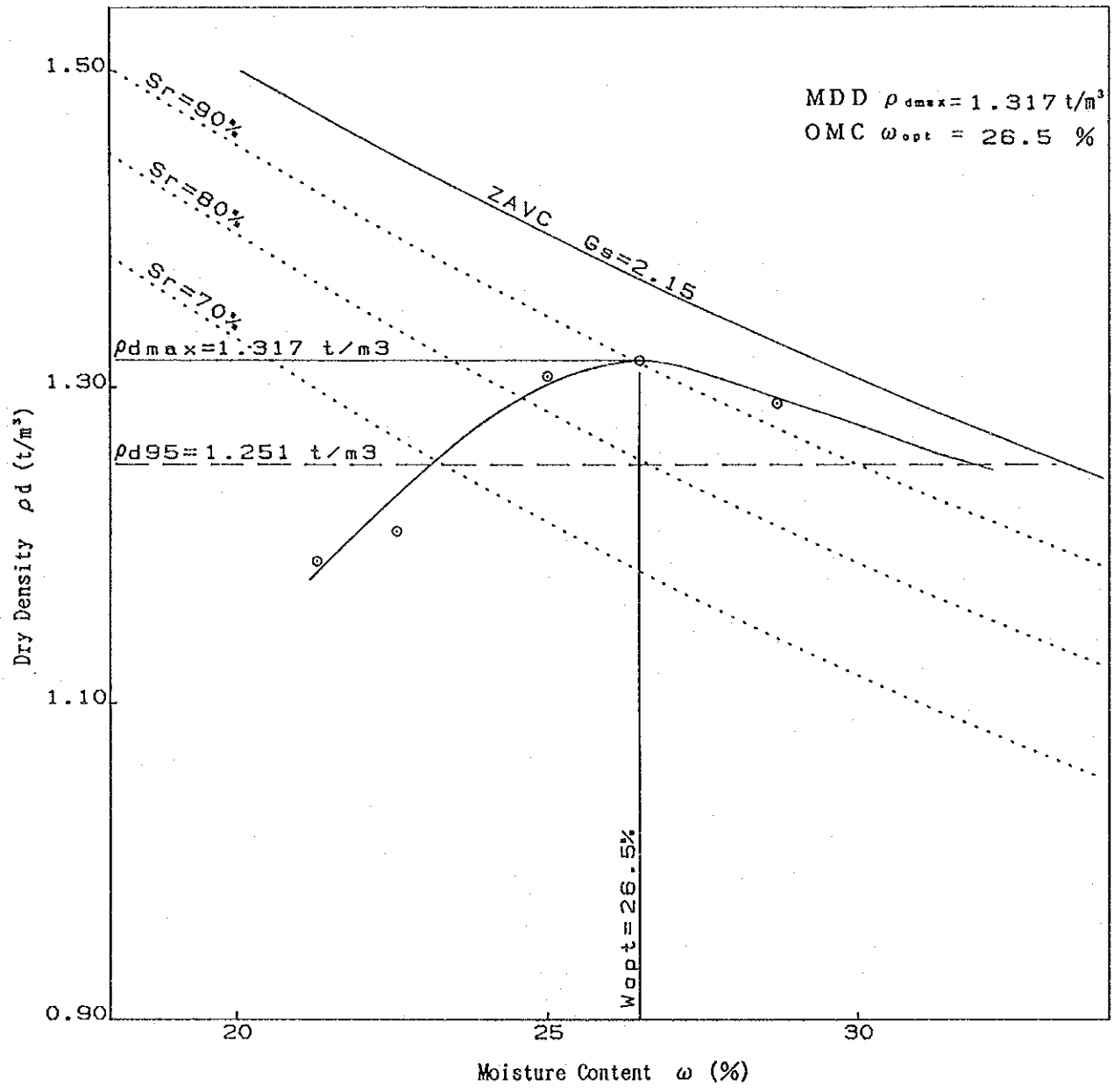

Fig. II-14 Compaction Curve (3 / 11)
Dry density／moisture content relation
(2.5kg rammer method)

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Sample No. TP－4 (1.0~1.5 m)

In situ moisture content (Wf) 17.6%
Specific gravity of soil grains (SG) 2.20
Amount retained on 19.1mm test sieve 0 %

Test No.	1	2	3	4	5
ρd t/m³	1.152	1.204	1.218	1.197	1.165
ω %	29.0	31.3	33.2	35.3	37.3

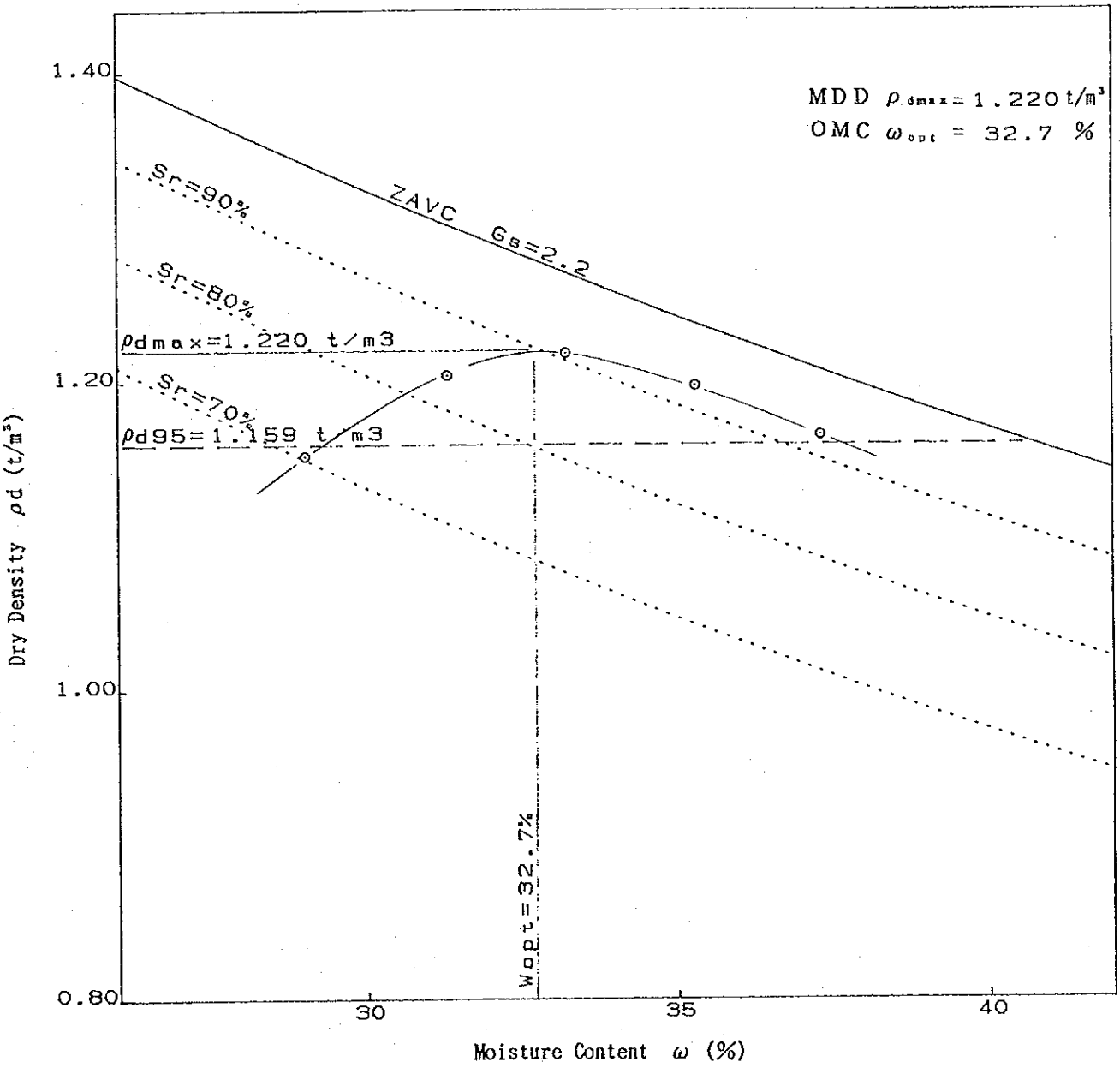

Fig. II-14 Compaction Curve (4 / 11)
Dry density／moisture content relation
(2.5kg rammer method)

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Sample No. TP－5 (2.0～2.5 m)

In situ moisture content (Wf) 13.0%
Specific gravity of soil grains (SG) 2.25
Amount retained on 19.1mm test sieve 0 %

Test No.	1	2	3	4	5
ρd t/m³	1.372	1.411	1.395	1.346	1.306
ω %	21.9	23.8	26.1	28.4	30.3

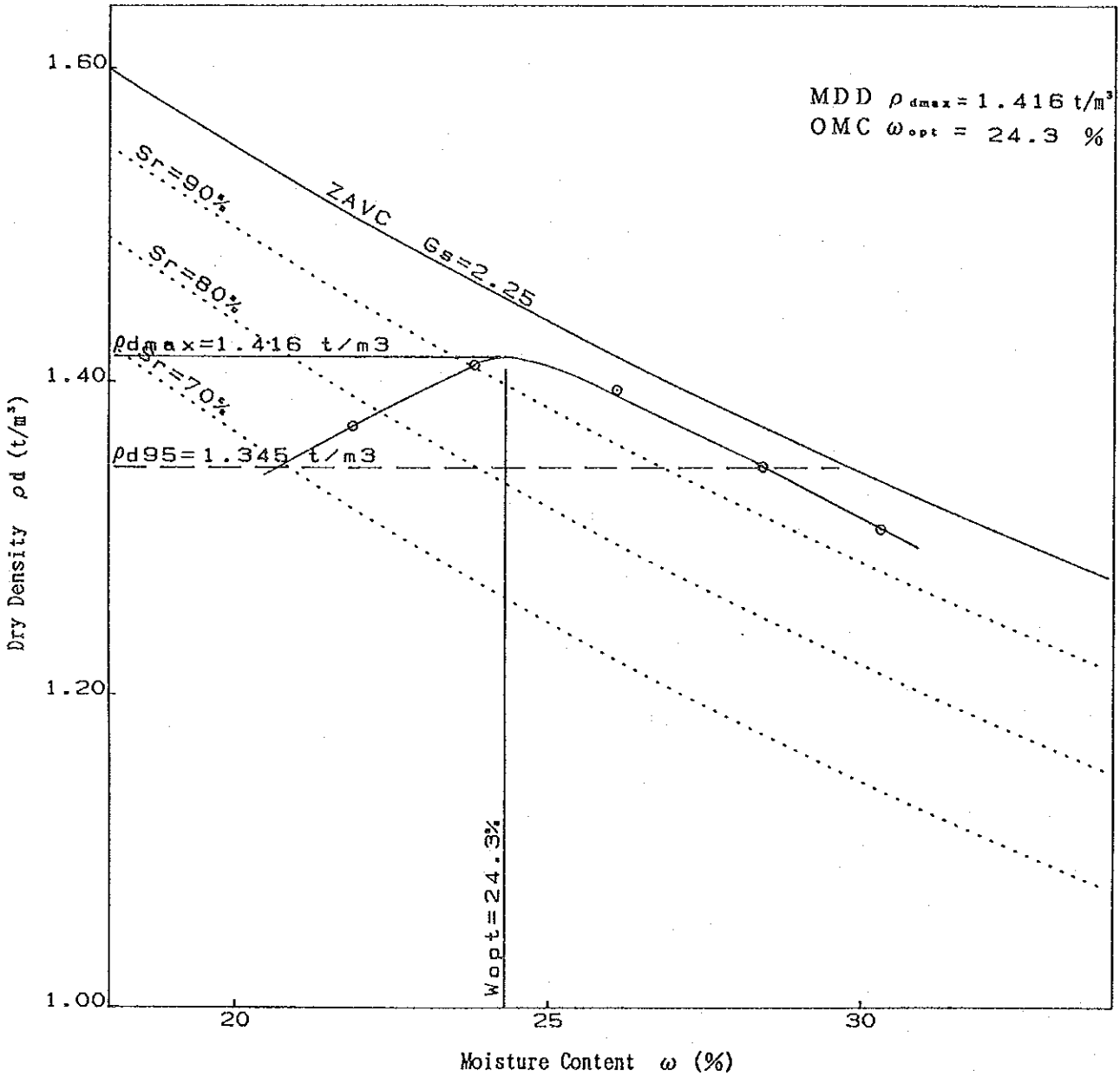

Fig. II-14 Compaction Curve (5 / 11)
Dry density／moisture content relation
(2.5kg rammer method)

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Sample No. TP-6 (1.0~1.5 m)

In situ moisture content	(Wf)	8.8 %
Specific gravity of soil grains	(SG)	2.52
Amount retained on 19.1mm test sieve		0 %

Test No.	1	2	3	4	5
ρd t/m³	1.548	1.608	1.610	1.569	1.520
ω %	16.3	18.1	20.4	22.4	24.5

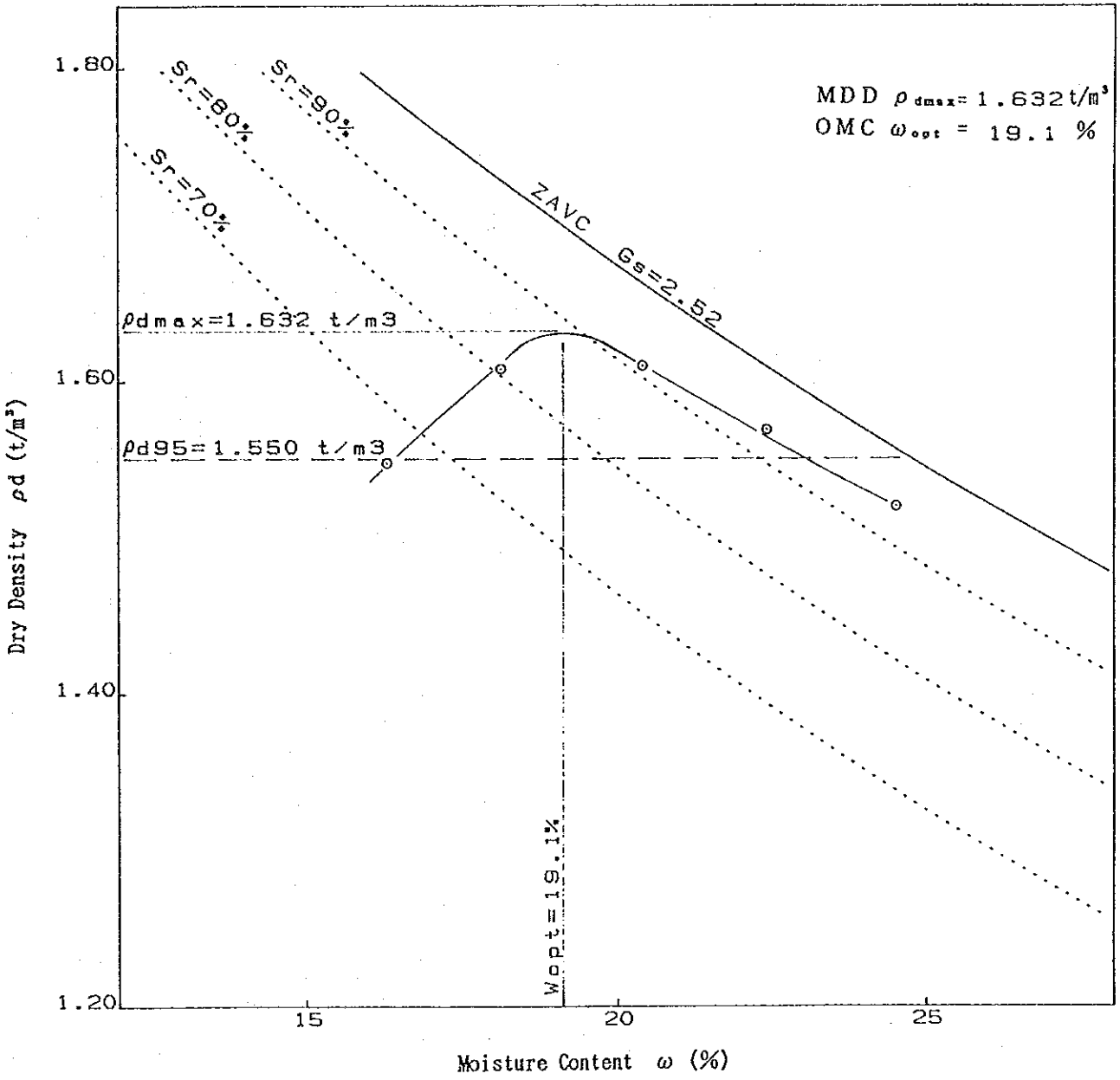

Fig. II-14 Compaction Curve (6 / 11)

Dry density/moisture content relation

(2.5kg rammer method)

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Sample No. TP-7 (1.5~2.0 m)

In situ moisture content	(Wf)	9.5 %
Specific gravity of soil grains	(SG)	2.60
Amount retained on 19.1mm test sieve		0 %

Test No.	1	2	3	4	5
ρd t/m³	1.447	1.556	1.631	1.636	1.592
ω %	14.5	17.4	19.1	21.4	23.3

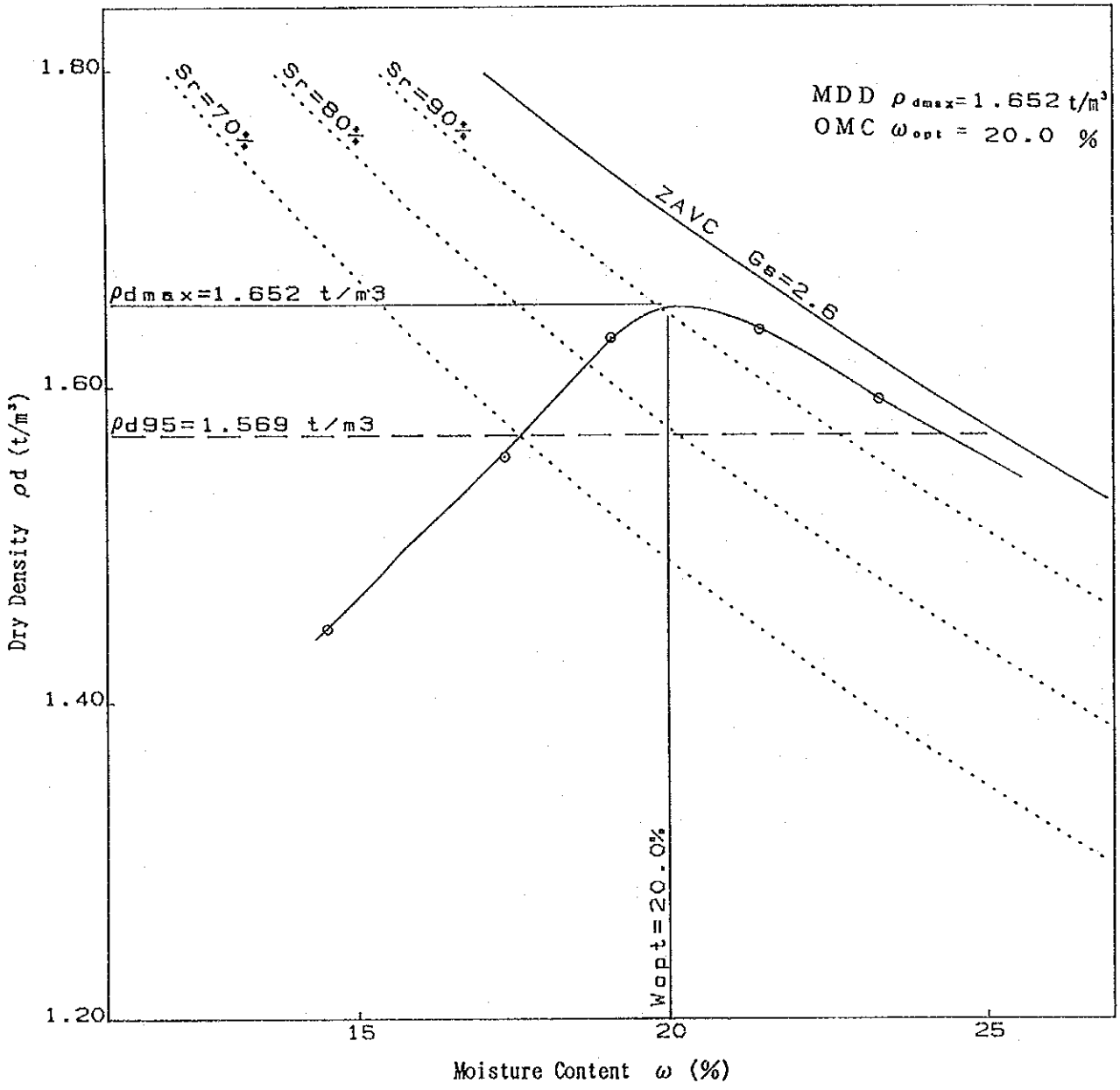

Fig. II-14 Compaction Curve (7 / 11)

Dry density/moisture content relation

(2.5kg rammer method)

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Sample No. TP-8 (1.5~2.0 m)

In situ moisture content (Wf) 13.8%
Specific gravity of soil grains (SG) 2.15
Amount retained on 19.1mm test sieve 0 %

Test No.	1	2	3	4	5
ρd t/m³	1.158	1.192	1.195	1.171	1.138
ω %	29.2	31.6	33.8	35.9	37.7

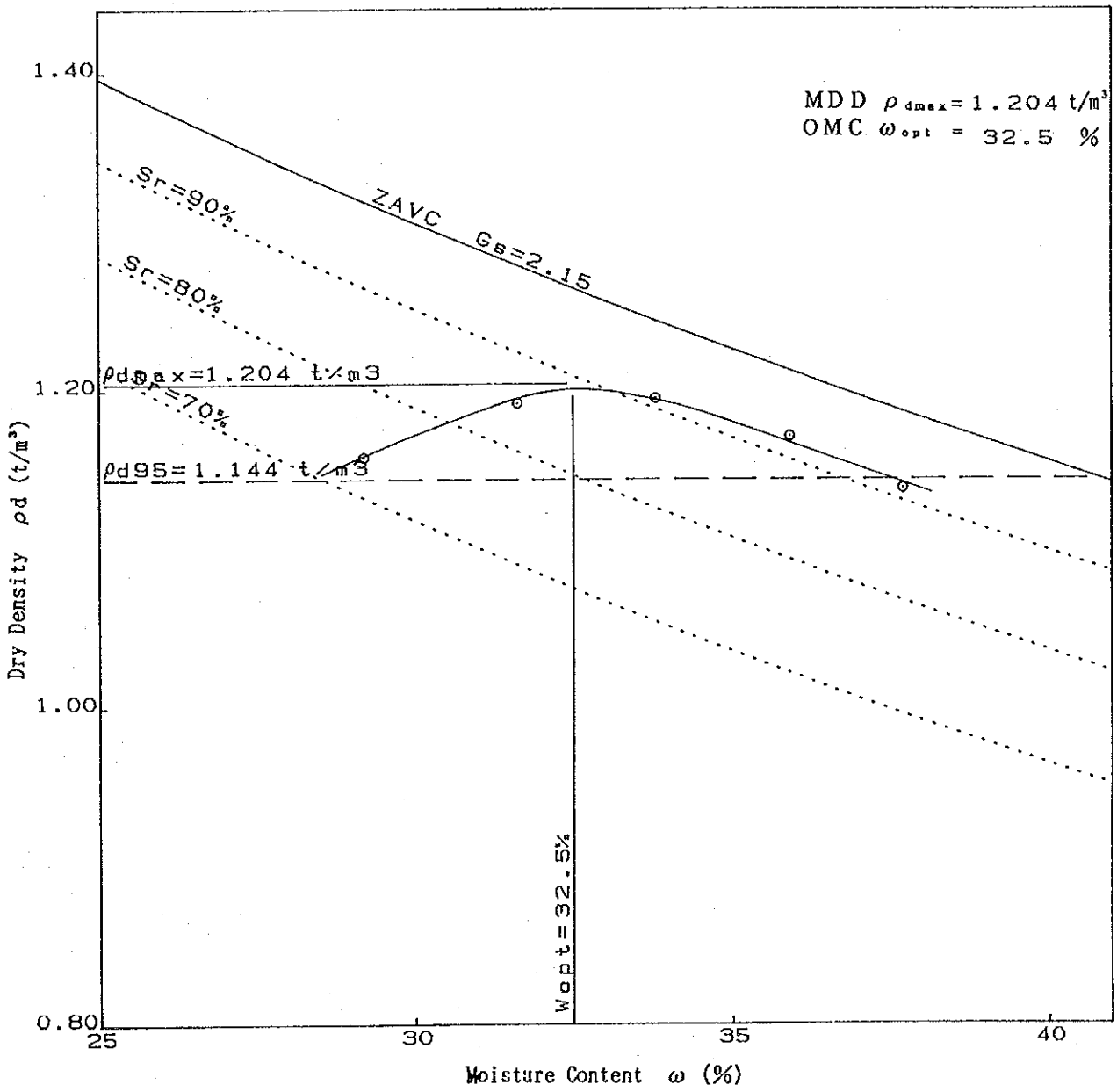

Fig. II-14 Compaction Curve (8 / 11)
Dry density/moisture content relation
(2.5kg rammer method)

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Sample No. TP－9 (1.5～2.0 m)

In situ moisture content	(Wf)	1．5 %
Specific gravity of soil grains	(SG)	2．55
Amount retained on 19.1mm test sieve		0 %

Test No.	1	2	3	4	5
ρd t/m³	1.463	1.513	1.510	1.468	1.429
ω %	20.0	22.0	24.2	26.1	28.3

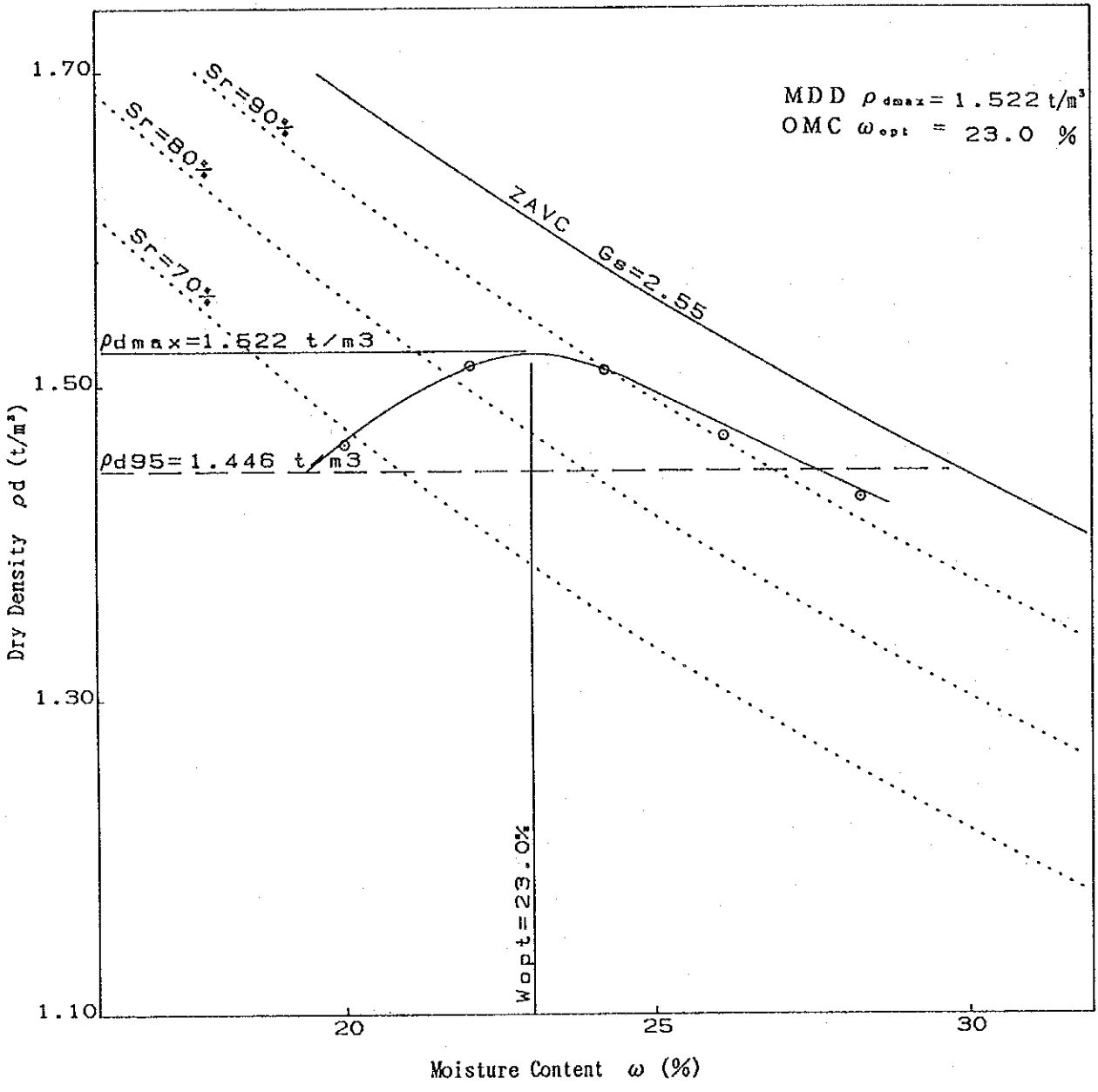

Fig. II-14 Compaction Curve (9 / 11)

Dry density／moisture content relation
(2.5kg rammer method)

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Sample No. TP-10 (1.5~2.5 m)

In situ moisture content (Wf) 27.7 %
Specific gravity of soil grains (SG) 2.15
Amount retained on 19.1mm test sieve 0 %

Test No.	1	2	3	4	5	6
ρd t/m³	1.163	1.195	1.230	1.234	1.206	1.175
ω %	25.5	27.6	29.6	31.8	33.8	35.6

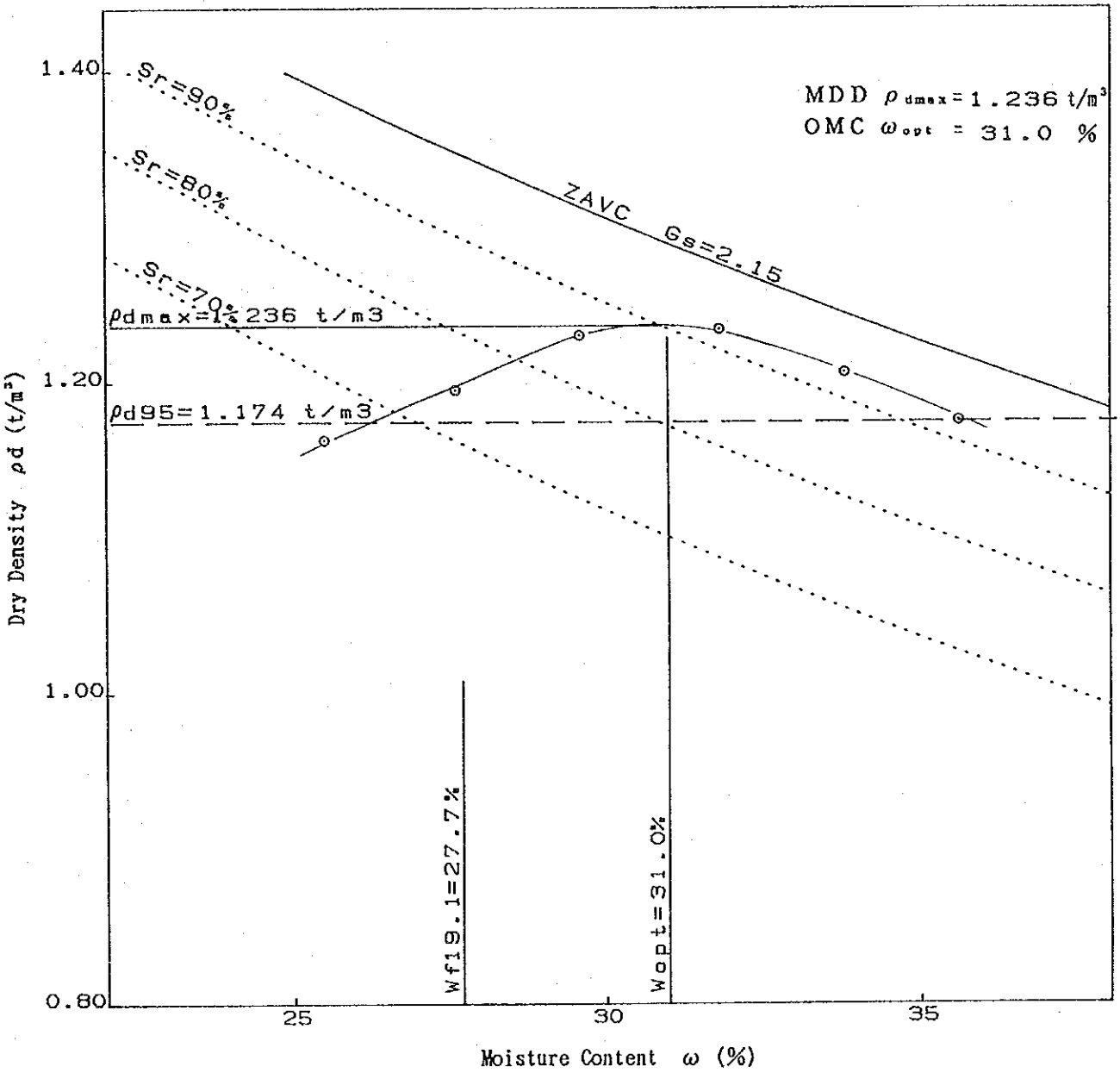

Fig. II-14 Compaction Curve (10 / 11)

Dry density/moisture content relation
(2.5kg rammer method)

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Sample No. TP-11 (1.5~2.0 m)

In situ moisture content (Wf) 15.6 %
Specific gravity of soil grains (SG) 2.35
Amount retained on 19.1mm test sieve 0 %

Test No.	1	2	3	4	5
ρd t/m³	1.547	1.679	1.761	1.715	1.678
ω %	8.3	10.4	12.5	14.5	16.4

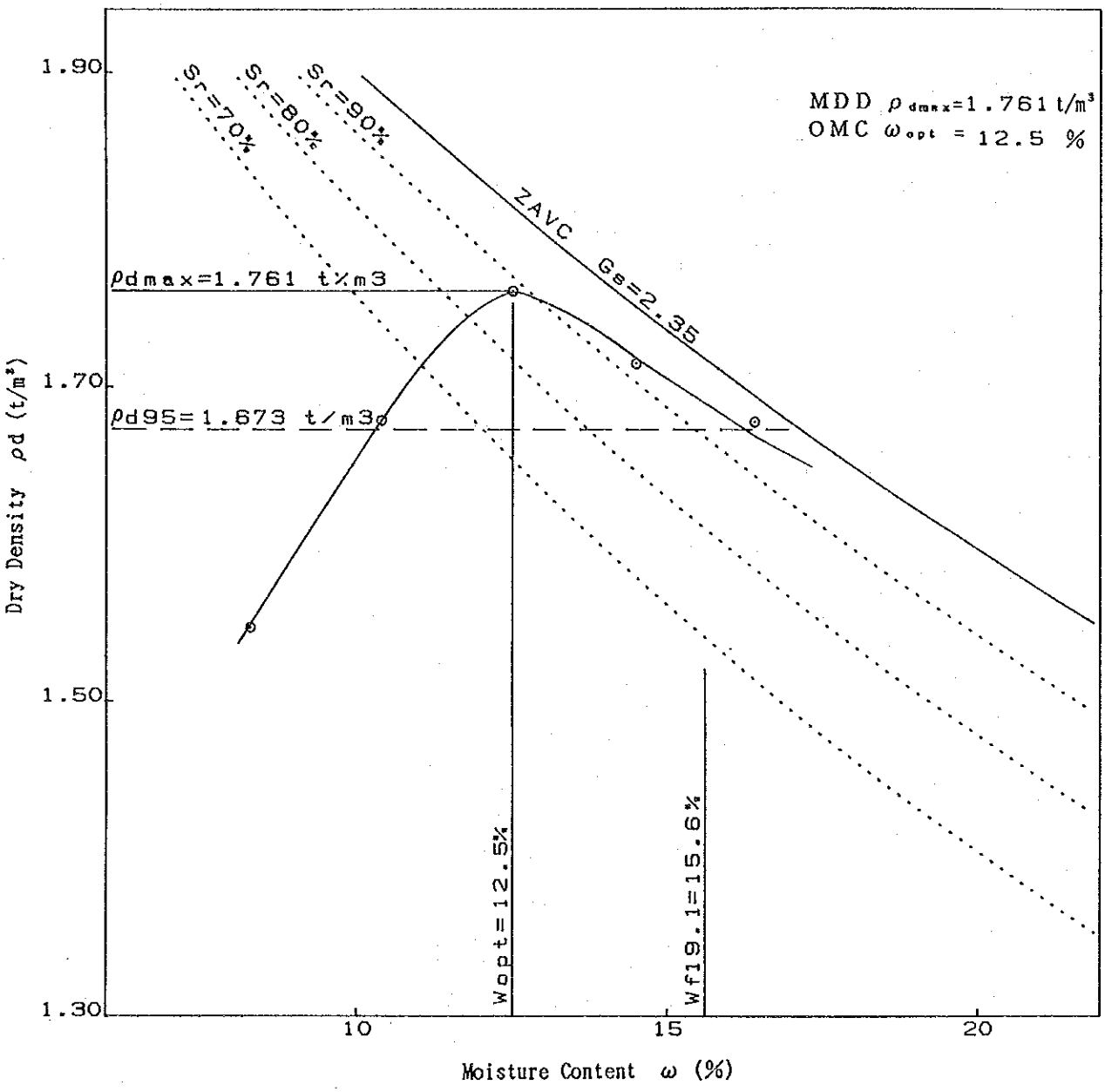

Fig. II-14 Compaction Curve (11 / 11)
Dry density/moisture content relation
(2.5kg rammer method)

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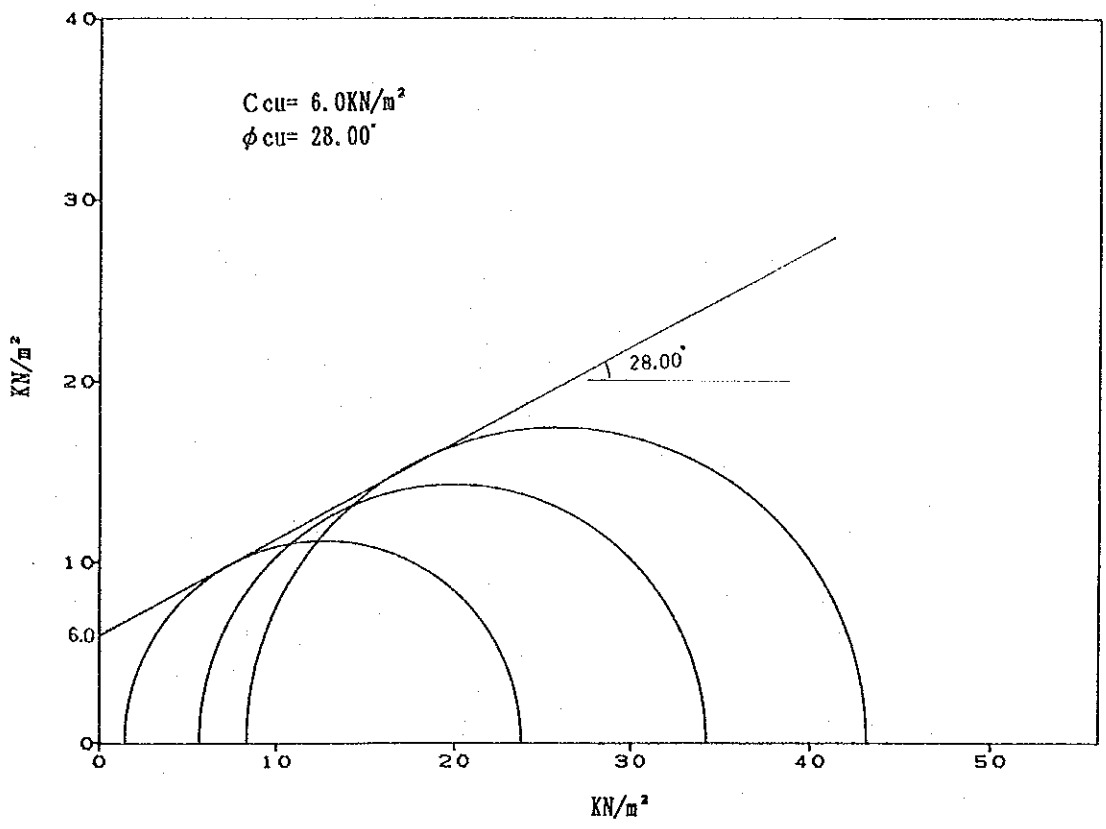
Sample No. TP－3 (1.5～2.0m) CU Test



Sample No. TP－5 (2.0～2.5m) CU Test

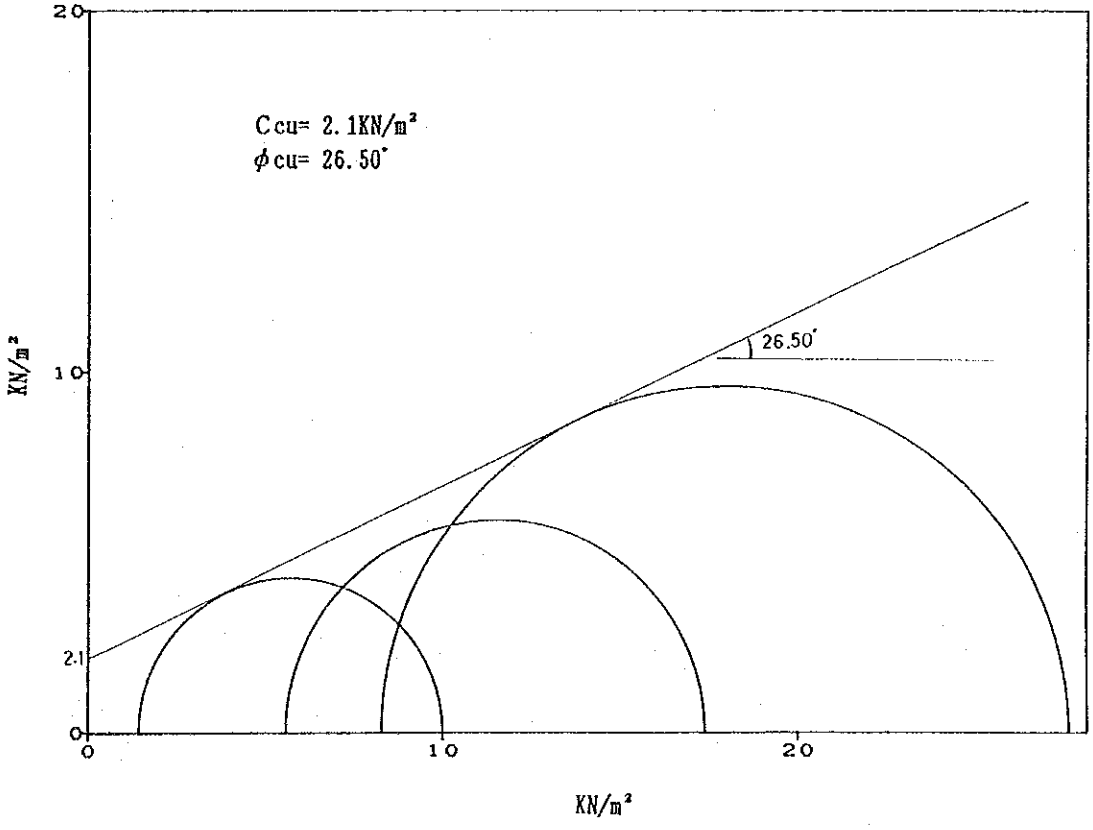


Fig. II-15 Triaxial Compression Test (Mohr's circle) (1 / 5)

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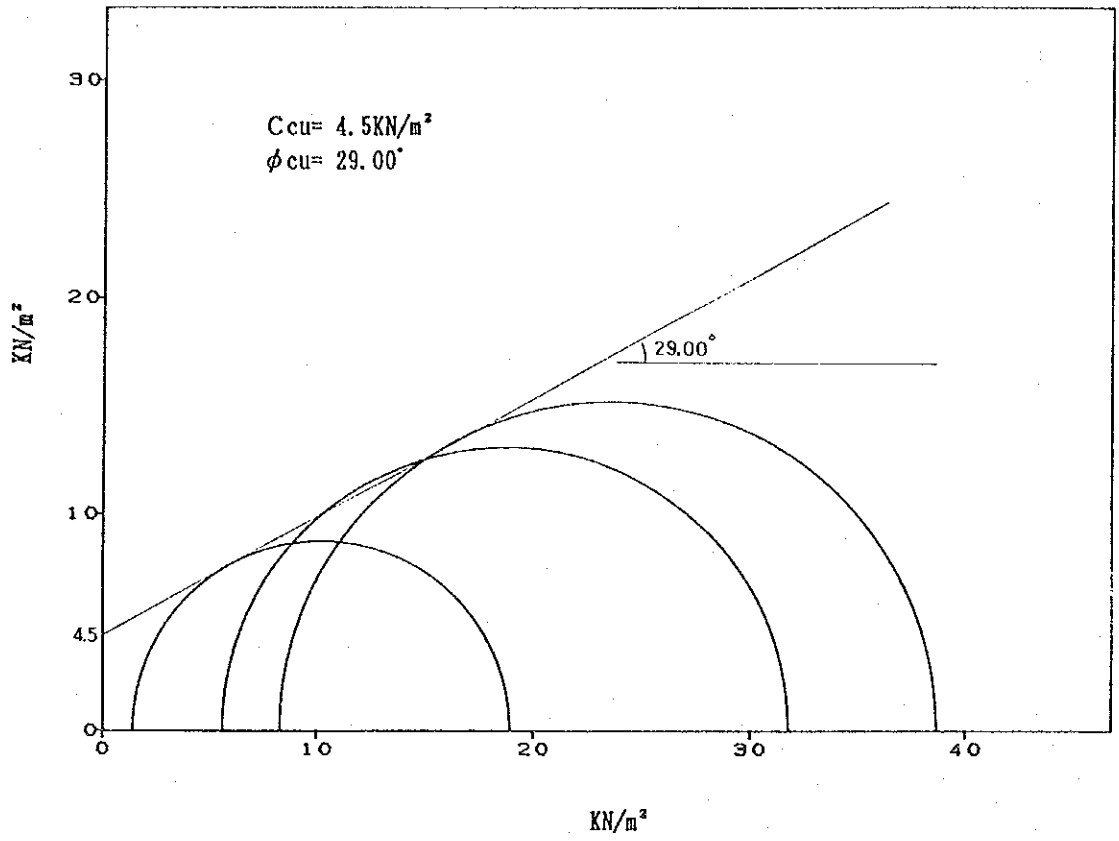
Sample No. TP－6 (1.0～1.5m) CU Test



Sample No. TP－8 (1.5～2.0m) CU Test

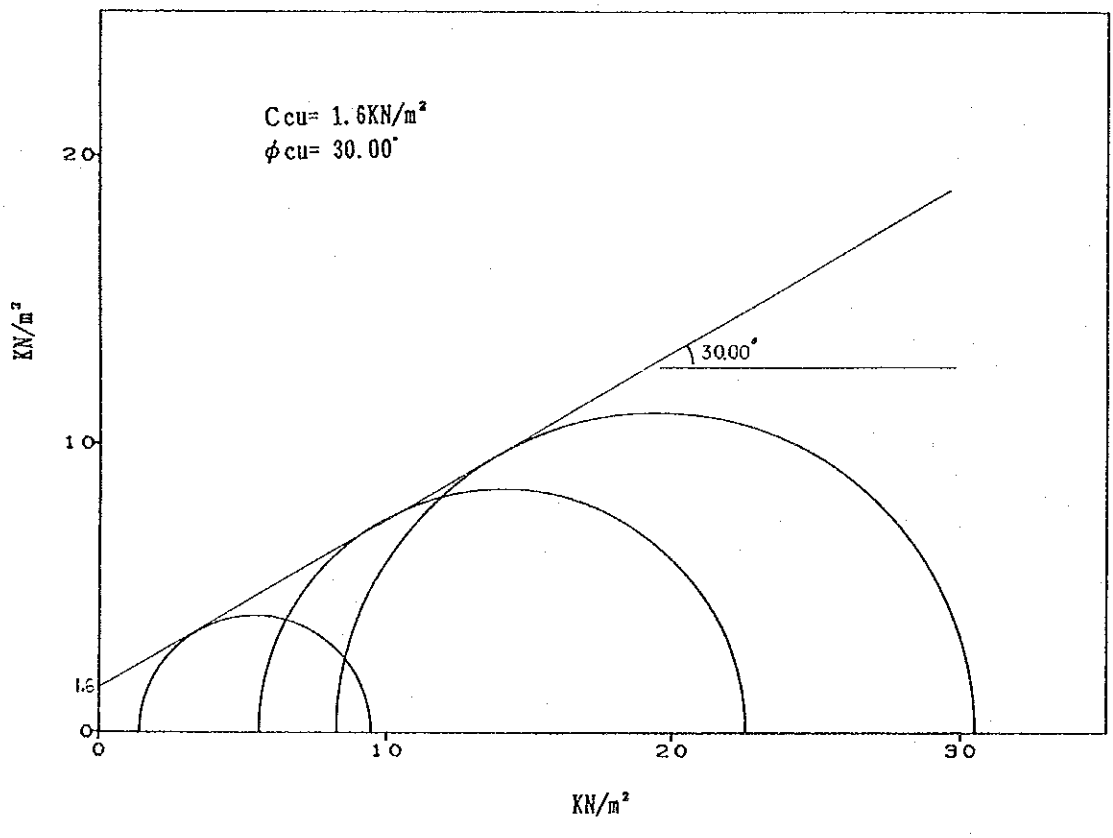


Fig. II-15 Triaxial Compression Test (Mohr's circle) (2 / 5)

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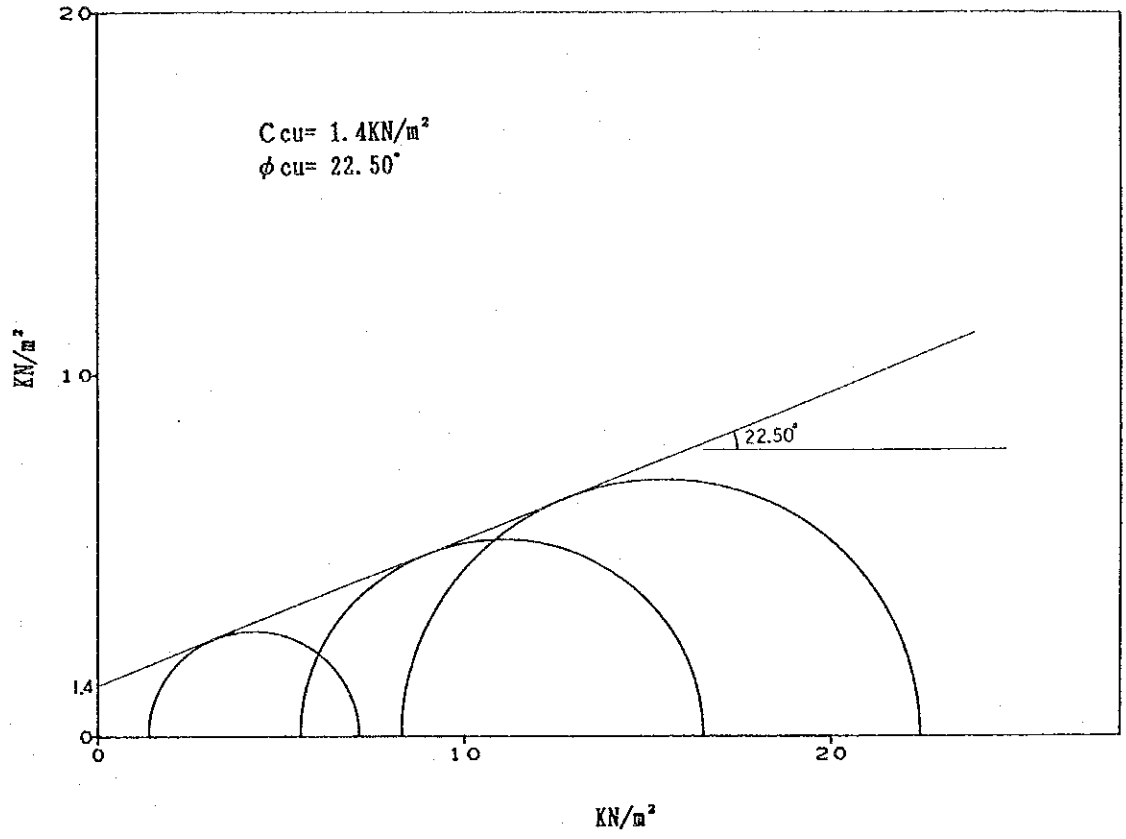
Sample No. TP－10 (1.5～2.5m) CU Test



Sample No. TP－11 (1.5～2.0m) CU Test

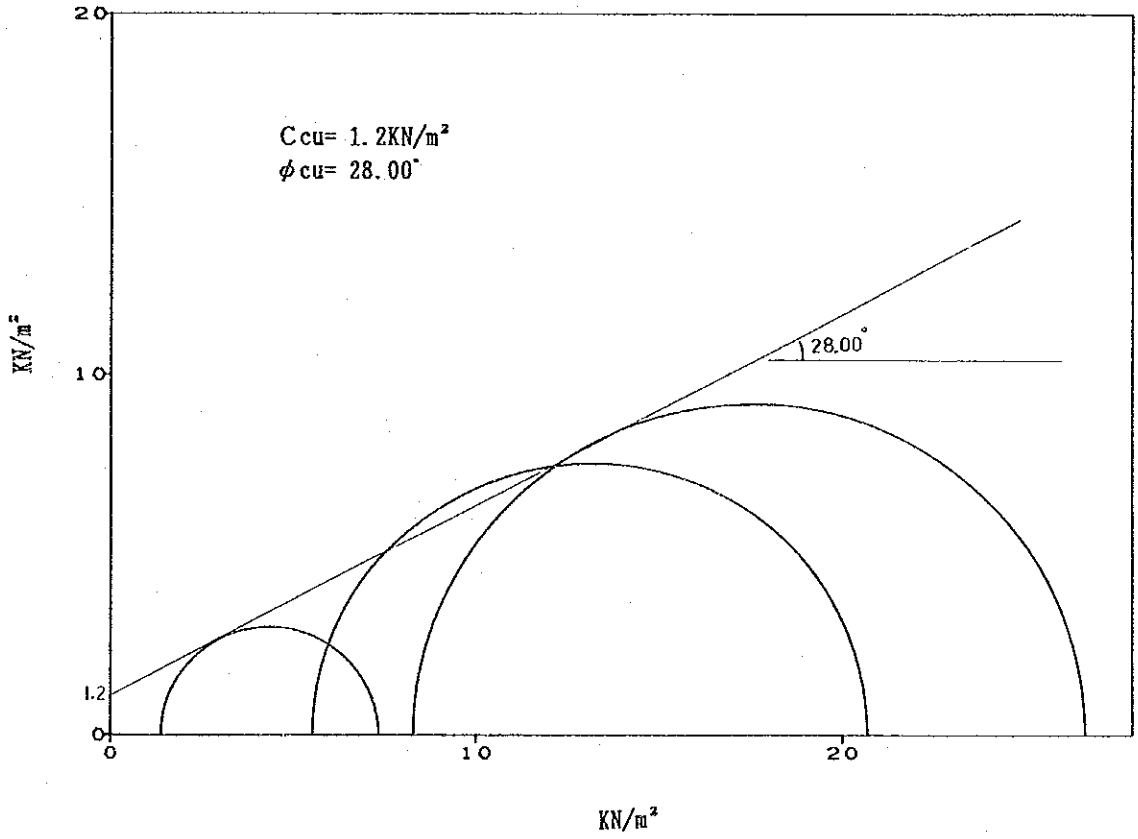


Fig. II-15 Triaxial Compression Test (Mohr's circle) (3 / 5)

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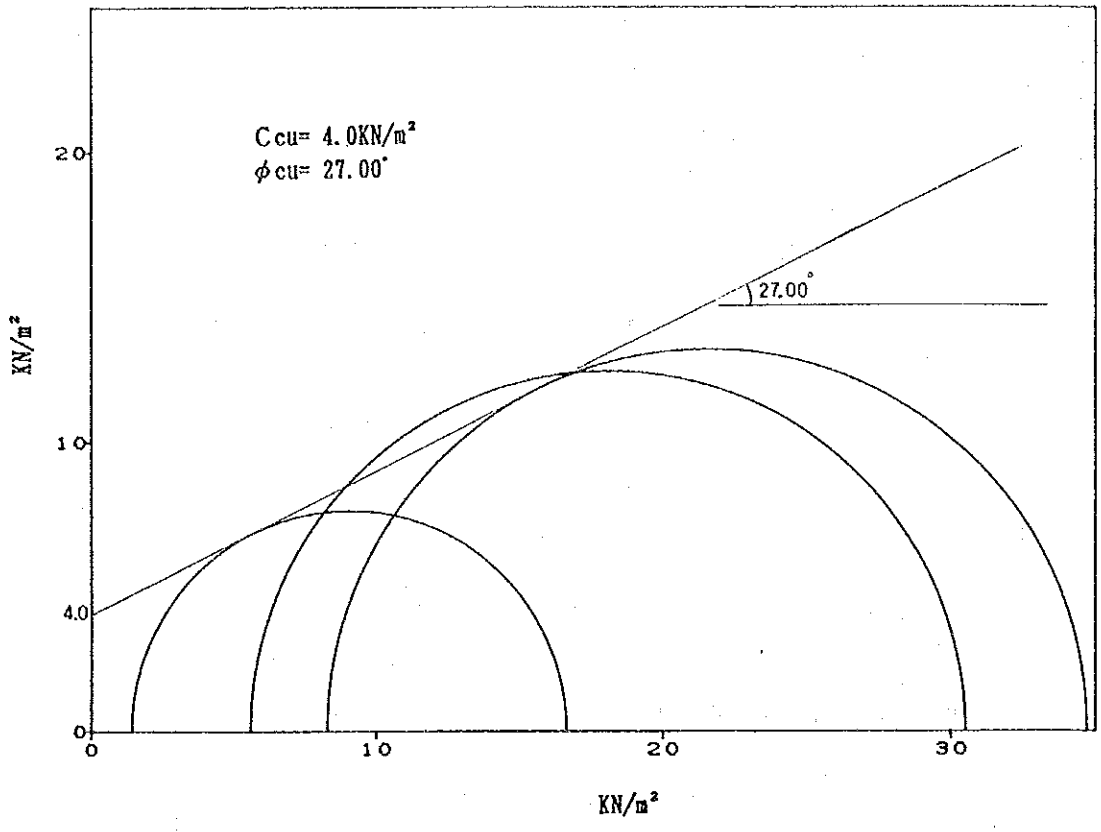
Sample No. TP－2 (2.4～3.0m) UU Test



Sample No. TP－4 (1.0～1.5m) UU Test

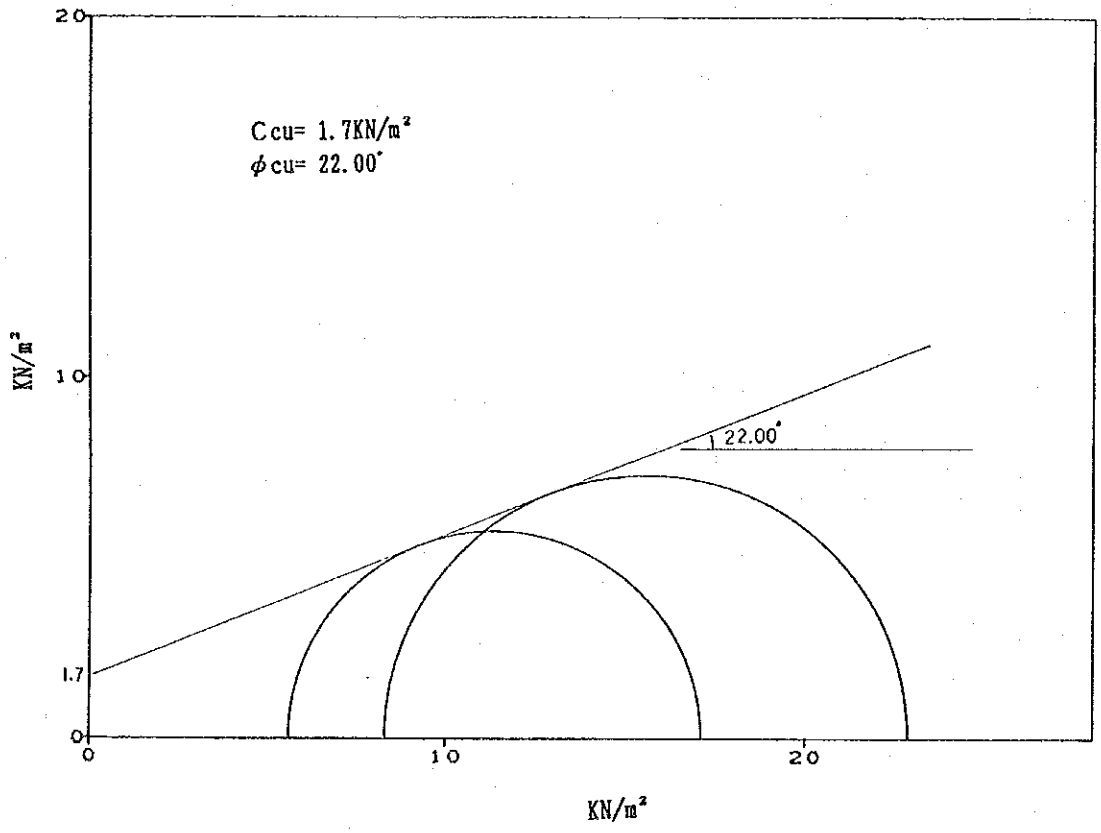


Fig. II-15 Triaxial Compression Test (Mohr's circle) (4 / 5)

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Sample No. TP－10 (1.5～2.5m) UU Test

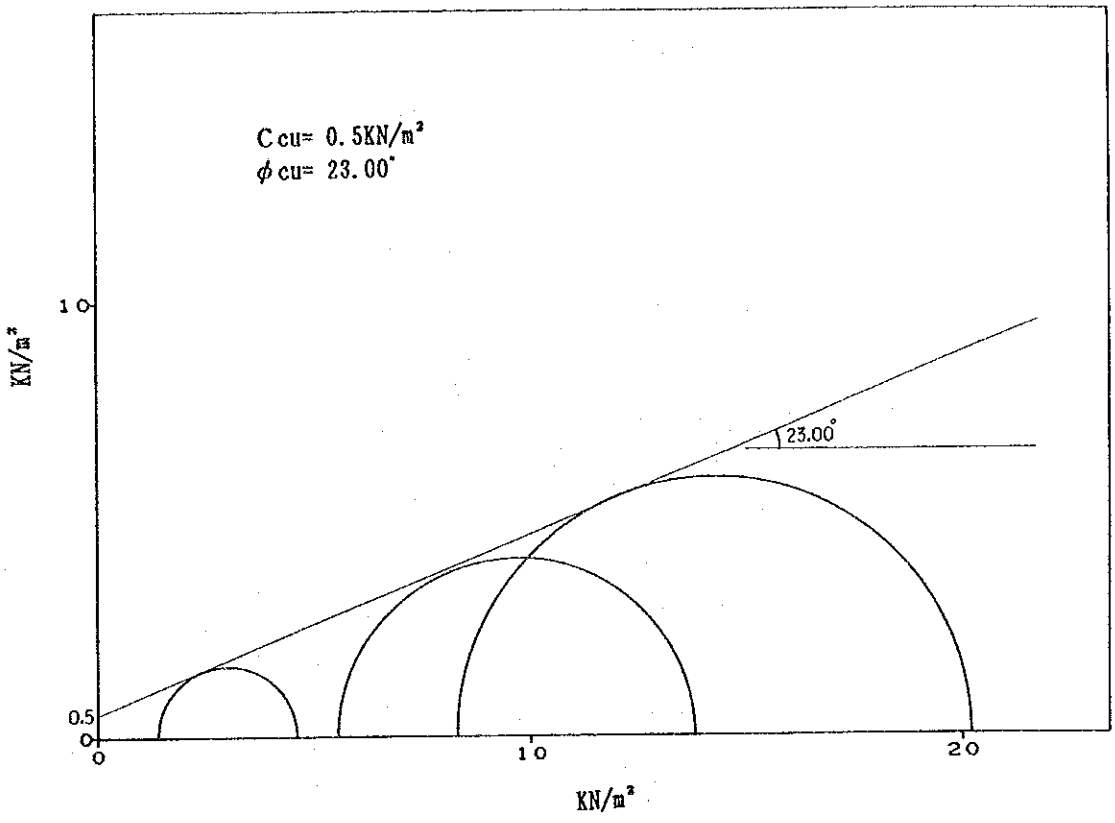

Fig. II-15 Triaxial Compression Test (Mohr's circle) (5 / 5)

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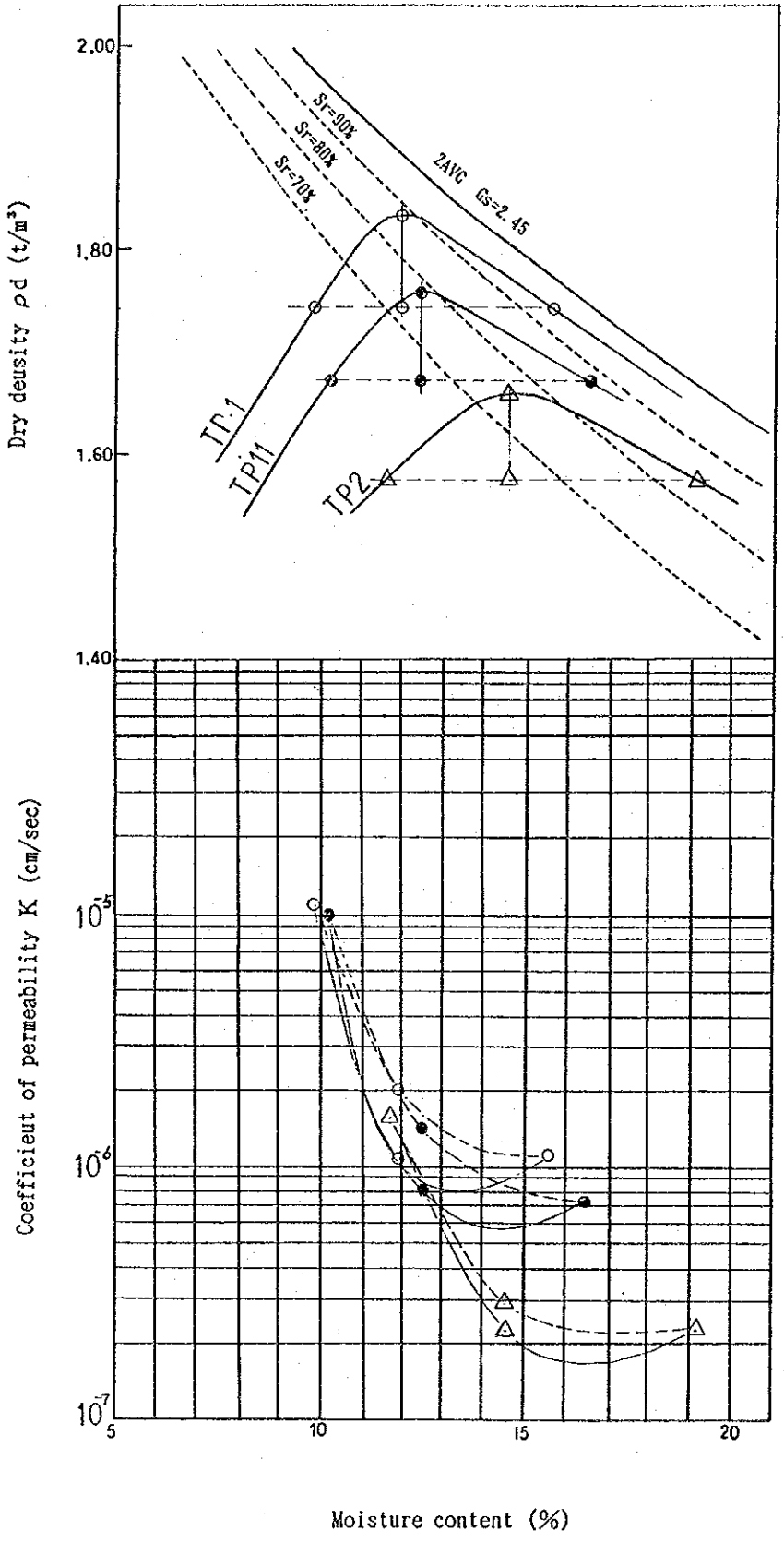

Fig. II-16

Compaction curve/permeability relation (1 / 5)
(Colluvium～Wethered Granitic Rocks)

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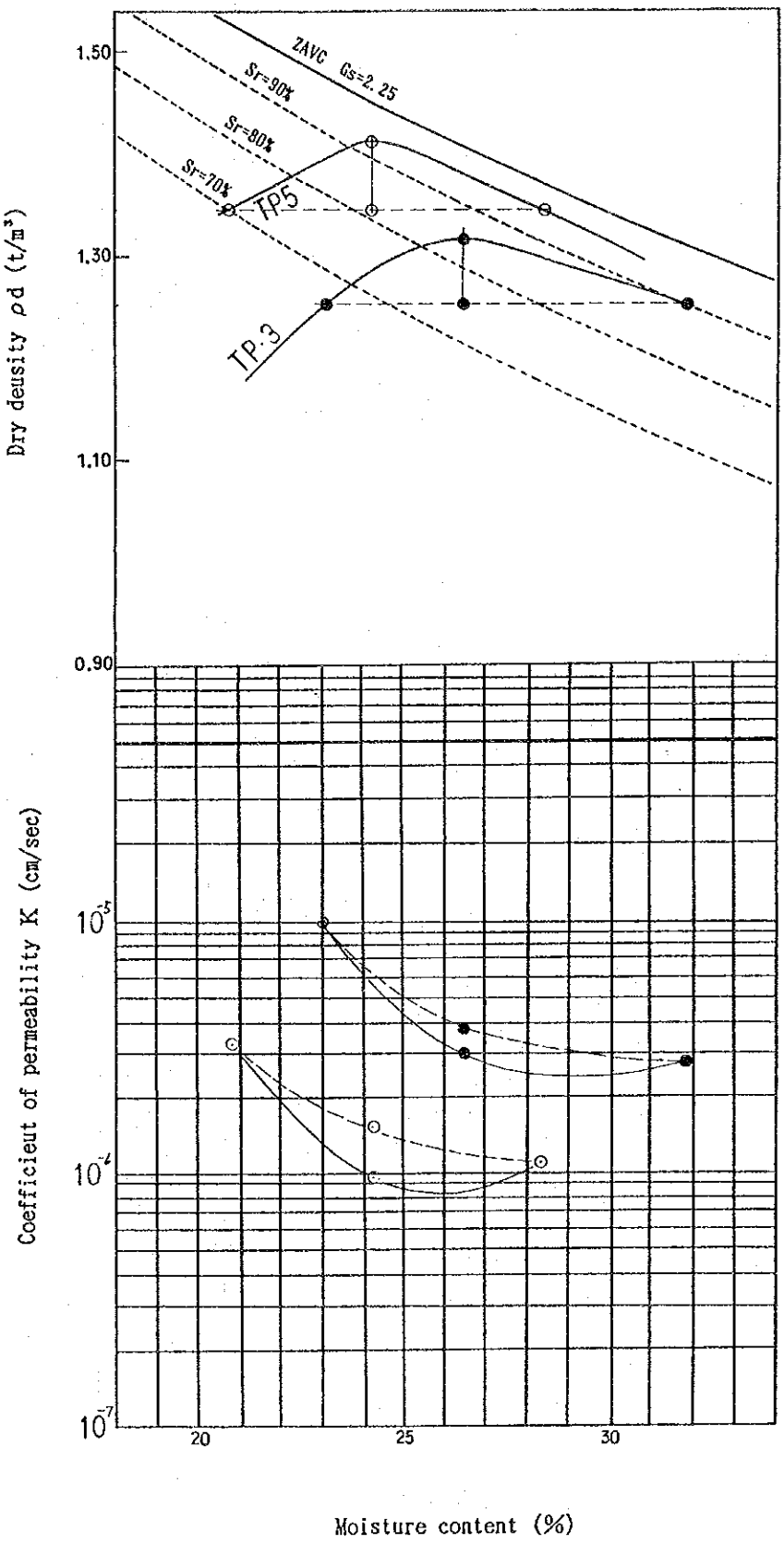

Fig. II-16

Compaction curve/permeability relation (2 / 5)

(Pleistcene Lake Deposits)

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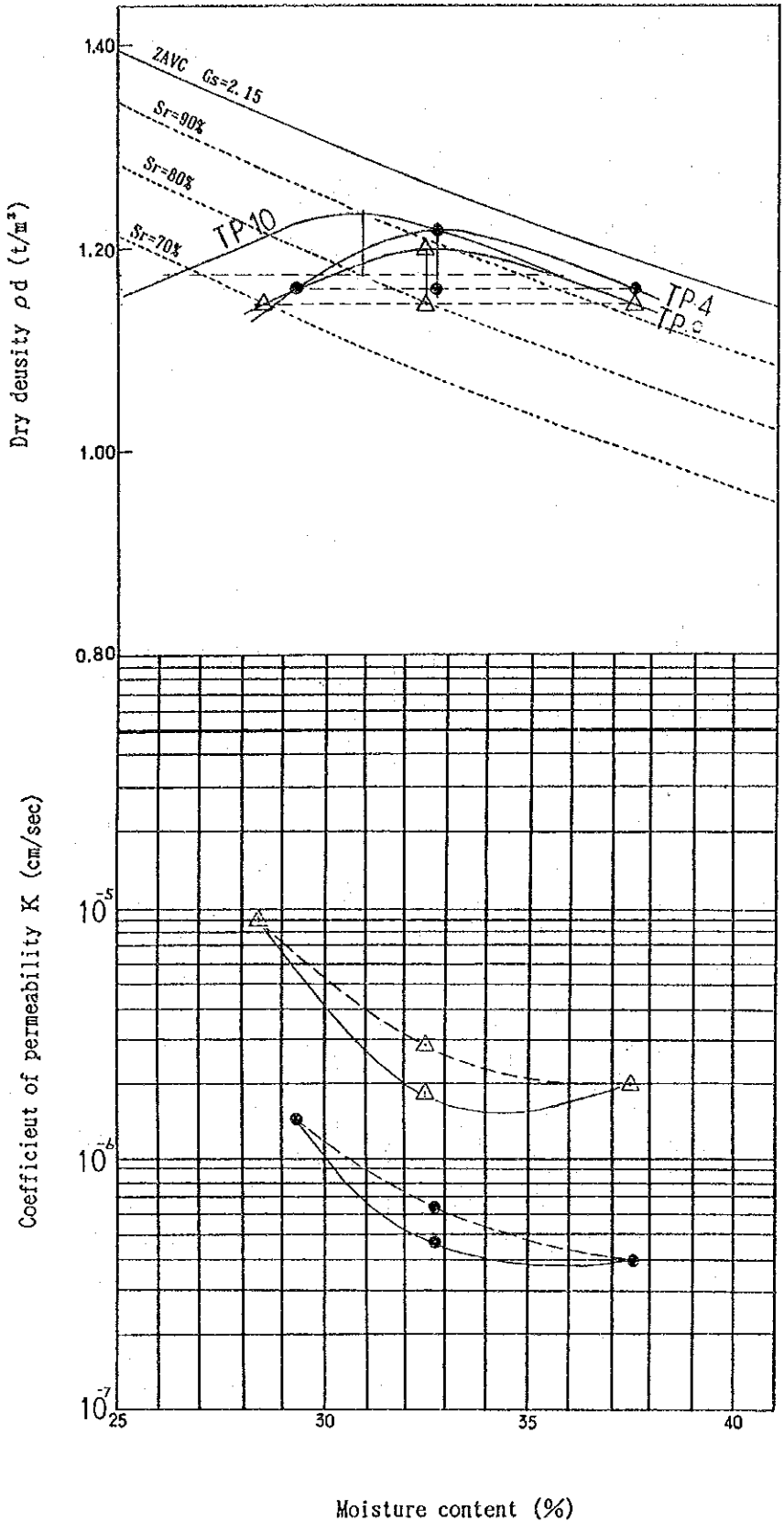

Fig. II-16

Compaction curve/permeability relation (3 / 5)

(Black Cotton Soils～Weathered Lake Deposits)

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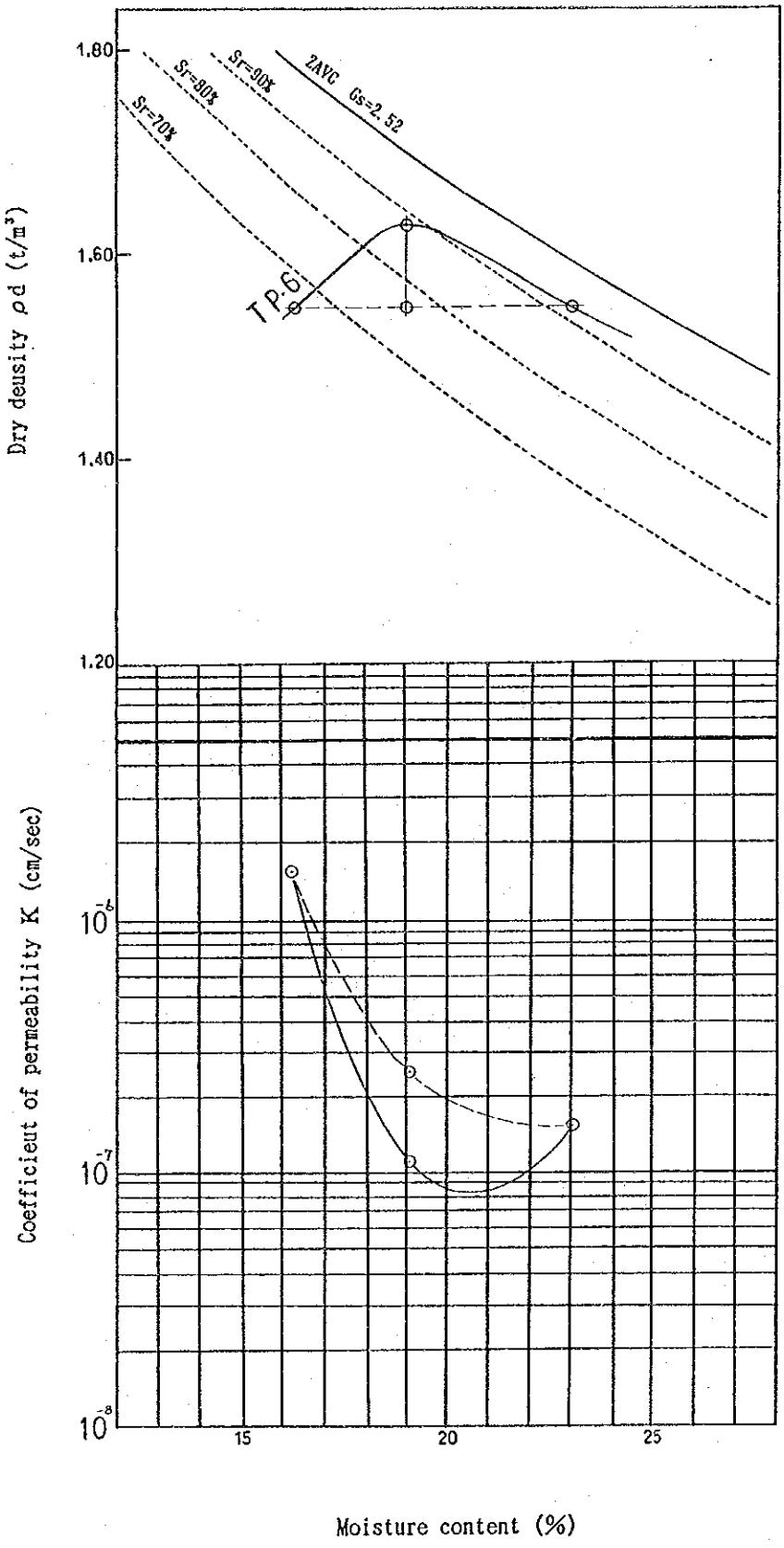

Fig. II-16
Compaction curve/permeability relation (4 / 5)
(Lateritic Ironstone)

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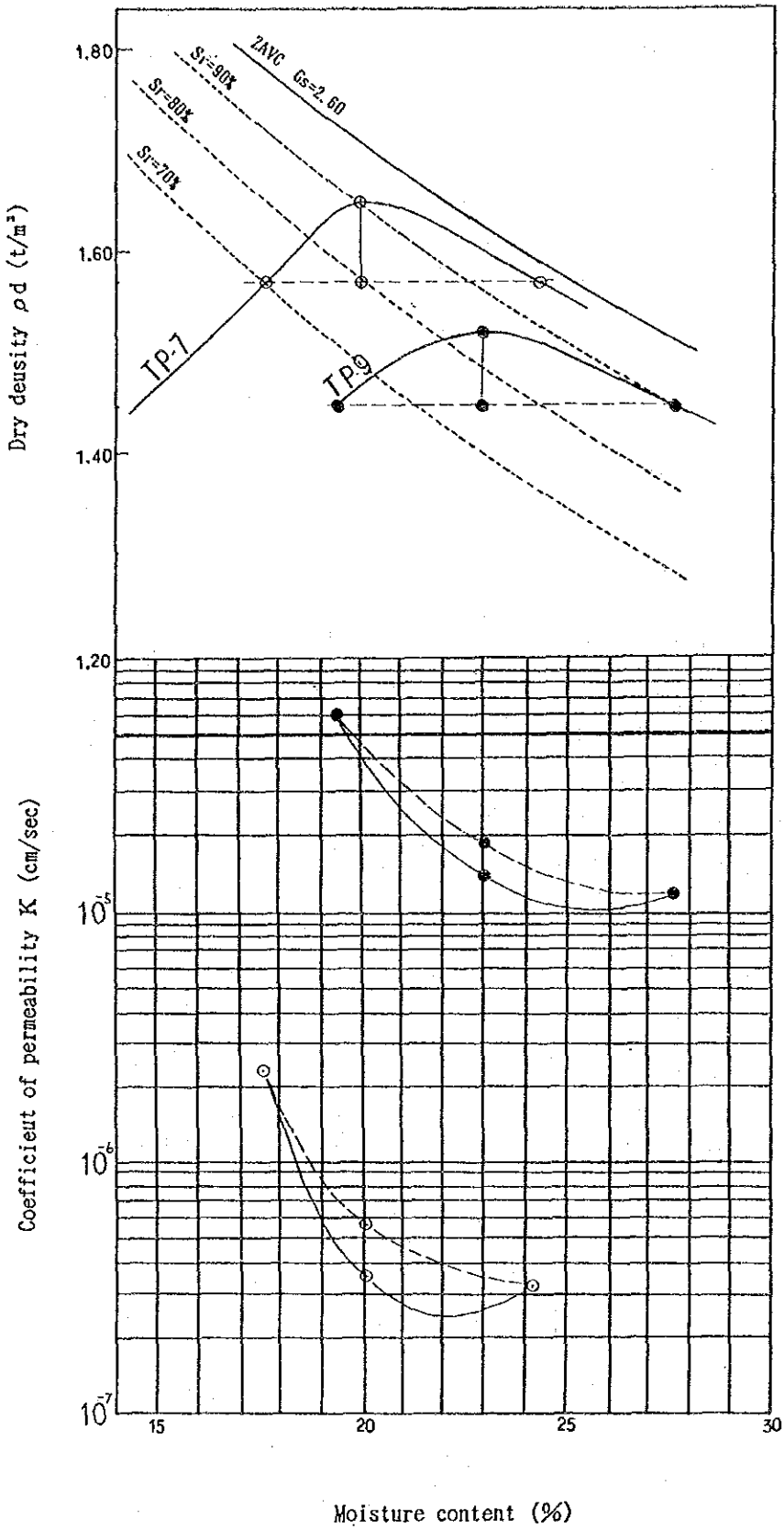

Fig. II-16
Compaction curve/permeability relation (5 / 5)
(Hillwash Deposits)

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Annex III

Soils and Land Classification

Feasibility Study
on
Kano Plain Irrigation Project

Annex III
Siols and Land Classification

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1. INTRODUCTION

For appraisal of the lands suitability for the future irrigation development, the semi-detailed soil survey was carried out in the Kano-Nyakach Plain.

The study area is located between latitude 0°5'S and 0°22'S and between longitude 34° 40'E and 35° 3'E. The area lies on the almost flat terrain which is bordered by Kisumu-Nairobi railway in north, Nyabondo escarpment in south, altitude at about 1200 m in east and Kendu Bay and Kibos river in west.

Soil observations and profile description were carried out in soil pit (digging hole about 80 cm depth) survey to characterize the soils and to confirm or adjust the adequacy of soil boundaries that were based on "Reconnaissance Soil Map of the LBDA area", scale 1:250,000 compiled in December, 1985. The soil types and their boundaries of this map were transferred to the topographic map, scale 1:50,000 used as the base maps for the soil survey.

The present study consists of two significant steps, i.e. soil classification and land evaluation. In the first step, the soils of the area were observed and described through the soil profile survey. At the representative test pit sites, the soils were collected for the later laboratory test. Based on the survey record and the laboratory test result, the soils are classified into the defined soil units, according to the international standard of soil classifications and soil units, the semi-detailed soil map is prepared. For the land evaluation, the basic land elements such as physiography, topography, surface geology soil characteristics and drainage condition are also presented on the soil map.

Following the soil classification, the land suitability for the future irrigation development is evaluated through interpretation of the above soil survey results. According to the Kenya's classification criteria, the irrigation suitability is assessed with respect to the soil mapping units. This information could be fully applied to the selection of the project area to be covered by the Project.

2. GENERAL DESCRIPTION OF THE AREA

2.1 Agro-climate

For assessment to identify the area climatically suitable for various land use alternatives with emphasis on the suitability for particular crops and crop varieties, Kenya Soil Survey (KSS) has prepared the agro-climatic zone maps covering all over Kenya on a scale of 1:1,000,000. This zoning system has two components, namely water availability (r/Eo = rainfall divided by evaporation) and temperature. The study area falls in the zone III-3 which means semi-humid and fairly warm. As for crop production, almost all the crops are adaptable in the zone III-3. The zone III-3 shows r/Eo ratio at 0.50 - 0.55 and mean annual temperature 20 - 22°C. The climatic designation is semi-humid and fairly warm, altitude is 1,150 - 1,200 m. The more detailed meteorological records are presented in "ANNEX I, Meteorology and Hydrology".

2.2 Physiography and Geology

The landscape of the area and its surrounding is recognized as a part of the Rift Valley system. It shows the typical fault formation resulting from the syntechtonic movement which has taken place during the Tertiary period. The landscape is represented by the uplifted horst (escarpment) and the downthrown graben along the Nyabondo fault line traversing with east-west direction. Granodiorite and phonolite are the predominant rocks. The Nyakach Plain is physiographically classified into piedmont plain. It is the coalescening colluvial and alluvial fans, which are formed immediately adjacent to the escarpment. The materials covering the piedmont plain are the unconsolidated reddish particles underlain by the dark lacustrine deposits originating from the Lake Victoria. The Kano Plain is mainly extending lacustrine plain. It appears as the pronounced physiography which occupies the eastern the shore of Lake Victoria. The geological origin is the lacustrine deposits which are characterized by montmorillonite clay with blackish colour. The Plain is incised by the various rivers and streams which drain into the Lake. The principal river is the Nyando on the eastern plain. The Nyando river flows across the plain with south-west direction and turns southwards at Ahero to terminate in the Miruka (Luo) swamp. Due to unfavourable drainage condition, the Plain partly suffers from seasonal flooding.

2.3 Vegetation and Land Use

Several types of natural vegetation are recognized in the area. The hilly lands are generally covered by evergreen or semi-evergreen forests, scrubs and grasses due to moderately high rainfall and soils of free drainage.

The lowland is mostly covered with grass and scrubs, as a result of comparatively lower rainfall and soils of imperfect drainage.

The Kano-Nyakach Plain and its surrounding highlands are extensively utilized for agricultural implements. In the large parts of the Nyakach plain, due to favourable drainage and relatively flat topography, the upland crops are mainly planted, however, the paddy field is extended in a low lying area due to imperfect drainage and flat topography. The main crops are maize and sorghum. Other crops are paddy, pulses, cotton, cassava and sweet potatoes. In the Kano Plain, upland crops such as maize, sorghum, cotton and sugarcane are planted relatively higher lying area and paddy field is developed in a low lying area especially along the rivers and streams or around the seasonal swamp. The homestead area, namely Bomma, is located associated with upland fields.

3. SURVEY PROCEDURE

3.1 Soil Survey

Through the soil survey, pits (about 80 cm depth) were dug at one hundred twenty (120) sites and the soil profile description were carried out according to "Guidelines for Soil Profile Description"(FAO). At the same time, the soil samples were collected for the later laboratory test. Finally one hundred twelve (112) soil samples which are 46 soil profiles were selected. In order to check the location of soil boundaries in the field, auger borings were additionally carried out.

3.2 Laboratory Test

Soil analysis aims at clarification of the physical and chemical properties of soils of the area. The selected 112 soil samples were sent to the Laboratory of Soil Science Division, Nairobi University. They were analyzed with respect to the following eight (8) test items:

1) Physical Analysis
   - particle size distribution (Soil texture)

2) Chemical Analyses
   - pH value
   - electrical conductivity (EC)
   - total carbon content
   - total nitrogen content
   - available phosphorous content
   - cation exchange capacity (CEC) at pH 7
   - exchangeable cations, i.e. Ca, Mg, Na and K

All the analyses are made according to the manual compiled by National Agricultural Laboratories, namely "Physical and Chemical Methods of Soil Analysis". Table III-3.1 summarizes the methods employed.

3.3 Classification and Mapping

Based on the field data and the laboratory test results, the soils were classified into Soil Units according to the legend of "Soil Map of the World" (FAO/UNESCO 1974), and the soil mapping units are set up for conducting the systematic legend of the soil map. Pursuant to the survey methodology applied in the reconnaissance survey, the semi-detailed soil survey is also carried out by physiographic approach. Therefore, the highest category of the legend is given by physiographic terms, i.e. hill, piedmont plain, lacustrine plain etc. These physiographic units are further divided into the lower categories on the basis of topographic conditions, geological origin, etc. These sub-divisions represent mapping units on which one or more Soil Units are identified. They may be similar or contrasting but occur together in a more or less regular pattern, and are so intimately associated that they cannot be separated by boundaries at the semi-detailed level.

In order to show the distribution and the extent of each mapping unit, the soil map is prepared at a scale of 1:50,000. This information is applied for the selection of the future irrigated land and the crops making comparison of the many crop alternatives.

3.4 Land Evaluation

Land evaluation is the process of interpretation of the basic information gathered through the soil survey, i.e. soil characteristics, topography, drainage condition and other aspects of land. In assessing the land suitability for the irrigation farming, the land qualities are selected and graded according to the specific criteria set for by the KSS.

Through the land evaluation, the location and extent of suitable land for irrigation farming are demarcated on land suitability classification map scaled at 1:50,000. This information is applied for the selection of the future irrigated land and the crops making comparison of the many crop alternatives.

4. SOILS

4.1 Result of Field Survey and Laboratory Test

According to the survey procedure mentioned above, the field survey and the laboratory test were carried out. The soil profile descriptions are summarized in Tables III-4.1 and III-4.2. The laboratory test result is presented in Table III-4.3. The representative profiles are given in Table III-4.4 to III-4.13.

4.2 Soil Classification

On the basis of field survey records and laboratory test results, the soils are classified into Soil Units according to the legend of Soil Map of the World (FAO/UNESCO, 1974) and its modification namely "Kenya Concept". Due to complexity of physiography and variation of geological origin, diversities of Soil Units are identified. The major Soil Units in and around the project area are presented below:

1. Lithosols
2. Ironstone soils
3. Ferralic Arenosols
4. Eutric Regosols
5. Chromic Cambisols
6. Vertic Cambisols
7. Calcaric Fluvisols
8. Eutric Fluvisols
9. Eutric Gleysols
10. Sodic Planosols
11. Pellic Vertisols
12. Chromic Vertisols
13. Humic Gleysols
14. Eutric Histosols

The following paragraphs explain the baseline features of Soil Units identified.

(1) Lithosols

By definition (FAO/UNESCO), Lithosols are soils limited in depth by continuous hard rock within 10 cm of the surface. This depth limitation was found to be inadequate for Kenyan conditions and is re-set at 25 cm. The soils are very shallow, dark reddish brown to brown, sandy clay loam to gravelly clay on the phonolite rock. Those soils are unsuitable for any crops.

(2) Ironstone soils

Ironstone soils are defined so as to embrace all soils with a massive ironstone layer (petro-ferric horizon) starting within 50 cm of the surface. It is a pragmatic grouping to cover a variety of Soil Units that all have in common the presence of massive ironstone at shallow depth, although the soils themselves may be genetically different. These soils are distributed on the piedmont plain and plateau, and not in the Kano Plain.

(3) Ferralic Arenosols

Arenosols are very light-coloured, coarse-textured sandy soils with a high proportion of almost pure quartz. The subsoil may show characteristics of an argilic, cambic or oxic B horizon. They do not, however,

have such horizons because the soil texture is too coarse. Ferralic Arenosols show the ferralic properties with many coarse mottles with hues redder than 7.5 YR or chromas more than 5.

(4) Eutric Regosols

Regosols are very young soils, almost without soil development. They consist mainly of unconsolidated soil materials, exclusive of recent alluvial deposits. Regosols retain little water. Eutric Regosols have a base saturation of 50 percent or more at least between 20 and 50 cm from the surface but not calcareous within this depth. Those soils are mainly distributed on the piedmont plain.

(5) Chromic Cambisols

Chromic Cambisols are Cambisols having an ochric A horizon and a base saturation of 50 percent or more at least between 20 and 50 cm from the surface but no calcareous within this depth. Those soils are distributed on the piedmont plain and on the cuspate delta.

(6) Vertic Cambisols

Cambisols have a cambic B horizon or an umbric A horizon (dark topsoils). The cambic B horizon is an altered horizon with a soil structure, or with some clay illuviation, or with a red colour. They are in a transitional stage of development between young soils and the more mature soils. Vertic Cambisols have an ochric A horizon (reddish topsoils) showing vertic properties.

(7) Calcaric Fluvisols

Calcaric Fluvisols are developed from recent fluvial deposits which have calcareous horizon within 50 cm of the surface. Those soils are distributed the recent flood plain on the cuspate plain.

(8) Eutric FLUVISOLS

Fluvisols are young soils consisting of various thin layers of sediment of deferring texture. Eutric Fluvisols are derived from recent fluvial deposits having a base saturation of 50 percent or more at least between 20 to 50 cm from the land surface but which are not calcareous at the same depth.

Soils in Kano Plain are well to imperfectly drained, deep, dark brown to brownish black, friable, stratified sandy clay loam to clay; in places mottled, firm clay. The eutric Fluvisols extend on the river levees; their distribution area is relatively wide in the Kano Plain.

(9) Eutric Gleysols

Gleysols are poorly drained soils, in low-lying areas and in depressions, which are influenced by high groundwater table, therefore they show hydromorphic properties. Eutric Gleysols have a base saturation of 50 percent or more at least between 20cm and 50 cm from the surface but not calcareous within this depth.

(10) Sodic Planosols

Sodic Planosols are well to imperfectly drained, deep, dark greyish brown to brown, mottled soils of varying consistence and texture; sodic and/or saline, clay and exchangeable base in the surface soils are elluviated to the subsoil, so the subsoil accumulates those materials.

(11) Pellic Vertisols

Vertisols are heavy clay soils (clay >30%) which shrink and have large deep cracks of more than 1 cm wide at a depth of 50 cm. The soil has a high water retention, but relatively small amount of water is available for plant growth. There are two types of Vertisols, namely pellic Vertisols and chromic Vertisols. Pellic Vertisols are dark, almost black, usually occupying shallow depression that are somewhat waterlogged during the rainy season. On the other hand, chromic Vertisols are brownish and better drained.

Pellic Vertisols are moderately well to imperfectly drained, very deep, dark greyish brown to black, very firm, cracking montmorillonite clay.

Pellic Vertisols are the most dominant soils of the Kano Plain, occupying wide level to slightly sloping situations.

(12) Chromic Vertisols

Chromic Vertisols are well to moderately well drained, moderately deep to deep, dark brown to dark grey, firm to very firm, cracking montmorillonite clay; in places slightly sodic. The chromic Vertisols are more brownish and better drained than the pellic Vertisols. Chromic Vertisols extend only the limited part of the Kano Plain.

(13) Humic Gleysols

Humic Gleysols are poorly to very poorly drained, dark grey to black, clayey soils with acid humus. The soils are influenced by high ground water table and show hydromorphic properties.

Humic Gleysols distribute around the permanent swamps and along the streams. Those soils are marginally suitable status for paddy plant only.

(14) Eutric Histosols

Eutric Histosols are very poorly drained, deep to very deep, dark grey to black, half clay with humic or histic topsoil; in many places peaty. The distribution of this soil is restricted in the permanent swamps.

4.3 Differentiation Criteria

In order to describe soil profile and differentiate the soil horizon, furthermore soil characteristics, the differentiation criteria are used as follows.

(1) Texture, structure and consistency are described according to the Guideline for soil profile description (FAO, 1977).

(2) Colour of the soils are described according to the Revised Standard Soil Colour Charts.

(3) Soil reaction is described according to the following classes corresponding to soil pH value.

Class	pH-H_2O
Extremely acid	< 4.5
Strongly acid	4.5 - 5.5
Slightly acid	5.6 - 6.5
Neutral	6.6 - 7.3
Moderately alkaline	7.4 - 8.4
Strongly alkaline	8.5 - 9.0
Very strongly alkaline	9.0 <

(4) Soil salinity is described according to the following classes corresponding to Electrical Conductivity (EC) value.

Salinity class	ECe (mmho/cm)	EC 2.5* (mmho/cm)
Non-saline	< 4	< 2
Slightly saline	4 - 8	2 - 4
Moderately saline	8 - 16	4 - 8
Strongly saline	16 <	8 <

*Valid for moist material with a texture of clay.

(5) Soil sodicity is described according to the following classes corresponding to Exchangeable Sodium Percentage (ESP).

Sodicity class	ESP *
Non-sodic	0 - 5
Slightly sodic	6 - 10
Moderately sodic	11 - 15
Strongly sodic	15 <

* : ESP can be given as a value of exchangeable Na divided by total exchangeable cations.

(6) Soil depth is described according to the following classes.

Effective Soil Depth Class	depth (cm)
Very shallow	< 30
Shallow	30 - 60
Fairly deep	60 - 90
Deep	90 <

(7) Topography is described according to the following

	Complex slope (%)	Class
A	0 - 2	G - flat to very gently undulating
B	2 - 5	G - gently undulating
C	5 - 8	U - undulating
D	8 - 16	R - rolling
E	16 - 30	H - hilly
F	< 30	

(8) Soil drainage refers to the rapidity and extent of the removal of water from the soil especially by surface runoff and by flow through the soil. On the bases of the observation, relative soil-drainage classes are described below.

1) Very poorly drained:
Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time. Soils usually occupy level or depressed sites and frequently ponded.

2) Poorly drained:
Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface during a considerable part of the year.

3) Imperfectly or somewhat poorly drained:
Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile.

4) Moderately well drained:
Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time. Moderately well drained soils commonly have a slowly permeable layer within or immediately beneath the solum.

5) Well drained:
water is removed from the soil readily but not rapidly. Well drained soils are commonly intermediate in texture.

6) Somewhat excessively drained:
Water is removed from the soil rapidly. Some of the soils are lithosolic. Many of them have little horizon differentiation and are sandy and very porous.

7) Excessively drained:
Water is removed from the soils very rapidly. Shallow soils on slopes may be excessively drained.

4.4 Mapping Unit Description

Thirty four soil mapping units were differentiated in the extending soils of the Kano-Nyakach Plain. The distribution of each mapping unit is presented on the semi-detailed soil map in Figure III-4.1. The detailed information of mapping units can be referred to the legend of soil map (Table III-4.14). The baseline features of each unit are described below.

4.5 Physical and Chemical Properties of Soils

4.5.1 Soil texture

The soil texture influences a number of the other properties of soil, e.g. structure, consistency, water holding capacity, permeability, infiltration rate, run-off rate, erodibility, workability, root penetration and fertility.

Soil texture is classified into soil textural classes based on United States Department of Agriculture (U.S.D.A.) system.

Soils	Texture	Class names
Sandy soils	coarse textured	S and LS
Loamy soils	moderately coarse textured	SL
	medium textured	L, SiL, and Si
	moderately fine textured	CL, SCL and SiCL
Clayey soils	fine textured	C, SC and SiC

The soils of the Nyakach Plain broadly vary from coarse to fine texture. The soils on the fan base and the lacustrine are rather finer, on the other hand; in the piedmont plain, some coarse textured soils are observed.

Almost of the soils distributed on the Kano Plain are fine textured. Some soils in the piedmont plain have coarse textured or moderately coarse textured.

4.5.2 Soil reaction (pH)

Soil reaction (pH), which is expressed by the negative logarithm of the hydrogen activity in a soil-water suspension, was determined in the laboratory. The pH value also shows the relationship between soil pH and electrical conductivity (EC). The pH values of 8.5 or more usually occur in the soils where presumably alkaline earth carbonates or much sodium ion are present.

The pH value of the soils range from 4.5 to 10.4. In cuspate delta, high pH of 9 or more is observed , and humic Gleysols (No. 104) near the swamp shows low pH value at 4.5.

4.5.3 Salinity

The EC values of all samples were measured in extraction from the soil-water (1:2.5) suspension. For some samples, saturated paste was prepared and EC of saturation extract (ECe) was measured. Assuming a liner inversed relationship between ECe and EC2.5, the ratio of 2:1 was roughly obtained. This conversion factor of 2 is applied for the appraisal of salinity hazard.

EC (1:2.5) of soils in the whole surveyed area ranged from 0.02 to 1.25 mmho/cm, and the major part of the surveyed soils are less than 1.0 mmho/cm. Therefore, almost all of the soils are "non-saline" (EC2.5 are less than 2 mmho/cm).

4.5.4 Sodicity

Sodicity of a soil is represented by Exchangeable Sodium Percentage (ESP) absorbed on the soil exchange complex. Soils which have more than 6% saturation with exchangeable sodium in some horizons within 100 cm of the surface are identified as soils with a sodic phase (FAO/UNESCO, 1974).

The soils having ESP of more than 15 are classified into alkaline soils. The extremely high ESP values are observed in the cuspate delta.

4.5.5 Cation exchange capacity and exchangeable bases

The CEC of the soils in the Kano Plain is very high, especially in Vertisols and humic Gleysols due to high contents of montmorillonite clay and humus. On the other hand, the CEC of Nyakach Plain widely ranges from 1.3 to 32.5. The CEC of the soils largely depends on clay and humus contents of the soil.

The major exchangeable bases are Ca, Mg, Na and K. The base saturation (%) is shown that the total exchangeable cations divided by CEC of soils. Soils in the area are generally high in the degree of base saturation except a few soils, and the degree of base saturation in the upper horizons is usually lower than that of the lower horizons.

As mentioned in section 4.5.4, another unfavourable condition is the relatively high amount of Na in the exchange complex which is associated with a considerable dispersion of the soil.

5. LAND EVALUATION

5.1 Classification System

The land classification system produced by the U.S. Bureau of Reclamation (USBR) has been applied to a number of irrigation projects in many countries. In the USBR system, the land is categorized into six suitability classes. The basic concept of this system is to evaluate the economic return against the investment for the project works.

Since it is difficult to adapt this system in Kenya directly due to lack of the economic data, KSS has modified the specified criteria to allow for the Kenyan conditions. The proposed criteria for irrigation suitability classification is set forth based primarily on the physical and chemical constraints of the area (F.N. Muchena, 1981). For the present study, this modified classification system is employed. In order to clarify the land suitability for the alternative crop production, the appraisal is made for both wetland paddy and the common upland crops.

5.2 Land Suitability Classes

There are two kinds of interpretative land classification as follows:

(a) Current land suitability :
an appraisal of the suitability of land for irrigation without significant land improvement measures as to alter the present limitations and qualities of the land.

(b) Potential land suitability:
an appraisal of the potential suitability of the land for irrigation with significant land improvement measures as to require improvement level and type of land.

In order to clarify the suitability for the future development, the appraisal of potential land suitability is carried out in the present study. The appraisal is done under the following conditions:

a) Sufficient irrigation water of good quality is supplied to the areas concerned. Irrigability is, therefore, not considered.

b) Proper drainage network is established. This allows to remove the stagnant water in the minor depressions and the excess irrigation water.

c) Except for the extremely populated area, the present inhabitant area can be changed into irrigated land in future.

According to the specific criteria, five suitability classes are designated as follows:

Class S1: Highly suitable
Land of high productivity for most crops under irrigation with minimum costs of development and management associated with the land.

Class S2: Moderately suitable
Land of moderate productivity due to slight to moderate limitations in land characteristics with moderate costs for development and management.

Class S3: Marginally suitable
Lands of restricted productivity due to moderate to severe limitations in land characteristics with relatively high costs for development and management.

Class NS1: Provisionally unsuitable
Lands which are considered unsuitable for irrigation but require further investigation.

Class NS2: Unsuitable
Land which are unsuited for irrigation due to severe limitations in soils, topography or drainage.

5.3 Specific Criteria

5.3.1 General

In Kenya, suitability for the future land use with irrigation is evaluated with the following land qualities (Muchena, 1981).

(a) soil deficiencies (symbol 's')
- soil texture
- soil depth
- alkalinity
- salinity

(b) drainage (symbol 'd')

(c) topography (symbol 't')
- slope
- microrelief

(d) vegetation (symbol 'T')

Table III-5.1 and Table III-5.2 give the specific criteria for paddy and common upland crops. The following paragraphs deal with the further details of the land qualities concerned.

5.3.2 Soil texture

Soil texture is given by the particle size fraction. The permeability and the water holding capacity of soil are directly governed by the soil texture. For upland crops, soils of sandy loam to friable clay are highly suitable. For paddy plant, the subsoil texture should be finer since low permeability is rather favourable. All soils on the Kano Plain has favourable soil texture for paddy. On the other hand, the soils on the Nyakach Plain are a little porous with the coarser particles.

Most of the soils in the area are deep enough for the minimum requirements of soil depth of 45 cm for upland crops and 30 cm for paddy plant.

5.3.3 Alkalinity and salinity

The soil pH is one of the important characteristics for the evaluation of the land suitability. Because of the basic geological origins, the soil pH values are generally high. Limitations due to acidity are not relevant to the study area. The pH value ranges between 4.8 and 10.4. Higher values occur locally only on the cuspate delta. Most of the surface soils on the Kano - Nyakach Plain are slightly acidic to neutral and subsoils are neutral to basic.

Sodic material has an adverse effect on the chemical and physical property of soils. The high sodium content on the exchange complex causes easy dispersion of the clay complex. As a result, the soils are extremely compacted and hard. Structure stability of this soil material is low. In the construction of canals, some difficulties may arise where the sodic materials present at shallow depth.

Soil salinity is also an important characteristics for the evaluation of the land suitability. The electrical conductivity (EC) can indicate the soil salinity classes. In the specific criteria, the EC value of the saturation extract (ECe) is used for the definition of salinity classes. Most of the soils in the area are rather low in soil salinity except for the special cases in the depression into which salts are drained.

5.3.4 Drainage

As mentioned in section 4.3, seven drainage classes are defined in broad terms. According to U.S. Soil Survey Manual, the necessity of artificial drainage works is dealt with these drainage classes.

(1) Very poorly drained
The soils are wet enough to prevent the growth of crops except rice without artificial drainage.

(2) Poorly drained
Artificial drainage is generally necessary for upland crop production, provided that other soil characteristics are favourable.

(3) Imperfectly or somewhat drained
The growth of upland crops is restricted to a marked degree, unless artificial drainage is provided.

(4) Moderately well drained and well-drained
The soils of these classes commonly retain optimum amounts of moisture for plant growth after rainfall or supply of irrigation water.

(5) Somewhat excessively drained
Only a narrow range of crops can be grown on these soils, and the yields are usually low without irrigation.

(6) Excessively drained
Enough precipitation is commonly lost from these soils to make them unsuitable for ordinary crop production.

In the study area, the soils of lowlying land in lacustrine plain fall the drainage classes 2 to 3. On the other, the soils of the piedmont plain are of the drainage classes 3.

5.3.5 Topography

Topography limitations are derived from micro-relief of the land. Micro-relief is expressed by the length and steepness of slope. Except the higher land lying adjacent to the hills, the slope is not limiting factor in the area. Micro-relief deals with irregularities of land within short distances. The minor irregularities shall be improved through the Project. Particularly for paddy field, the land levelling shall be required.

5.3.6 Vegetation

This factor indicates the degree of land clearing. Vegetation cover ranges from grass to dense forest. This variation directly relates to the clearing cost. As for clearing needed, the project area is not restricted by vegetation.

5.4 Result of Land Evaluation

5.4.1 General

The appraisals of land suitability are made both for paddy and common upland crops. Land suitable classification map is presented in Figure III-5.1 (Land suitability for paddy plant and upland crops). Following tables, summarize the land suitable classification for paddy and upland crops.

Land Suitability Classes for Paddy Plant (Study Area)

Suitability Class	ha	%
S1	9,160	12.6
S2	26,350	36.1
S3	16,690	22.9
NS	20,780	28.4
Total	72,980	100.0

Land Suitability Classes for Upland Crops (Study Area)

Suitability Class	ha	%
S1	2,850	3.9
S2	13,950	19.1
S3	36,900	50.6
NS	19,280	26.4
Total	72,980	100.0

Out of 72,980 ha of the area, 52,200 ha (72%) are suitable for paddy and 53,700 ha (74%) are suitable for upland crops.

5.4.2 Land suitability classes for wetland paddy

Owing to flat topography and finer soil, the lowlying land on the Kano Plain (K2, K3) is categorized into highly and moderately suitable land. Although the irregular micro-relief occurs resulting from small gullies, the lower parts of the piedmont plain (P31, P32) small parts of (K13, K21, K3) and the fan base (F11, F12, F22) are marginally suitable.(Table III-5.3).

Due to unfavourable topographic condition and coarser soil, the higher parts of piedmont plain (P11, P2, P33, P34) are unsuitable for paddy. The shallow soil depth also restricts the paddy cultivation on the uplands (U1, U2).

In views of distribution of each suitability class, the large portion of Sub-area III to VIII is highly to moderately suitable for paddy cultivation. Besides, Sub-areas I and II are marginally suitable for paddy.

The eutric Fluvisols of the Kano plain area has highly suitable lands for the cultivation of paddy plant. The chromic Vertisols and pellic Vertisols are highly to moderately suitable, however, they are very low permeability due to containing a lot of montomorillonite clay. The land suitability classes for paddy field in and surrounding project area (subarea I to V) are summerized as follows:

Suitability Class	Project and Sorrounding Area		ProjectArea	
	ha	%	ha	%
S1	4,460	12.0	3,320	22.2
S2	1,420	3.8	1,020	6.8
S3	14,820	39.9	10,590	70.9
NS	16,480	44.3	0	0.0
Total	37,180	100.0	14,930	100.0

Those Vertisols are well suited for irrigated paddy cultivation. The sodic Planosols are also marginally suitable because their subsoils are sodic and have low permeability.

The eutric Histosols and Fluvisols saline-sodic phase existed in the permanent swamp and the Lake Victoria shore, respectively, both soils are very poorly drained, so that they are unsuitable for paddy cultivation. The Lithosols are also unsuitable, because they are very shallow soil on the rock land, their distribution in limited one place of Buoye village only.

5.4.3 Land suitability classes for upland crops

Highly suitable land exists only in a limited area in the project area because of topography dissected by many streams. The lower parts of the piedmont plain (P31, P32) and the rather well-drained land of the Kano Plain (K21, K3) are highly to moderately suitable for diversified upland crops. The other suitable lands

distributed on the fan base (F11, F12, F22, F3, F4) and the lowlying area of the Kano Plain (K21, K22). They are marginally suitable for upland crops due to imperfect drainage condition (Table III-5.3-2).

The soils on the lake shore (P33, P34) and on the delta (D1) are marginally suitable to unsuitable due to the potential alkalinity and salinity hazard and in perfect drainage condition. The upland (U1, U2) is also unsuitable due to shallow soil depth.

As mentioned above, about 74% of the study area is suitable for upland crops. Sub-area II lying on the piedmont plain may be the most suitable area for the large scale irrigation farming with upland crops. The land suitability classes for upland field in and surrounding project area (subarea I to V) are summerized as follows:

Suitability Class	Project and Sorrounding Area		Project Area	
	ha	%	ha	%
S1	2,080	5.6	1,310	8.8
S2	9,280	25.0	5,280	40.0
S3	12,440	33.3	7,800	52.2
N	13,380	36.0	0	0.0
Total	37,180	100.0	14,930	100.0

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4. Ministry of Agriculture - National Agricultural Laboratories, Kenya Soil Survey: Soil condition in the South Western Kano Plains (Kisumu District), site evaluation report No. p82 (1987).

5. Republic of Kenya, Lake Basin Development Authority: Sondu River Multipurpose Development Project, Volume - V, Supporting Study Report for Irrigation Plan, , appendix III. Soil and Land Evaluation (December, 1985).

Tables

Table III-3.1 Laboratory Test Methods of Soil Analyses

Test Item	Principle or Method
Sample preparation	; Breaking up of aggregates by careful pounding; seaving through a 2mm sieve. This sieved fraction (<2mm) is used for further analyses.
Particle size analysis	; Hydrometer method - shaking overnight with sodium hexametaphosphate/sodium carbonate in an end-over-end shaker at 40 r.p.m.; measuring silt+clay (0-50 μm) and clay (0-2 μm) with a hydrometer after 40 seconds and 2 hours respectively. Sand fraction (50-2000 μm) is obtained by substracting the sum of silt and clay from 100% (Day, 1956)
pH (H_2O, KCl) and EC	; pH and EC are routinely measured in suspension with a soil:water ratio of 1:2.5. Suspensions are prepared by placing 10g of fine earth and adding it to 25ml of distilled water. pH-KCl is also measured by adding 1M-KCl solution 25ml instead of H_2O 25ml.
Carbon	; Walkley and Black method (Black, 1965).
Nitrogen	; Kjeldhal digestion method
Available phosphorus	; Olsen-P method
Cation exchange capacity	; CEC is determined by successive leachings of the soil with 1M ammonium acetate of pH 7.0. Determing NH_4 in the leachate.
Exchangeable cations	; Leaching of the soil with 1M NH_4OAc of pH 7.0. Determing Na, K and Ca by flame photometer. Mg is determined by atomic absorption spectrophotometer.

Source : Prepared by JICA Study Team

Table III-4.1 Generalized Description of Soil Profile Key of Description

Boundary of horizon: a (abrupt, less than 2.5cm), c (clear, 2.6 - 6.3cm)
g (gradual, 6.4 - 12.5cm), d (diffuse, more than 12.6cm)

Form of boundary: s (smooth), w (wavy), i (irregular), b (broken)

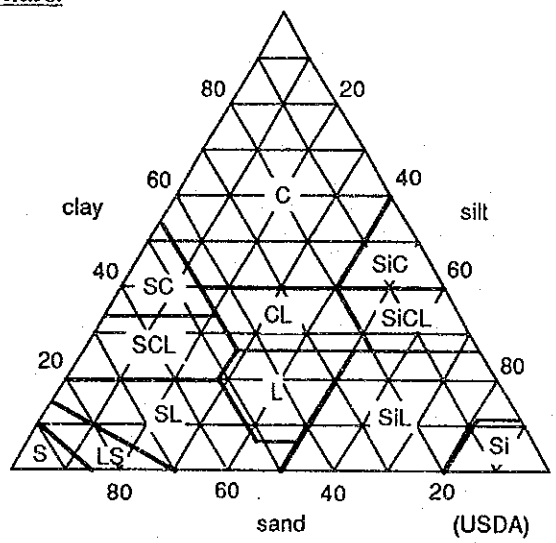
Mottling:

abundance	size	contrast
f (few, 2%)	f (fine, 5mm)	f (faint)
c (common, 2 - 20%)	m (medium, 5 - 15mm)	d (distinct)
m (many, 20%)	c (coarse, 15mm)	p (prominent)

Structure:

grade	type or form
1 (structureless)	pr (prismatic)
w (weak)	co (columnar)
m (moderate)	bk (blocky)
s (strong)	abk (angular blocky)
	sbk (subangular blocky)
	pl (platy)
	gr(granular)
	cr (crumb)
	sg (single grain)
	m (massive)

Texture:



Size:

(unit:mm)

size/type	granular	blocky	prismatic
vf (very fine)	<1	<5	<10
f (fine)	1 - 2	5 - 10	10 - 20
m (medium)	2 - 5	10 - 20	20 - 50
c (coarse)	5 - 10	20 - 50	50 - 100
vc (very coarse)	10<	50<	100<

Consistence:

wet soil	moist soil	dry soil
ns (non-sticky)	lo (loose)	lo (loose)
ss (slightly sticky)	vfr (very friable)	s (soft)
s (sticky)	fr (friable)	sh (slightly hard)
vs (very sticky)	fi (firm)	h (hard)
np (non-plasticity)	vfi (very firm)	vh (very hard)
sp (slightly plasticity)	efi (extremely firm)	eh (extremely hard)
p (plasticity)		
vp (very plasticity)		

Source : Prepared by JICA Study Team

Table III - 4. 2 Generalized Description of Soil Profile (1/6)

No.	Horizon	Depth of Horizon (cm)	Boundary of Horizon	Form of Boundary	Colour wet	Colour dry	Textural Class	Structure Grade	Structure Type	Structure Size	Consistence wet	Consistence moist	Consistence dry	Remarks
1.	Al	0 - 13	g	s	10YR3/1	10YR3/1	CL	m	sbk	f	ss,sp	fi	h	
	C	13 - 90		s	7.5YR3/2	7.5YR4/2	C	s	sbk	m	s, p	fi	h	weakly developed slickonside crack to 60 cm at depth.
2.	A1	0 - 18	g	s	10YR3/2	10YR4/2	C	s	sbk	f	s, p	vfi	vh	
	C	18 - 110			10YR2/3	10YR2/2	C	s	sbk	m	vs,vp	vfi	vh	no crack, weakly developed slickenside
3.	Ap	0 - 13	c	s	10YR3/1	10YR4/2	C	l	-	-	ss, sp	-	lo	
	C	13 - 50			2.5Y2/1	2.5Y2/1	C	s	sbk	m	s, p	-	vh	
4.	Al	0 - 13	c	s	7.5YR3/4	7.5YR3/4	grav. SC	l	-	-	ss, np	-	lo	gravel - ø0.5-2cm, 40%
	C	13 - 100			2.5Y2/1	2.5Y3/1	SC	m	sbk	m	s, p	-	-	few crack to 10cm at depth
5.	Al	0 - 22	g	i	10YR2/2	10YR3/2	SCL	l	-	-	ss, sp	-	lo	partly red rounded cobbles
	C	22 - 70			10YR2/2	10YR3/2	SC	w	sbk	f	s, sp	-	sh	no crack
6.	Al	0 - 22	c	s	7.5YR2/2	7.5YR3/2	grav.C	M	sbk	f	ns, np	-	sh	gravel - ø0.5 - 1.0 cm, 5%
	Cl	22 - 65	g	s	10YR2/1	10YR3/1	C	M	sbk	f	ss, sp	-	vh	slickonside 1cm x 15 cm
	C2	65 - 100			10YR3/3	10YR3/3	C	l	-	-	ss, sp	fr	vh	
7.	Al	0 - 4	g	s	10YR2/2	10YR3/3	grav.C	w	sbk	f	ss, np	-	sh	
	Cl	4 - 54	g	s	10YR2/1	10YR2/1	C	s	sbk	f	s, p	-	eh	crack 0.5 - 1.0 cm x 50 cm
	C2	54 - 150			10YR3/2	10YR5/3	C	w	sbk	f	ss, sp	-	vh	tufficious gravel ø0.5 - 0.8 cm 5%
8.	Ap	0 - 20	c	s	10YR3/2	10YR3/3	grav. C	w	sbk	f	ss, np	-	h	red rounded gravel ø0.2 cm
	C	20 - 60			10YR2/2	10YR2/2	C	l	-	-	s, p	-	h	
9.	Ap	0 - 18	c	s	10YR3/2	10YR3/3	CL	l	-	-	ss, np	-	sh	
	C	18 - 100			10YR2/2	10YR2/2	SC	w	sbk	f	s, sp	-	sh	rounded cobbles ø0.3-5cm 5% on surface
10.	Al	0 - 5	d	i	10YR2/2	10YR3/2	grav.CL	-	-	-	ns, np	-	sh	red rounded gravel ø0.3-0.5 cm 20%
	Cl	5 - 33	c	i	10YR2/2	10YR3/2	grav. CL	-	-	-	ss, np	-	sh	red rounded gravel ø0.5-1.0 cm 10%
	C2	33 - 90			10YR2/2	10YR3/1	grav. CL	-	-	-	ss, np	-	sh	
11.	Ap	0 - 12	c	s	7.5YR3/3	7.5YR4/3	grav. SCL	l	-	-	ss, np	-	s	rounded gravel ø0.1-1.0 cm 10%
	Bl	12 - 40	g	s	7.5YR3/2	-	grav. C	w	sbk	f	ss, np	-	h	rounded gravel ø0.2-0.4 cm 20%
	B2	40 - 80			7.5YR4/4	-	grav. C/CL	w	sbk	f	s, p	-	vh	rounded gravel ø0.2-0.4 cm 10%

Table III - 4. 2 Generalized Description of Soil Profile (2/6)

No.	Horizon	Depth of Horizon (cm)	Boundary of Horizon	Form of Boundary	Colour wet	Colour dry	Textural Class	Structure Grade	Structure Type	Structure Size	Consistence wet	Consistence moist	Consistence dry	Remarks
12.	A1	0 - 20	-	-	7.5YR4/6		grav. SL	1	-	-	ns, np	-	s	ø10 - 50 cm angular stones
13.	A1	0 - 5	-	-	7.5YR4/6		grav. SL	1	-	-	ns, pp	-	lo	tufficious sandstone
14.	A1	0 - 15	c	s	10YR3/3	10YR3/3	CL	w	sbk	f	ss, np	-	s	
	C	15 - 80			10YR3/1	10YR3/1	CL	w	sbk	m	ss, sp	-	s	overlying the weathered granite
15.	Ap	0 - 22	g	s	10YR2/2	10YR3/2	C	w	sbk	f	s, sp	-	s	
	C	22 - 100			2.5Y3/1	2.5Y4/1	C	w	sbk	f	vs, vp	fr	vh	
16.	A11	0 - 5	a	s	-	10YR3/3	LS	1	-	-	ns, np	-	lo	root mat
	A12	5 - 30	g	i	-	10YR3/3	LS	w	sbk	m	ss, sp	-	sh	
	C1	30 - 80	g	i	-	10YR4/1	SCL	w	sbk	m	ss, sp	-	sh	
	C2	80 - 100			10YR3/3	10YR5/3	CL	w	sbk	m	s, sp	-	sh	
17.	A1	0 - 23	c	w	10YR2/3	-	CL	w	sbk	m	s, sp			gravel 10 - 20%
	C	23 - 80			7.5YR3/3	-					ns, np			rounded cobble and stone 70%
18.	A1	0 - 5	a	s	10YR3/2	-	SiCL	w	sbk	f-m	-	-	-	
	C1	5 - 52	a	s	7.5YR3/4.4/6	-	SC	w	sbk	m	-	-	-	
	C2	52 - 86	a	s	7.5YR3/4	-	SC	1	-	-	-	-	-	
19.	Ap	0 - 28	a	w	10YR2/1	-	C	w	sbk	f	s, p	-	-	cobble ø0.5 - 3.0 cm, 30%
	C1	28 - 56	a	w	7.5YR3/2	-	SCL	1			ss, sp	-	-	
	C2	56 - 80			2.5Y2/1	-	C	m	sbk	m	vs, vp	-	-	
20.	Ap	0 - 36	c	s	10YR3/3	10Y4/3	CL	w	sbk	f	s, sp	fr	s	ø0.2-0.8 cm,10%, mottles of Mn and Fe
	C	36 - 80			10YR3/1	10YR3/1	C	-	-	-	vs, p	fr	sh	
21.	Ap	0 - 29	a	s	10YR2/1	10YR2/1	C	w	sbk	f	s, p	-	-	
	C	29 - 80+		s	7.5YR4/4	10YR6/3	S	1	-	-	ns, np	-	-	
23.	A1	0 - 10	c	s	10YR2/2	-	CL	1	-	-	ss, sp	fi	h	f.m.d mottles (7.5YR4/6)
	C1	10 - 29	a	s	2.5Y2/1	-	CL	1	-	-	s, p	fr	-	vf.m.f mottles (10YR5/8)
	C2	29 - 60	a	s	10YR4/3	-	L	w	sbk	m	s, p	vfr	-	
	C3	60 - 130+			2.5Y3/2	-	L	1			vs, p	-	-	

Table III - 4. 2 Generalized Description of Soil Profile (3/6)

No.	Horizon	Depth of Horizon (cm)	Boundary of Horizon	Form of Boundary	Colour wet	Colour dry	Textural Class	Structure Grade	Structure Type	Structure Size	Consistence wet	Consistence moist	Consistence dry	Remarks
25.	A1	0 - 6	a	s	10YR2/2	10YR4/3	SiC	w	sbk	f	ss, sp	-	-	
	C1	6 - 40	c	s	10YR2/2	10YR2/2	C	w	sbk	f	s, p	-	-	gravel (quartz) ø0.2-0.4, 5%
	C2	40 - 50+			10YR6/2	10YR6/2	C	s	abk	m	-	-	-	m.m.d. mottles (10YR5/8)
26.	A1	0 - 11	c	s	10YR2/1	10YR2/1	C	w	sbk	f	s, p			weekly develop. slickenside
	C	11 - 50+			10YR3/2	10YR5/2	C	m	abk	m	vs, p			0.3 x 10 cm cracks
27.	A	0 - 36	a	s	7.5YR3/2	10YR3/1	SL	1			ns, np	fr	s-sh	
	C	36 - 100+			10YR4/4	10YR5/1	CL	s	abk	c	s, p	fi	eh	crack 1 x 30 cm, slickenside
29.	A1	0 - 14	c	s	7.5YR3/3	7.5YR4/3	SiL	w	sbk	vf	ss, np		vh	ø0.2-0.4 cm, 5%
	C	14 - 70+			7.5YR2/1	7.5YR3/1	SiCL	m	abk	f	s, sp		vh	ø0.3-0.5 cm, 10%
30.	A1	0 - 10	a	w	10YR3/2	10YR5/2	grav. L	1			ns, np			ø1.0-2.5 cm, 80%
	C	10 - 70+												weathered granite
31.	A1	0 - 18	a	w	7.5YR2/3	7.5YR4/3	grav.L	1						ø0.5-1.0 cm, 80%
	C	18 - 100+												weathered granite
32.	A11	0 - 3	d	s	7.5YR3/4	7.5YR4/3	grav. L	1			ns, np	-	sh	ø0.5-2.0 cm, 5%
	A12	3 - 13	c	s	7.5YR3/4	7.5YR4/3	grav. L	w	sbk	f	ns, np	-	h	ø0.3-0.5 cm, 10%
	C1	13 - 56	c	w	7.5YR2/3	7.5YR4/3	grav. SL	1			ns,np	-	vh	ø0.3-0.5 cm 20%
	C2	56 - 100+			10YR2/2	10YR3/2	SC	m	abk	f	ns, np	-	vh	ø0.3-0.5 cm 20%
33.	A1	0 - 6	a	s	10YR2/2	10YR3/2	C	m	abk	f	s, p		vh	
	C	6 - 100			10YR1.7/1	10YR1.7/1	C	m	abk	m	s, p		eh	crack 1x40cm weekly slickenside
34.	A1	0 - 10	a	s	10YR2/2	10YR2/2	SCL/CL	w	sbk	f	ss, sp	fr	sh	
	C1	10 - 27	c	s	10YR3/1	10YR3/1	C/CL	s	pr	m	s, p	fr	sh	crack common 1 x 50 cm
	C2	27 - 65	g	s	10YR2/1	10YR2/1	C	s	abk	m	s, p	fi	h	
	C3	65 - 100			10YR2/1	10YR2/1	C	s	abk	m	s, p	fir	h	
35.	A1	0 - 9	c	s	10YR3/3	10YR4/4	SiL	1			ss, np			
	C	9 - 80+			10YR2/1	10YR2/1	C	m	sbk	m	s, p		h	

Table III - 4. 2 Generalized Description of Soil Profile (4/6)

No.	Horizon	Depth of Horizon (cm)	Boundary of Horizon	Form of Boundary	Colour wet	Colour dry	Textural Class	Structure Grade	Structure Type	Structure Size	Consistence wet	Consistence moist	Consistence dry	Remarks
37.	Ap	0 - 23	c	s	2.5YR3/4		grav. SiL	1			ss, np	fr		ø0.3-0.8 cm, 20%
	B11	23 - 37	c	w	2.5YR3/4		CL	1			ns, np			ø0.5-1.0 cm, 70% (7.5YR5/8) iron
	B12	37 - 90+			2.5YR4/6		CL	1			ns, np			ø0.5-1.0 cm, 80%
38.	A1	0 - 13	a	s	10YR3/2	10YR5/3	SiL	w	sbk	f	ns, np	vfr		root mat 3 cm thick
	C1	13 - 43	c	w	10YR2/2		SiCL	w	abk	f-m	ss, sp	fr		
	C2	43 - 70+			10YR3/3		SCL	w	abk	f	ss, np	fr		
39.	A1	0 - 10	a	s	7.5YR3/3	-	SL	w	sbk	f	ns, np		sh	
	B11	10 - 25	c	s	10YR2/3	10YR3/3	SC	s	abk	m	ss, sp	fi	eh	
	B12	25 - 37	c	s	10YR2/3	10YR3/3	grav. SC	1			ss, sp		eh	ø0.5-1.0 cm, 20%
	C	37 - 60+			10YR3/2	10YR5/3	grav. SL	m	abk	m	s, sp		eh	
40.	A1	0 - 21	c	s	7.5YR3/3	7.5YR5/3	LS	1			ss, np	vfr	s	
	C1	21 - 45	c	w	7.5YR4/4	7.5YR5/3	LS	1			ns, np	vfr	s	
	C2	45 - 69	a	s	7.5YR4/4	7.5YR5/4	LS	1			ns, np	vfr	s	
	C3	69 - 80+			10YR3/2	10YR4/2	CL	m	abk		s, sp	fi	vh	
41.	A1	0 - 21	a	s	7.5YR4/4	7.5YR6/6	grav. LS	l			ns, np	lo	lo	fine roots, sratified
	C1	21 - 53	a	s	10YR2/2+5/4	10YR4/3+6/4	C/CL	w	sbk	f	ns, np	fr	sh	mixed matrix, colour motting
	C2	53 - 65+			10YR2/2		grav. SL	1						vf.f.d(7.5YR5/8)
42.	Ap	0 - 16	c	s	10YR3/4	10YR5/3	grav. SiL	1			ns, np	-	lo	ø0.5-7.0 cm, 30%
	B11	16 - 28	c	i	10YR2/3		grav. SL	1			ns, np	-	lo	ø0.5-3.0 cm, 10%
	B12	28 - 35+			10YR4/3	10YR6/3	grav. L	m	abk	f	ns, np	-	eh	
43.	Ap	0 - 12	a	s	10YR3/3	10YR6/2	grav. SiL	1			ns, np	fr	s	ø0.3-0.5 cm, 5%
	B11	12 - 38	c	s	10YR2/2	10YR4/2	grav. C	w	abk	f	ss, sp	fi	h	ø0.5-0.8 cm, 20%
	B12	38 - 60+			10YR3/3	10YR3/3	grav. SC	1			ns, np	fi	sh	
44.	A1	0 - 18	c	s	10YR5/2	10YR5/2	CL	w	sbk	f	ss, sp	vfi	h	fine-medium roots
	C	18 - 70+			10YR1.7/1	10YR1.7/1	C	s	sbk	f	vs, vp	fr	eh	cracks common
45.	A1	0 - 28	a	w	7.5YR4/4	10YR6/4	S	1						
	C1	28 - 80+	c		7.5YR4/6	7.5YR5/4	S+Si	1						

Table III - 4. 2 Generalized Description of Soil Profile (5/6)

No.	Horizon	Depth of Horizon (cm)	Boundary of Horizon	Form of Boundary	Colour wet	Colour dry	Textural Class	Structure Grade	Structure Type	Structure Size	Consistence wet	Consistence moist	Consistence dry	Remarks
46.	A1	0 - 4	a	s	7.5YR3/4	7.5YR5/4	SC	w	sbk	f	ss, sp	-	sh	
	B11	4 - 21	c	s	7.5YR3/3	7.5YR4/3	CL	s	abk	f	s, sp	-	h	clay cutan colour mottling
	B12	21 - 50+			7.5YR3/3	7.5YR4/4	L	m	abk	f	s, sp	-	vh	c.c.d 7.5YR5/8 , f.f.f 7.5YR5/8
47.	A1	0 - 5	a	s	10YR2/3	10YR4/2	CL	w	sbk	vf	ss, np	vfr	s	root mat
	C1	5 - 13	a	s	10YR7/1	10YR7/1	SL	1			ns, np	vfr	s	
	C2	13 - 31	c	s	10YR2/2	10YR2/2	C	w	sbk	f	s, p	fi	h	shining ped, surface
	C3	31 - 50+			10YR3/3	10YR3/4	C	w	sbk	vf	ss, sp	fr	sh	
48.	A1	0 - 26	g	s	10YR4/3	10YR5/5	Si-S	1			ns, np	fr	lo	
	B1	26 - 60+			10YR3/4	10YR4/4	SiCL	w	sbk	f	ss, sp	fr	s	colour mottling f.m.f 10YR5/8
49.	A1	0 - 12	g	s	10YR4/1.5	10YR6/1	SCL	m	sbk	f	ss, sp	fr	h-vh	
	B11	12 - 51	c	s	10YR3/2	10YR4/2	L	m	sbk	f	s, sp	fr	h	ø0.3-0.5 cm few purmis
	B12	51 - 85			10YR3/4		L	m	abk	f	s, p	fr	h	
50.	A11	0 - 9	c	s	10YR4/1	10YR6/1	SiL	1			ns, np	fr	sh	
	B11	9 - 32	c	s	10YR3/2	10YR4/1	SiC	w	sbk	f	s, p	fr	sh	
	B12	32 - 60+			10YR3/3		SiCL	w	sbk	f	s, sp	fr	h	
51.	A1	0 - 14	g	s	10YR3/1	10YR4/2	CL	w	sbk	f	ss, np	vfr	s	fine roots
	C1	14 - 70+			10YR2/1	10YR4/1	C	s	abk	m	s, p	fr	vh	0.5 cm x 20 cm cracks
52.	A1	0 - 7	a	s	10YR3/3	10YR3/2	SiCL	w	sbk	vf	ss, np	fr	sh	
	C	7 - 60+			10YR3/1	10YR4/1	SiC	m	sbk	f	s, p	fi	h	
55.	Ap	0 - 18	a	s	7.5YR3/4	7.5YR5/3	S	1	-	-	ns, np	lo	lo	ø0.3-0.5 cm, 30%
	C1	18 - 32	a	s	7.5YR4/3	7.5YR5/3	S	1	-	-	ss, sp	lo	lo	ø0.3-0.5 cm, 50%
	C2	32 - 60+			7.5YR3/2	7.5YR3/3	S	1	-	-	ss, sp	lo	lo	ø0.3-0.5 cm, 70%
56.	A1	0 - 11	c	s	10YR4/1	10YR7/1	CL	w	sbk	vf	ns, np	fi	h	
	B11ca	11 - 21	c	s	10YR3/2	10YR4/2	C	m	sbk	f	ss, sp	fr	sh	
	B12ca	21 - 40	a	s	10YR3/3	-	C	m	sbk	f	ss, sp	fr	sh	
	Cca	40 - 60+			10YR2/2	-	C	s	sbk	f	s, p	vfi	h	

Table III - 4. 2 Generalized Description of Soil Profile (6/6)

No.	Horizon	Depth of Horizon (cm)	Boundary of Horizon	Form of Boundary	Colour wet	Colour dry	Textural Class	Structure Grade	Structure Type	Structure Size	Consistence wet	Consistence moist	Consistence dry	Remarks
57.	Ap	0 - 18	a	s	10YR3/2	10YR5/2	grav. SiL	w	sbk	f	ss, np	vfr	s	
	C1	18 - 60+			10YR3/3	10YR4/3	SiC	m	abk	f	s, sp	vfi	h	
58.	A1	0 - 8			7.5YR4/6	7.5YR4/4	grav.SL	1	-	-	ns, np	lo	lo	ø0.3-1.0 cm, 60%
59.	Ap	0 - 5	a	s	7.5YR4/6	7.5YR5/4	SL	vw	sbk	vf	ns, np	-	lo	ø0.3-0.5 cm, 5%
	B11	5 - 18	a	s	7.5YR4/6	7.5YR5/4	grav. CL	m	sbk	f	ss, sp	-	eh	ø0.3-0.5 cm, 20%
	B12	18 - 60+					grav. C	s	sbk	f	s, np	-	eh	ø0.3-0.5 cm, 40%
60.	Ap	0 - 6	c	s	10YR2/3	10YR4/3	grav. SL	vw	sbk	vf	ns, np	-	lo	ø0.3-0.5 cm, 10%
	B11	6 - 34	g	s	10YR2/2	10YR4/2	grav. SL	m	abk	f	ns, np	-	h	ø0.3-0.5 cm, 30-50%
	B12	34 - 60+			7.5YR3/3	-	grav. S	1	-	-	ns, np	-	vh	ø0.3-0.5 cm, 70-80%
63.	Ap	0 - 30	a	s	7.5YR4/3	7.5YR6/3	grav. SL	1	-	-	ns, np	fi	h	
	A12	30 - 50	g	s	7.5YR4/3	7.5YR6/2	SL	1	-	-	ns, np	fi	h	
	C1	50 - 120+			10YR3/1	10YR4/1	SL	m	abk	f	ss, sp	vfi	vh	
64.	A11	0 - 26	a	w	10YR3/3	10YR4/3	grav. SL	1	-	-	ns, np	-	vh	ø0.2-0.4 cm, 10%
	A12	43 - 43	a	w	10YR3/3	10YR4/3	grav. SL	1	-	-	ns, np	-	lo	ø1-8 cm, 60%
65.	A1	0 - 49	a	s	10YR2/2	10YR4/3	grav. SL	w	sbk	f	ns, np		vh	ø1-5 cm, 5%
	C1	49 - 80+			10YR2/2	10YR3/3	grav. SCL	m	abk	m	s, sp		eh	
66.	Ap	0 - 16	a	s	10YR2/1	-	HC	w	sbk	f	vs, vp	vfi	vh	colour mottling c.f.d. 7.5YR5/8
	C1	16 - 51	c	s	10YR2/1	-	HC	s	bk	c	vs, vp	-	-	
	C2	51 - 70+			10YR2/1	-	HC				vs, vp	-	-	
67.	Ap	0 - 30	a	s	10YR2/2	10YR3/2	SL	w	sbk	vf	ns, np	fr	-	ø03-0.5 cm, few
	B11	30 - 90	c	s	10YR2/1	-	SL	1	-	-	ns, np	fr	-	
	B12	90 - 120+			7.5YR2/2	-	grav. SL	1	-	-	ns, np	fr	-	ø0.3-0.5 cm, 10%
70.	Ap	0 - 15	a	s	10YR2/3	10YR5/2	SCL	w	sbk	-	ss, sp	-	lo	colour mottling f.f.f 2.5YR4/8
	B11	15 - 51	c	s	10YR2/1	-	SCL	1	-	-	ss, np	-	h	- do- c.m.f 7.5YR5/8
	B12	51 - 70+			10YR4/2	-	SCL	1	-	-	ss, np	-	vh	- do - c.m.d 7.5YR5/8

Source : Prepared by JICA Study Team

Table III - 4.3 Physical and Chemical Properties of Soils (1/4)

Phys. Unit	Profile No.	Depth (cm)	Particle Size (%)			Texture	pH		EC	C	N	P-Olsen	CEC	Exchangeable Cations (me/100g)					Base Sat.	ESP
			Sand	Silt	Clay	Class	H2O	KCl	(mmho)	(%)	(%)	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	(%)	(%)
P11	11	0-12	50	16	34	SCL	7.3	6.1	0.06	0.58	0.11	3	26.1	14.8	2.94	0.72	1.84	20.3	78	4
		12-40	40	18	42	C	7.3	5.9	0.08	0.64	0.11	3	29.3	18	4.69	0.78	1.8	25.27	86	3
		40-80	40	20	40	C/CL	8.4	5.3	0.11	2.16	0.22	4	31.5	22.6	5.9	2.2	1.68	32.38	103	7
P31	15	0-22	20	18	62	C	6.2	5.3	0.22	2.16	0.22	13	32.5	22.8	6.76	1.17	2.04	32.77	101	4
		22-100	24	20	56	C	7.4	6	0.25	0.61	0.06	4	24.5	18	5.92	1.1	1.42	26.44	108	4
P31	33	0-6	20	26	46	C	6.9	5.5	0.12	1.23	0.11	11	19.5	9.6	3.54	1.1	1.42	15.66	80	7
		6-100	24	18	58	C	7.4	6.2	0.3	1.23	0.09	3	24.5	16	5.14	2.9	1.44	25.48	104	11
P31	34	0-10	48	20	32	SCL/CL	6.8	5.5	0.12	2.4	0.27	13	22.7	11.4	4.64	0.78	1.8	18.62	82	4
		10-27	42	18	40	C/CL	6.4	5.1	0.17	1	0.12	5	23.5	9.6	3.94	0.86	1.26	15.66	67	5
		27-65	44	14	42	C	6.5	5.1	0.1	0.97	0.1	4	26.1	12.6	5.62	0.88	0.96	20.06	77	4
		65-100	42	16	42	C	7.1	5.3	0.14	1	0.12	6	24.5	12.6	3.86	1.68	0.74	18.88	77	9
P31	40	0-21	88	4	8	LS	6.8	5.8	0.04	0.17	0.05	2	3.9	1.6	0.14	0.48	0.24	2.46	63	20
		21-45	88	4	8	LS	6.8	6	0.06	0.26	0.05	2	4.3	2.4	0.18	0.6	0.28	3.46	80	17
		45-69	82	14	4	LS	7.2	5.8	0.02	0.17	0.03	2	1.3	0.9	0.1	0.48	0.12	1.6	123	30
		69-80	36	32	32	CL	7	5.3	0.04	0.74	0.09	2	17.7	8.4	1.62	0.84	0.16	11.02	62	8
P31	51	0-14	20	40	40	CL	6.1	4.6	0.12	2.53	0.27	8	23.3	8	1.35	0.74	0.89	10.98	47	7
		14-70	20	32	48	C	6.4	6.1	0.05	2.62	0.25	14	27.6	9.4	2.66	0.65	0.98	13.69	50	5
P31	63	0-30	68	14	18	SL	7.2	6	0.09	0.26	0.06	3	11.1	6	0.78	0.64	0.39	7.81	70	8
		30-56	70	18	12	SL	7.5	6.8	0.13	0.1	0.04	4	8.9	7	0.5	0.54	0.52	8.56	96	6
		56-120	46	14	40	SC	8.5	6.5	0.13	0.6	0.07	3	26.3	17	2.18	3.74	0.75	23.67	90	16
P32	27	0-36	76	8	16	SL	7.2	5.9	0.04	0.5	0.04	3	8.5	5.6	0.62	0.54	0.24	7	82	8
		36-100	42	20	38	CL	7.8	5.8	0.1	0.41	0.05	2	26.1	12.8	2.34	1.98	1.08	18.2	70	11
P33	38	0-13	78	12	10	SL	7.6	6	0.06	1.2	0.19	4	6.7	2	0.46	1.25	0.84	4.55	68	27
		13-43	52	20	28	SCL	10	8.2	2.25	0.4	0.09	3	13.9	9.9	0.3	5.85	2.01	18.06	130	32
		43-70	54	20	26	SCL	10	8.9	2.25	1.26	0.03	6	16.1	12	0.18	6	1.64	19.82	123	30
D11	49	0-12	50	26	24	SCL	10	8.2	0.65	0.29	0.05	4	19.5	9.8	0.36	7.43	3.64	21.23	109	35
		12-51	32	42	20	L	10	8.2	0.65	0.29	0.05	4	17.5	6.6	0.25	9.45	3.42	19.72	113	48
		51-85	46	30	24	L	9.8	7.8	0.55	0.13	0.06	4	22.5	10.7	0.2	9.45	3.6	23.95	106	39
D11	57	0-18	66	20	14	SL	8.7	6.8	1.1	0.7	0.09	6	9.3	10	0.11	1.98	2.84	14.93	161	13
		18-60	30	42	28	CL	9.3	7.6	0.5	0.17	0.05	4	21.5	11.6	0.18	5.34	6.39	23.51	109	23

Table III - 4.3 Physical and Chemical Properties of Soils (2/4)

Phys. Unit	Profile No.	Depth (cm)	Particle Size (%)			Texture	pH		EC	C	N	P-Olsen	CEC	Exchangeable Cations (me/100g)					Base Sat.	ESP
			Sand	Silt	Clay	Class	H2O	KCl	(mmho)	(%)	(%)	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	(%)	(%)
D12	47	0-5	30	34	36	CL	6.4	4.8	0.24	5.59	0.56	5	32.5	4.6	0.56	1.24	2.84	9.24	28	13
		5-13	24	60	16	SL	8.8	6.4	0.18	0.26	0.09	2	14.5	1.6	0.34	2.14	1.74	5.82	40	37
		13-31	22	38	40	C	9.6	7.9	1.25	0.32	0.07	2	22.5	6	0.52	7.45	6.35	20.32	90	37
		31-50	22	38	40	C	10	8	0.8	0.2	0.07	3	19.5	7	0.37	8.28	6.82	22.47	115	37
D12	56	0-11	32	32	36	CL	8.4	6.5	0.6	1.69	0.15	5	19.7	10.3	0.15	5.84	1.8	18.09	92	32
		11-21	30	26	44	C	9.6	8	1.1	0.26	0.08	4	24.5	14.9	0.2	7.43	5.64	28.17	115	26
		21-40	26	20	54	C	9.7	8.1	1.5	0.15	0.03	5	26.5	11.9	0.18	10.55	6.04	28.67	108	37
		40-60	32	24	44	C	9.5	6.3	0.16	0.05	0.01	2	20.2	9.5	0.22	11.85	4.64	26.21	130	45
D2	46	0-4	16	44	42	SC	4.8	3.8	0.15	2.74	0.28	6	32.5	3.2	0.76	0.59	0.84	5.39	17	11
		4-21	24	40	36	CL	5.1	3.4	0.06	1.08	1.18	5	23.3	4	0.9	0.64	0.28	5.82	25	11
		21-50	38	38	24	L	6.8	4.6	0.05	1.22	0.07	3	18.2	5.2	0.76	0.56	0.04	6.56	36	9
D2	55	0-18	92	4	4	S	6.7	5.4	0.04	0.52	0.09	7	1.8	0.6	0.1	0.25	0.28	1.23	68	20
		18-32	90	4	6	S	6.5	4.9	0.02	0.35	0.08	6	2.9	1	0.12	0.18	0.2	1.5	52	12
		32-60	90	4	6	S	6.5	4.8	0.02	0.37	0.06	4	2.9	1	0.11	0.24	0.04	1.39	48	17
F12	1	0-13	26	32	42	CL	7.2	5.3	0.18	0.5	0.11	10	23.3	12	2.02	1.88	1.85	17.75	76	11
		13-90	18	28	54	C	8	6.5	0.27	0.73	0.06	6	24.5	18	3.14	4.42	1.6	27.16	111	16
F12	7	0-4	38	16	46	C	6.8	5.6	0.12	0.79	0.09	7	21.5	16.5	5.84	1.36	1.64	25.34	118	5
		4-54	22	16	62	C	7.8	6.2	0.16	1.22	0.1	2	25.5	20	6.94	3.66	1.44	32.04	126	11
		54-150	24	16	60	C	8.3	6.8	0.3	0.41	0.03	5	29.3	18	3.9	3.6	1.45	26.95	92	13
F22	6	0-22	32	16	52	C	7.3	5.8	0.27	1.4	0.13	5	21.5	15	4.14	1.88	1.8	22.82	106	8
		22-65	22	14	64	C	8.1	6.2	0.35	1.4	0.12	4	22.5	17	4.54	3.52	1.64	26.7	119	13
		65-100	20	16	64	C	6.7	6.8	0.23	0.43	0.06	3	24.5	22.1	5.82	4.02	1.8	33.74	138	12
K21	19	0-28	18	36	46	C	6.8	5.2	0.1	1.25	0.1	12	24.5	15	4.98	0.86	1.6	22.44	92	4
		28-56	68	8	24	SCL	7.4	5.7	0.1	0.5	0.05	4	9.9	6	1.56	0.78	0.44	8.78	89	9
		56-80	18	22	60	C	7.8	5.7	0.09	0.93	0.08	5	25.5	17.6	2.75	1.14	1.25	22.74	89	5
K3/K21	20	0-36	40	24	36	CL	8.1	6.5	0.09	0.58	0.06	5	22.1	16.8	2.22	1.64	1.42	22.08	100	7
		36-80	44	16	40	C	6.7	6.1	0.12	0.38	0.05	4	25	18.3	3.14	1.1	1.04	23.58	94	5
K21	21	0-29	44	18	38	CL	8	6.5	0.17	0.85	0.09	5	26.1	16.5	1.74	2.66	1.2	22.1	85	12
		29-80	74	6	20	SCL/SL	8.2	6.8	0.15	0.26	0.05	4	11.5	10.4	1.02	2.04	0.8	14.26	124	14
K21	26	0-11	18	32	50	C	6.2	5	0.16	1.41	0.15	3	19.5	9.2	3.62	1.04	1.85	15.71	81	7
		11-50	20	28	52	C	7.1	5.2	0.09	1.08	0.14	2	21.5	11.8	5.02	1.36	1.6	19.78	92	7

Table III - 4.3 Physical and Chemical Properties of Soils (3/4)

Phys. Unit	Profile No.	Depth (cm)	Particle Size (%)			Texture	pH		EC	C	N	P-Olsen	CEC	Exchangeable Cations (me/100g)					Base Sat.	ESP
			Sand	Silt	Clay	Class	H2O	KCl	(mmho)	(%)	(%)	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	(%)	(%)
K22	2	0-18	14	24	62	C	6.4	4.1	0.05	0.58	0.07	7	19.5	10	2.02	1.28	1.84	15.14	78	8
		18-110	14	40	46	C	6.9	5.2	0.1	0.96	0.13	7	26.7	11.6	2.9	1.16	1.32	16.98	64	7
K22	3	0-13	28	16	56	C	7	5.6	0.2	0.7	0.06	3	25.5	20	5.92	2.12	1.84	29.88	117	7
		13-50	24	12	64	C	7.5	5.9	0.35	0.82	0.08	2	24.5	18	5.62	3.52	1.6	28.74	117	12
K22	23	0-10	32	36	32	CL	6.6	5.3	0.1	0.96	0.11	14	24.5	10.8	2.94	0.73	1.84	16.31	67	4
		10-29	30	36	34	CL	7.3	5.6	0.1	0.32	0.07	7	24.5	11	3.02	1.04	1.26	16.32	67	6
		29-60	34	42	24	L	8.2	6.3	0.12	0.19	0.04	4	15.5	9.4	1.74	1.2	1.12	13.46	87	9
S1	41	0-21	82	14	4	LS	8.3	5.9	0.05	0.04	0.03	3	1.7	0.7	0.38	0.64	0.2	1.92	113	33
		21-53	36	38	26	C/CL	7.2	5.6	0.07	0.43	0.07	4	14.1	8	1.92	0.94	0.98	11.84	84	8
		53-65	76	8	16	SL	7	5.5	0.05	0.43	0.06	4	6.9	3.6	0.5	0.6	0.16	4.86	70	12
ARPS	66	0-16	12	16	72	C	6.6	5	0.16	1.43	0.18	22	28.5	13	7.7	0.95	1.85	23.5	82	4
		16-51	14	10	76	C	6.4	5.2	0.23	1	0.12	22	29.5	14.6	7.71	2.15	1.64	26.1	88	8
		51-70	16	14	70	C	6.4	5	0.21	0.73	0.08	26	24.5	12.8	12.8	1.35	7.52	34.47	141	4
SB	67	0-30	60	22	18	SL	6.6	5.1	0.06	1.31	0.12	10	9.1	3.4	1.38	0.47	0.92	6.17	68	8
		30-90	76	12	12	SL	6.4	5.1	0.03	1.31	0.06	10	6.9	2.6	0.82	0.48	0.24	4.14	60	12
		90-120	68	20	12	SL	6.7	5.2	0.04	0.44	0.05	8	5.5	1.6	0.53	0.48	0.2	2.81	51	17
SB	68	0-30	54	14	32	SCL	6.1	4.7	0.04	0.61	0.1	5	11.1	4.7	4.3	0.78	0.76	4.74	43	16
SB	69	0-30	50	12	38	SC	5.6	4.7	0.04	0.7	0.1	4	10.3	8	3.7	0.49	0.54	4.99	48	10
SB	70	0-15	54	22	24	SCL	5.4	4.9	0.4	1.92	0.2	18	16.5	5	2.3	0.62	1.6	9.52	58	7
		15-51	56	14	30	SCL	5.5	4.6	0.12	1.02	0.1	11	13.9	4.4	1.38	0.43	0.74	6.95	50	6
		51-70	64	16	20	SCL	6.4	5	0.04	0.61	0.07	4	9.5	3	0.1	0.37	0.14	3.61	38	10

Remarks; ARPS - Ahero Rice Pilot Scheme
SB - Sugarcane Belt

Table III - 4.3 Physical and Chemical Properties of Soils (4/4)

Phys. Unit	Profile No.	Depth (cm)	Particle Size (%)			Texture Class	pH		EC (mmho)	C (%)	N (%)	P-Olsen (ppm)	CEC (me/100g)	Exchangeable Cations (me/100g)					Base Sat. (%)	ESP (%)
			Sand	Silt	Clay		H2O	KCl						Ca	Mg	Na	K	Total		
122	AE	0-6	62	19	19	SL	6.7	4.9	0.06	0.99	0.12	3	10.8	0.9	1.9	0.43	0.42	3.66	33.9	12
	B11	6-13	64	17	19	SL	7	4.9	0.08	0.7			8.9	0.9	1.5	0.79	0.39	3.58	40.2	12
	B12	13-31	56	23	21	SCL	8	6.3	0.45	0.51			9	2.4	2.8	1.52	0.76	7.48	83.1	20
117	A	0-19	68	15	17	SL	6.9	5.9	0.24	1.1	0.08	3	11.7	3.7	1.7	0.29	0.22	5.91	50.5	5
	2A	19-32	58	7	35	SCL/SC	6.7	5.1	0.15	0.91			22.5	10.2	4.9	1.05	0.62	16.77	78.9	6
	3A	32-57	60	7	33	SCL	6.9	5.1	0.13	0.4			19.7	10	4.7	1.01	0.71	16.42	83.9	6
143	Ap	0-14	42	25	33	CL	6.7	5.2	0.19	0.87	0.14	36	25	4.7	4.3	1.78	2.89	13.67	54.6	13
	2A	14-47	44	19	37	CL	7	5.2	0.13	0.33			25.4	13	5.4	2.41	1.95	22.86	90	11
	3A	47-80+	20	21	59	C	7.4	5.6	0.25	0.65			39.1	20.4	6.9	3.17	2.46	33.93	86.9	9
141	A	0-7	48	17	35	SCL/SC	6.7	5.1	0.13	1.15	0.11	3	23.7	8	3.7	1.28	1.19	14.17	69.8	9
	B2	7-66	28	17	55	C	6.4	4.7	0.22	0.83			33.2	10.1	4	1.82	0.83	16.75	50.4	11
	C	66-80+	24	17	59	C	6.7	5	0.26	0.48			41	17.2	6	3.26	1.7	28.16	69.9	12
101	A	0-32	18	13	69	C	7.6	6.4	0.5	1.31	0.12	3	58.5	27.1	13.4	4.03	0.95	45.48	77.8	9
	B	32-80+					8.4	8.6	0.65	1.43			55	30.5	14.2	7.63	1.24	53.57	97.4	14
110	A	0-21	24	15	61	C	6.9	5.1	0.22	1.49	0.12	2	50.7	22.4	7.6	1.14	1.25	33.39	65.8	3
	AB	21-62	24	13	63	C	7	6	0.55	1.15			50	27.8	9.8	2.77	1.49	41.86	83.7	7
	2C	62-80+	42	19	39	CL	7.7	6.4	0.5	0.3			29.5	20.2	4.1	2.55	1.95	28.8	90.7	9
126	A	0-12	28	31	41	C	6.7	4.6	0.04	0.9	0.09	3	32.5	5.5	4.2	0.43	0.54	10.67	32.8	4
	B1sa	6-25	34	13	43	C	6.1	4.2	0.04	0.66			29	5	3.7	0.25	0.13	9.08	31.3	3
	B2	13-48	38	19	43	C	5.7	4	0.04	0.46			27.5	5.8	3.8	0.38	0.18	10.16	37.1	4
	B3	48-80+	30	21	49	C	6.1	4.1	0.07	0.35			30.7	7.3	4	0.56	0.25	12.11	39.4	5
134	A11	0-8	14	17	69	C	6.5	4.9	0.21	1.17		20	41.5	17	5.6	2	1.37	25.97	62.6	8
	A12	8-24	14	17	69	C	6.7	4.9	0.22	0.75			38	19.7	7	2.5	0.96	30.16	79.2	8
	Bir	24-80+	14	21	65	C	6.4	5.1	0.25	0.65			40.5	17	6.9	2.41	0.59	26.9	66.4	9
149	A	0-10	20	29	51	C	6.9	5.8	0.35	1.93	0.22	20	44.9	25	8.3	2.05	2.8	38.15	84	5
	B2ir	10-30	18	33	49	C	6.6	5.7	0.21	1.12			41.2	23.3	6.9	1.87	1.24	33.31	80.8	6
	B32	68-80+	12	17	71	C	6.5	5.3	0.24	0.91			52.5	24	5.4	2.9	1.17	33.47	63.9	9
104	A	0-26	16	13	71	C	5.5	4.3	0.27	3.04	0.39	2	62	15.9	4.2	0.83	0.74	25.87	41.7	3
	Bg	26-51	14	13	73	C	4.5	4	0.11	1.58			57.2	12.7	7.6	0.92	0.91	22.13	38.4	4
	Cg	51-80+	14	15	71	C	5.1	3.7	0.08	0.53			55.3	15.7	7.6	1.06	1.51	25.87	46.9	4

Source : Prepared by JICA Study Team

Table III - 4.4 Profile Description of Ironstone Soils

1.	Profile No.		:	37
2.	Observation Date		:	July 16, 1985
3.	Location		:	Bodi
4.	Soil Name		:	Ironstone Soils
5.	Mapping Unit		:	plateu (Hill)
6.	Parent Material		:	phonolite
7.	Topography	meso	:	slightly underlating (0-2%)
		micro	:	irregular
8.	Vegetation Land Use		:	maize fields
9.	Drainage Condition		:	
		internal	:	impeded
		external	:	well
10.	Flooding		:	free
11.	Profile Description		:	
	Ap	0 - 23 cm		Dark reddish brown (2.5YR3/4, wet); gravelly silty loam; large particles ø0.3-0.8 cm 20%; structureless single grain; slightly sticky and non-plastic wet; friable moist; clear smooth boundary.
	B_{11}	23 - 37 cm		Dark reddish brown (2.5YR3/4, wet); clay loam; iron nodule ø0.5-1.0 cm 70%; structureless single grain; non-sticky and non-plastic wet clear wavy boundary.
	B_{12}	37 - 90 +cm		Reddish brown (2.5YR4/6 wet); clay loam; iron nodule ø0.5-1.0 cm 80%; structureless single grain, non-sticky and non-plastic wet.

Source : Prepared by JICA Study Team

Table III - 4.5 Profile Description of Ferralic Arenosols

1. Profile No. : 40
2. Observation Date : July 17, 1985
3. Location : Bugo Mbugra river bank
4. Soil name : Ferralic Arenosols
5. Mapping Unit : Colluvial footslopes of piedmont plain convex slopes (P11)
6. Parent Material : colluvial and alluvial deposits derived from granodiorite
7. Topography meso : slightly undulating (0-2%)
   micro : smooth
8. Vegetation Land Use : eroded land, partly cultivated with maize & sorghum
9. Drainage Condition internal : well
   external : well
10. Flooding : free
11. Profile Description

A1 0 - 21 cm Dark brown (7.5YR3/3, wet), dull brown (7.5YR5/3, dry), Loamy sand, gravel ø0.5-12 cm 5%; structureless single grain; slightly sticky and non-plastic wet, very friable moist; soft dry; clear smooth boundary.

C1 21 - 45 cm Brown (7.5YR4/4, wet) dull brown (7.5YR5/3, dry); Loamy sand; structureless single grain; non-sticky and non-plastic wet, very friable moist, soft dry; clear wavy boundary.

C2 45 - 69 cm Brown (7.5YR4/4, wet), dull brown (7.5YR5/4 dry); Loamy sand; structureless single grain; non-sticky and non-plastic wet, very friable moist, loose dry; abrupt smooth boundary.

C3 69 - 85 cm Brownish black (10YR3/2 wet), greyish yellow brown (10YR4/2, dry); clay loam; moderately developed angular blocky; sticky and slightly plastic wet, firm moist, very hard dry.

12. Physical and Chemical Properties:

Horizon	Depth (cm)	Particle Size(%) Sand	Silt	Clay	Texture Class	pH H_2O	pH KCl	EC2.5 (mmho/cm)	C (%)	N (%)
A1	88	4	8		LS	6.8	5.8	0.04	0.17	0.05
C1	88	4	8		LS	6.8	6.0	0.06	0.26	0.05
C2	82	14	4		LS	7.2	5.8	0.02	0.17	0.03
C3	36	32	32		CL	7.0	5.3	0.04	0.74	0.09

Horizon	P (ppm)	CEC (me/100g)	Exchangeable Cations (me/100g) Ca	Mg	Na	K	Total	Base Saturation (%)	ESP (%)
A1	2	3.9	1.6	0.14	0.42	0.24	2.46	80	20
C1	2	4.3	2.4	0.18	0.60	0.28	3.46	80	17
C2	2	1.3	0.9	0.10	0.48	0.12	1.60	123	30
C3	2	17.7	8.4	1.62	0.84	0.16	11.02	62	8

Source : Prepared by JICA Study Team

Table III - 4.6 Profile Description of Eutric Regosols

1. Profile No. : 27
2. Observation Date : July 13, 1985
3. Location : Paponditi, Omondo river bank
4. Soil Name : Eutric Regosols
5. Mapping unit : alluvial toeslopes of piedmont plain, stream bank (P32)
6. Topography meso : flat (0%)
   micro : irregular
7. Parent Material : colluvium overlying old lacustrine deposits
8. Vegetation Land Use : grass land, partly cultivated with maize
9. Drainage Condition :
   internal : well
   external : well
10. Flooding :free
11. Profile Description :

A1	0-36 cm	Brownish black (7.5YR3/2, wet), brownish black (10YR3/1, dry); sandy loam; structureless massive; non-sticky and non-plastic wet, friable moist; soft to slightly hard; stratified with thin layers; abrupt smooth boundary,
C	36-100+ cm	Brown (10YR4/4, wet), brownish grey (10YR5/1, dry); clay loam; strongly developed angular blocky, coarse; sticky and plastic wet, firm moist, extremely hard dry; vertical cracks 1 cm wide x 30 cm deep; slickensides

12. Physical and chemical Properties

Horizon	Depth (cm)	Particle Size(%) Sand	Silt	Clay	Texture Class	pH H_2O	KCl	EC2.5 (mmho/cm)	C (%)	N (%)
A1	0-36	76	8	16	SL	7.2	5.9	0.04	0.50	0.04
C	36-100+	42	20	38	CL	7.8	5.8	0.10	0.41	0.05

Horizon	P (ppm)	CEC (me/100g)	Exchangeable Cations (me/100g) Ca	Mg	Na	K	Total	Base Saturation (%)	ESP (%)
A1	3	8.50	5.60	0.62	0.24	0.54	7.00	82	8
C	2	26.10	12.80	2.34	1.08	1.98	18.20	70	11

Source : Prepared by JICA Study Team

Table III - 4.7 Profile Description of Calcaric Fluvisols

1. Profile No. : 56
2. Observation Date : July 30, 1985
3. Location : Osodo
4. Soil Name : Calcaric Fluvisols, sodic phase
5. Mapping unit : recent flood plain widely extending on cuspate delta formed in the river mouth of Sondu (D12)
6. Topography meso : flat (0%)
   micro : smooth
7. Parent Material : recent fluvial deposits derived from Sondu river
8. Vegetation Land Use : grass land used for animal grazing
9. Drainage Condition :
   internal : poorly
   external : poorly
10. Flooding :suffering from frequent flooding in rainy season
11. Profile Description :

A1	0-11 cm	Brownish grey (10YR4/1, wet), light grey (10YR 7/1, dry); clay loam; weakly developed subangular blocky; very fine; non sticky and non plastic wet, firm moist, hard dry; fine roots of grasses common; clear smooth boundary.
B11ca	11-21cm	Brownish black (10YR3/2, wet), brownish grey (10YR4/2, dry); clay; moderately developed subangular blocky, fine, slightly sticky and slightly plastic wet, friable moist, slightly hard dry; fine roots of grasses few; clear smooth boundary.
B12ca	21-40cm	Dark brown (10YR3/3, wet); clay; moderately developed subangular blocky, fine, slightly sticky and slightly plastic wet, very firm moist, slightly hard dry; fine purmis few; abrupt smooth boundary.
Cca	40-60 cm	Brownish black (10YR2/2, wet); clay; strongly developed angular blocky fine; sticky and plastic wet, very firm moist, hard dry; shine ped surface.

12. Physical and Chemical Properties

Horizon	Depth (cm)	Particle Size(%) Sand	Silt	Clay	Texture Class	pH H_2O	KCl	EC2.5 (mmho/cm)	C (%)	N (%)
A	0-11	32	32	36	CL	8.4	6.5	0.60	1.69	0.15
$B_{11}ca$	11-21	30	26	44	C	9.6	8.0	1.10	0.26	0.08
$B_{12}ca$	21-40	26	20	54	C	9.7	8.1	1.50	0.15	0.03
Cca	40-60	32	24	44	C	9.5	6.3	0.16	0.05	0.01

Horizon	P (ppm)	CEC (me/100g)	Exchangeable Cations (me/100g) Ca	Mg	Na	K	Total	Base Saturation (%)	ESP (%)
A	5	19.70	10.30	0.15	1.80	5.84	18.09	92	32
$B_{11}ca$	4	24.50	14.90	0.20	5.64	7.43	28.17	115	26
$B_{12}ca$	5	26.50	11.90	0.18	6.04	10.55	28.67	108	37
Cca	2	20.20	9.50	0.22	4.64	11.85	26.61	130	45

Source : Prepared by JICA Study Team

Table III - 4.8 Profile Description of Eutric Gleysols

1. Profile No. : 23
2. Observation date : July 11, 1985
3. Location : Wasare
4. Soil Name : Eutric Gleysols
5. Mapping Unit : lowlying terrain of Kano plain, receiving drainage (K22)
6. Parent Material : fluvium of Nyando
7. Topography meso : gently slopping (2-4%)
   micro : smooth
8. Vegetation Land Use : grass
9. Drainage Condition : Well drained
   internal : poorly
   external : poorly
10. Flooding : inundated during June - July
11. Profile Description:

A1	0 - 10 cm	Brownish black (10YR2/2, wet); clay loam; structureless massive; slightly sticky and slightly plastic wet, firm moist, hard dry; few, medium, distinct colour mottling, brown (7.5YR4/6); fine roots many, clear, smooth boundary.
C1	10 - 29 cm	Black (2.5Y2/1, wet); clay loam; structureless massive; sticky and plastic wet, friable moist; very few, medium fine colour mottling, brown (25YR4/6); abrup smooth boundary.
C2	29-60 cm	Dull yellowish brown (10YR4/3, wet); loam; weakly developed subangular blocky, medium; sticky and plastic wet, very friable moist; abrupt smooth boundary.
C3	60-130+ cm	Brownish black (10YR4/3, wet); loam; structureless massive; very sticky and plastic wet.

12. Physical and Chemical Properties:

Horizon	Depth	Particle Size(%)			Texture	pH		EC2.5	C	N
	(cm)	Sand	Silt	Clay	Class	H_2O	KCl	(mmho/cm)	(%)	(%)
A1	0-10	32	36	32	CL	6.6	5.3	0.10	0.96	0.11
C1	10-29	30	36	34	CL	7.3	5.6	0.10	0.32	0.07
C2	29-60	34	42	34	L	8.2	6.3	0.12	0.19	0.04

Horizon	P	CEC	Exchangeable Cations (me/100g)					Base Satu-	ESP
	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	ration (%)	(%)
A1	14	24.50	10.80	2.94	1.84	0.73	16.31	67	4
C1	7	24.50	11.00	3.02	1.26	1.04	16.32	67	6
C2	4	15.50	9.40	1.74	1.12	1.20	13.46	87	9

Source : Prepared by JICA Study Team

Table III - 4.9 Profile Description of Pellic Vertisols

1. Profile No. : 110

2. Observation Date : August 30, 1990

3. Location : Kusiango, Kamagaga, North East Kano

4. Soil Name : pellic VERTISOLS

5. Physiography : Lacustrine plains

6. Topography : undulating, B slope (2-8%)

7. Parent Material : lacustrine deposits

8. Vegetation Land Use : grazing pasture

9. Drainage : moderately well drained.

10. Profile Description :

A 0 - 21 cm Black (10YR1.7/1, wet); clay; moderately well developed coarse prismatic structure; very sticky and very plastic wet, very firm moist; very abundant in humus; none gravel; clear smooth boundary.

AB 21 - 62 cm Black (10YR1.7/1, wet); clay; moderately well developed coarse subangular blocky structure; sticky and plastic wet; firm moist; very abundant in humus; common light grey unweathered medium gravels; clear smooth boundary.

2C 62 - 80 cm+ Greyish brown (7.5YR4/2, wet); clay; structure- less massive; slightly sticky and slightly plastic wet; friable moist; few humus; many light yellow (80%) and light grey (20%) fine unweathered and semi-weathered gravels.

11. Physical and Chemical Properties:

Horizon	Depth	Particle Size(%)			Texture	pH		EC2.5	C	N
	(cm)	Sand	Silt	Clay	Class	H_2O	KCl	(mmho/cm)	(%)	(%)
A	0-21	24	15	61	C	6.9	5.1	0.22	1.49	0.12
AB	21-62	24	13	63	C	7.0	6.0	0.55	1.15	
2C	62-80+	42	19	39	CL	7.7	6.4	0.50	0.30	

Horizon	P	CEC	Exchangeable Cations (me/100g)					Base Satu-	ESP
	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	ration (%)	(%)
A	2	50.7	22.4	7.6	1.25	1.14	33.39	65.8	3
AB		50.0	27.8	9.8	1.49	2.77	41.86	83.7	7
2C		29.5	20.2	4.1	1.95	2.55	28.80	97.6	9

Source : Prepared by JICA Study Team

Table III - 4.10 Profile Description of Sodic Planosols

1. Profile No. : 122

2. Observation Date : September 3, 1990

3. Location : Chiga, Chiga, East Kolwa

4. Soil Name : sodic PLANOSOLS

5. Physiography : sacustrine plains

6. Topography : almost flat, A slope (<2%)

7. Parent Material : lacustrine and alluvial deposits

8. Vegetation Land Use : grazing pasture

9. Drainage : well drained

10. Profile Description :

AE 0 - 6 cm Greyish brown (7.5YR4/2, wet), light brownish grey (7.5YR7/1, dry); clay loam; moderately well developed fine to medium subangular blocky structure; sticky and plastic wet, friable moist; common humus; none gravel; abrupt smooth boundary.

B_{11} 6 - 13 cm Brown (7.5YR4/3, 60%, wet) and light grey(7.5YR4/3, 60%, wet) and light grey(7.5YR8/1, 40%, wet); sandy clay loam; moderately well developed coarse angular blocky structure;slightly sticky and slightly plastic wet, very firm moist; few humus; none gravel; clear smooth boundary.

B_{12} 13 - 31 cm Greyish brown (7.5YR4/2, wet); sandy clayloam; moderately well developed coarse angularblocky structure; sticky and plastic wet, friable moist; common humus; none gravel; clear smooth boundary.

C 31 - 80 cm+ Greyish brown (7.5YR4/2, wet); sandy clayloam; structureless massive; slightly sticky and slightly plastic wet, friable moist; few humus; few medium greyish white (N8/0) weathered gravels.

11. Physical and Chemical Properties:

Horizon	Depth	Particle Size(%)			Texture	pH		EC2.5	C	N
	(cm)	Sand	Silt	Clay	Class	H_2O	KCl	(mmho/cm)	(%)	(%)
AE	0-6	62	19	19	SL	6.7	4.9	0.06	0.99	0.12
B_{11}	6-13	64	17	19	SL	7.0	4.9	0.08	0.70	
B_{12}	13-31	56	23	21	SCL	8.0	6.3	0.45	0.51	

Horizon	P	CEC	Exchangeable Cations (me/100g)					Base Satu-	ESP
	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	ration (%)	(%)
AE	3	10.8	0.9	1.9	0.42	0.43	3.66	33.9	12
B_{11}		8.9	0.9	1.5	0.39	0.79	3.58	40.2	22
B_{12}		9.0	2.4	2.8	0.76	1.52	7.48	83.1	20

Source : Prepared by JICA Study Team

Table III - 4.11 Profile Description of Humic Gleysols

1. Profile No.	:	104
2. Observation Date	:	August 28, 1990
3. Location	:	Mogare, Wangaya II, North East Kano
4. Soil Name	:	Humic GLEYSOLS
5. Physiography	:	lacustrine plains
6. topography	:	almost flat, A slope (<2%)
7. Parent Material	:	lacustrine deposits
8. Vegetation Land Use	:	papyrus, sedge (seasonal swamp)
9. Drainage	:	poorly drained
10. Profile Description	:	

A 0-26 cm — Pale yellow (5Y8/2, wet); clay; weakly developed medium subangular blocky structure; very sticky and very plastic wet; friable moist; abundant in humus; none gravel; many fine distinct mottles; clear smooth boundary.

B_g 26-51 cm — Greyish olive (7.5Y4/1, wet); clay; structureless massive; very sticky and very plastic wet; firm moist; abundant in humus; none gravel; common fine distinct brown (7.5YR4/6) mottles; clear smooth boundary.

C_g 51-80 cm+ — Grey (7.5Y5/1, wet); clay; structure less massive; very sticky and very plastic wet, friable moist; abundant in humus; none gravel; common fine distinct brown (7.5YR4/4) mottles.

11. Physical and Chemical Properties:

Horizon	Depth	Particle Size(%)			Texture	pH		EC2.5	C	N
	(cm)	Sand	Silt	Clay	Class	H_2O	KCl	(mmho/cm)	(%)	(%)
A	0-26	16	13	71	C	5.5	4.3	0.27	3.04	0.39
B_g	26-51	14	13	73	C	4.5	4.0	0.11	1.58	
C_g	51-80+	14	15	71	C	5.1	3.7	0.08	0.53	

Horizon	P	CEC	Exchangeable Cations (me/100g)					Base Satu-	ESP
	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	ration (%)	(%)
A	2	62.0	15.9	4.2	0.74	0.83	25.87	41.7	3
B_g		57.2	12.7	7.6	0.91	0.92	22.13	38.4	4
C_g		55.3	15.7	7.6	1.51	1.06	25.87	46.9	4

Source : Prepared by JICA Study Team

Table III - 4.12 Profile Description of Chromic Vertisols

1. profile No. : 141

2. Observation Date : September 13, 1990

3. Location : Rabuor, Kochieng', North West Kano

4. Soil Name : chromic VERTISOLS

5. Physiography : lacustrine plains

6. Topography : undulating, B slope (2-8%)

7. Parent Material : lacustrine deposits

8. Vegetation Land Use : grazing pasture

9. Drainage : well drained

10. Profile Description :

A 0 - 7 cm — Brownish black (7.5YR3/2, wet), greyish yellow brown (10YR5/2, dry); sandy clay loam, few fine and medium round gravels; weakly developed medium, subangular blocky structure; sticky and plastic wet, firm moist, very hard dry; abundant in humus; clear smooth boundary.

B_2 7 - 66 cm — Black (7.5YR2/1, 90%, wet) and dull reddish brown (5YR414, 10%, wet); clay, few fine gravels; moderately well developed coarse subangular blocky structure; very sticky and very plastic wet, firm moist; abundant in humus; abrupt smooth boundary.

C 66 - 80 cm+ — Dark brown (7.5YR3/3, wet); clay loam, few fine unweathered and weathered light grey (2.5Y8/1) gravels; structureless massive; sticky and plastic wet, friable moist; common in humus.

11. Physical and Chemical Properties:

Horizon	Depth	Particle Size(%)			Texture	pH		EC2.5	C	N
	(cm)	Sand	Silt	Clay	Class	H_2O	KCl	(mmho/cm)	(%)	(%)
A	0-7	48	17	35	SCL/SC	6.7	5.1	0.13	1.15	0.11
B_2	7-66	28	17	55	C	6.4	4.7	0.22	0.83	
C	66-80+	24	17	59	C	6.7	5.0	0.26	0.48	

Horizon	P	CEC	Exchangeable Cations (me/100g)					Base Satu-	ESP
	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	ration (%)	(%)
A	3	23.7	8.0	3.7	1.19	1.28	14.17	69.8	9
B_2		33.2	10.1	4.0	0.83	1.82	16.75	50.4	11
C		41.0	17.2	6.0	1.7	3.26	28.16	69.9	12

Source : Prepared by JICA Study Team

Table III - 4.13 Profile Description of Eutric Fluvisols

1. Profile No. : 143

2. Observation Date : September 13, 1990

3. Location : Arembo, Kowino, South West Kano

4. Soil Name : eutric FLUVISOLS

5. Physiography : floodplains

6. Topography : almost flat, A slope (<2%)

7. Parent Material : Alluvial deposits

8. Vegetation Land Use : grazing pasture

9. Drainage : moderately well drained

10. Profile Description :

Ap 0 - 14 cm — Dark brown (7.5YR3/3, wet), brown (7.5YR4/3, dry);clay loam, few fine and medium semi-weathered gravels; moderately well developed medium to coarse subangular blocky structure; sticky and plastic wet, friable moist; common in humus; clear smooth boundary.

2A 14 - 47 cm — Very dark brown (7.5YR2/3, 60%, wet) and dull reddish brown (5YR4/4, 40%, wet); clay, few fine and medium gravels; moderately well developed coarse angular blocky structure; very sticky and very plastic wet, firm moist; common in humus; clear smooth boundary.

3A 47 - 80 cm+ — Brownish black (7.5YR3/1, 60%, wet) and light reddish brown (5YR5/6, 40%, wet); clay; weakly developed medium angular blocky structure; very sticky and very plastic wet, firm moist; abundant in humus; none gravel.

11. Physical and Chemical Properties:

Horizon	Depth	Particle Size(%)			Texture	pH		EC2.5	C	N
	(cm)	Sand	Silt	Clay	Class	H_2O	KCl	(mmho/cm)	(%)	(%)
Ap	0-14	42	25	33	CL	6.7	5.2	0.19	0.87	0.14
2A	14-47	44	19	37	CL	7.0	5.2	0.13	0.33	
3A	47-80+	20	21	59	C	7.4	5.6	0.25	0.65	

Horizon	P	CEC	Exchangeable Cations (me/100g)					Base Satu-	ESP
	(ppm)	(me/100g)	Ca	Mg	Na	K	Total	ration (%)	(%)
Ap	36	25.0	4.7	4.3	2.89	1.78	13.67	54.6	13
2A		25.4	13.0	5.4	1.95	2.41	22.86	90.0	11
3A		39.1	20.4	6.9	2.46	3.17	33.93	86.9	9

Source : Prepared by JICA Study Team

Table III-4.14 Description of Land Form and Mapping Symbol (Legend of Soil Map) (1/3)

Land Form	Subdivisions	Mapping Symbol	Mapping Unit	Slope (%)	Drainage Condition	Colour	Texture	Depth	Soil Unit	Extent (ha)
Hills intermediate igneous rocks	Plateau mainly phonolite H1	H11	higher parts with irregular microrelief	0 - 3	well	dark red. brown to dark red	friable clay, ironstones	deep	Ironstone Soils nito-rhodic Ferralsols	0
		H12	lower bottom lands	0 - 1	well	dark red	friable clay over petro-plinthite	mod. deep to deep	chromic Cambisols rhodic Ferralsols	0
H	Escarpment	H21	phonolite, highly resistant to erosion	25<	excessively well to well	dark red	friable sandy loam clay to clay, rocky	shallow rocky	Lithosols Ironstone Soils	0
	H2	H22	granodiorite, granite	25<	excessively well to well	dark red to brown	friable sandy clay loam to clay, rocky	shallow	Lithosols Ironstone Soils	0
Piedmont Plain coalescing alluvial and colluvial fans	Transportional colluvial footslopes	P11	convex slopes	1 - 4	excessively well to well	dark reddish brown to yellow. brown	gravelly loam	moderately deep to shallow	ferralic Arenosols Ironstone Soils	90
	P1	P12	valley bottoms	0 - 2	moderately well	dark red to brown	clay loam to loam	very deep to deep	chromic Cambisols ferralic Arenosols ferralic-chromic/ orthic Luvisols	0
	Midslopes P2	P2	transitional unit between P1 and P3	0 - 2	well	red. brown to yellow. brown	clay loam	deep	ferralic Arenosols chromic Cambisols	410
P	Alluvial toeslopes overlying old lacustrine depsits	P31	almost flat terrain	0 - 1	moderately well to well	red. brown (black to dark grey subsoil)	clay loam to clay	deep	eutric Regosols chromic Cambisols	4,320
		P32	streams bank (gullies)	0 - 1	moderately well	yellow. brown	clay loam	very deep	eutric Regosols chromic Cambisols	590
	P3	P33	old stream courses	1 - 4	poorly	very dark brown. grey to dark grey. brown	sandy clay loam	deep	eutric Regosols chromic Cambisols	180
		P34	raised lake beach	0 - 2	well to poorly	very dark brown to grey	silty clay to sandy clay loam	mod. deep	eutric Regosols	120

Table III-4.14 Description of Land Form and Mapping Symbol (Legend of Soil Map) (2/3)

Land Form	Subdivisions	Mapping Symbol	Mapping Unit	Slope (%)	Drainage Condition	Colour	Texture	Depth	Soil Unit	Extent (ha)
Cuspate Delta fluvium, partly lacustrine deposite D	Deltaic deposits widely extending terrain formed in the river mouth of Sondu D1	D11	terrace-like higher land	0	well	brown to dark grey	silty clay loam	deep	calcaric Fluvisols, sodic phase	570
		D12	recent flood plain	0	poorly to mod. well	brown. grey to brown. black	silty loam	deep	calcaric Fluvisols, sodic phase eutric Fluvisols	680
		D13	former river courses & point bar complex	0	poorly to mod. well	brown. black	sandy clay to silty clay	deep to very deep	eutric Fluvisols, sodic phase	180
		D14	depression seasonally submerged	0	poorly	dark grey to black	clay	deep	eutric Fluvisols, sodic phase	270
	Sand ridges D2	D2	higher lands (1-2in.) on unit D1	0 - 1	well to excessively well	dark brown to yellow. brown	sandy clay to loamy sand	mod. deep to deep	eutric Regosols chromic Cambisols	430
Uplands lavaflow hill of kericho phonolites U	Platform U1	U1	footslopes of phonolite hills & plateau	2 - 8	excessively well	red. brown to grey. brown	gravelly to stony clay	very shallow	chromic Cambisols Ironstone Soils	40
	Slope U2	U2	edge and flank of U1	0 - 2	well to poorly	dark grey. brown to red. brown	gravelly clay to sandy clay	shallow	Ironstone Soils	340
Fan Base colluvial apron and fan base F	Fan base F1	F11	extending fan base (phonolite) U	1 - 2	poorly	very dark grey	sandy clay to clay	deep	chromic Vertisols pellic Vertisols	1,740
		F12	lower alluvial fan base hills granodiolite	0 - 4	poorly	black to very dark grey to brown	clay	deep	chromic Vertisols pellic Vertisols	1,240
	Old streams F2	F21	old stream courses, eroded sites	1 - 4	poorly	very dark brown. grey to dark grey. brown	sandy clay loam	deep	gleyic Luvisols, sodic phase	480
		F22	old stream courses, below colluvial apron	0 - 2	poorly	dark grey. brown	clay	deep	pellic Vertisols	600
	Higher sites of colluvial aprons F3	F3		1 - 4	moderately well to poorly	dark brown, dark grey. brown	sandy clay to sandy loam	deep	eutric Regosols	150
	Micro-ridges F4	F4		1 - 3	moderately well to impeded	dark brown, red. brown	coarse clay loam to sandy loam, gravel	mod. deep	eutric Fluvisols eutric Regosols	180

Table III-4.14 Description of Land Form and Mapping Symbol (Legend of Soil Map) (3/3)

Land Form	Subdivisions	Mapping Symbol	Mapping Unit	Slope (%)	Drainage Condition	Colour	Texture	Depth	Soil Unit	Extent (ha)
Lacustrine Plain lacustrine deposit and mudstone material K	Slightly higher lands, mainly alkarine and calcareous mudstone K1	K11	flatish summit of minor ridge	0 - 2	impeded	dark brown to grey. brown	gravelly sandy clay to clay loam	very shallow	vertic Cambisols	440
		K12	gently sloping land	1 - 3	poorly	very dark brown to grey	clay	shallow	pellic Vertisols, paralithic	2,340
		K13	depression	0 - 2	poorly	very dark grey to brown	clay	mod. deep	pellic Vertisols	3,240
	Lowlying extensive terrain, lacustrine deposits K2	K21	base level	0	poorly	very dark grey	clay	very deep	pelliv Vertisols chromic Vertisols	29,960
		K22	receiving drainage	0	very poorly	very dark grey to black	clay	very deep	pelliv Vertilsols eutric Gleysols	2,110
	Active stream banks K3	K3	irregular micor-relief	0 - 2	well to poorly poorly	very dark brown to grey	clay to silty clay	mod. deep	eutric Fluvisols	6,090
	Old levee K4	K4	slopy mound, uneven	0	moderately well to	very dark brown to dark grey. brown	sandy clay loam	deep to very deep	dystric Regosols, saline phase	330
	Raised lake beach K5	K5		0 - 2	well to poorly	very dark brown to grey	silty clay to sandy clay loam	mod. deep	eutric Regosols, saline-sodic phase	50
Swamp covered by papyrus and reeds S	Seasonal swamp S1	S1		0 - 2	very poorly	very dark grey to black	clay	very deep	pellic Vertisols eutric Gleysols humic Gleysols	1,940
	Permanent swamp S2	S2		0	very poorly	very dark grey to black	peaty	very deep	eutric Histosols humic Gleysols pellic Vertisols	13,880

Source : Prepared by JICA Study Team

Table III - 5.1 Land Suitability Criteria for Lowland Paddy

Land characteristics	Land Class			
	S1	S2	S3	NS1 and NS2
Texture(s)	Topsoil: Fine sandy loam to clay Subsoil: Clay	Topsoil: Fine sandy loam to clay loam Subsoil: Sandy clay to clay	Topsoil: Sandy loam to clay loam Subsoil: Clay to clay loam	NS1: Includes lands which require additional investigations to determine their irrigability. NS2: Includes lands which do not meet the minimumrequirements for the other land classes.
Depth(after]and development) To clear sand or gravel.	Over 80cm	Over 50cm	Over 30cm	
To relatively impermeable zone (water)	less than 210cm	less then 210cm	less than 210cm	
Alkalinity (reaction)	pH-H2O less than 7.5 for non-calcareous soils and less than 8.6 for calcareous soils	pH-H2O less than 9.0 unless soil is calcareous and non-sodic	pH-H2O less than 9.0 unless soil is calcareous and non-sodic	
Salinity(ECe)	Total salts not to exceed 0.2%, ECe less than 4mmhos/cm 8mmhos/cm	Total salts not to exceed 0.5%, ECe less than 8mmhos/cm	Total salts not to exceed 0.5%, ECe less than	
Slope (t)	less than 1%	less than 1%	less than 2%	
Surface (micro relief, t)	Smooth except for gilgai and minor undulations.	Smooth except for gilgai and minor undulations (sink holes).	Somewhat irregular but no major gulleys, sink holes or dissection.	
Vegetation(T)	Woody cover less than 20% Clearing cost small. moderate cost.	Woody cover less than 40%. Clearing required but at	Woody cover less then 80%. Expensive clearing required.	
Drainage(d)	Well drained to imperfectly drained may have surface water but only for short period.	Well drained to poorly drained, may have surface water for several months.	Well drained to very poorly drained, may have surface water or be waterlogged for major parts of the Year.	

Source : Prepared by JICA Study Team

Table III - 5.2 Land Suitability Criteria for Upland Crops (maize, beans, sugarcane, groundnuts, and cotton)

Land characteristics	Land Class			
	S1	S2	S3	NS1 and NS2
Texture(s) loam to clay	Sandy loam to friable clay clay, non-compacted	Sandy loam to permeable impermeable clay	Loamy sand to almost	NS1: Includes lands which require additional investigations to determine their irrigability. NS2: Includes lands which do not meet the minimum requirements for the other land classes and are not suitable for irrigation. These include lands with very shallow soils and impermeable soils.
Depth(s) to sand, gravel horizon	90cm plus and greater than 150cm to impermeable horizon	60cm plus and greater than 120cm to impermeable horizon	45cm plus and greater than 100cm to impermeable	
Alkalinity (reaction) less than 8.6 for	pH-H2O less than 7.5 for non-calcareous soils and calcareous soils	pH-H2O less than 9.0 unless soil is calcareous and non-sodic	pH-H2O 9.0 or less unless soil is calcareous and non-sodic	
Salinity (ECe)	Total salts not to exceed 0.2%, ECe less then 4mmhos/cm	Total salts not to exceed 0.5%, ECe less than 8mmhos/cm	Total salts not to exceed 0.5%, ECe less than 8mmhos/cm	
Slopes(t) lating (less than 2%)	Flat to very gently undulating (less than 2%)	Flat to very gently undulating (less than 5% in general)	Flat to undulating (less than 8% in general)	
Surface (micro-relief)	Even enough to require only small amounts to levellingand no heavy grading.	Moderate grading required but in amounts found feasible at reasonable cost.	Heavy and expensive grading required	
Vegetation(T)	Woody cover less than 20%. Clearing cost small.	Woody cover less then 40%. Clearing required but at a moderate cost.	Woody cover less than 80%. Expensive clearing costs.	
Drainage(d)	Well drained to moderately well drained. No flooding.	Well drained to imperfectly drained. May have surface water for short periods.	Well drained to poorly drained, may have surface water for several months	

Source : Prepared by JICA Study Team

Table III-5.3 Extent of Land Suitability Classes

for paddy plant

(Unit:ha)

Class	I	II	III	IV	V	VI	VII	VIII	Total
S1	0	100	1,270	1,690	1,400	2,130	650	1,920	9,160
S2	260	50	380	410	320	7,990	3,570	13,370	26,350
S3	1,060	4,600	2,440	3,040	3,680	540	220	1,110	16,690
N	930	2,930	1,010	1,740	9,870	420	10	3,870	20,780
Total	2,250	7,680	5,100	6,880	15,270	11,080	4,450	20,270	72,980

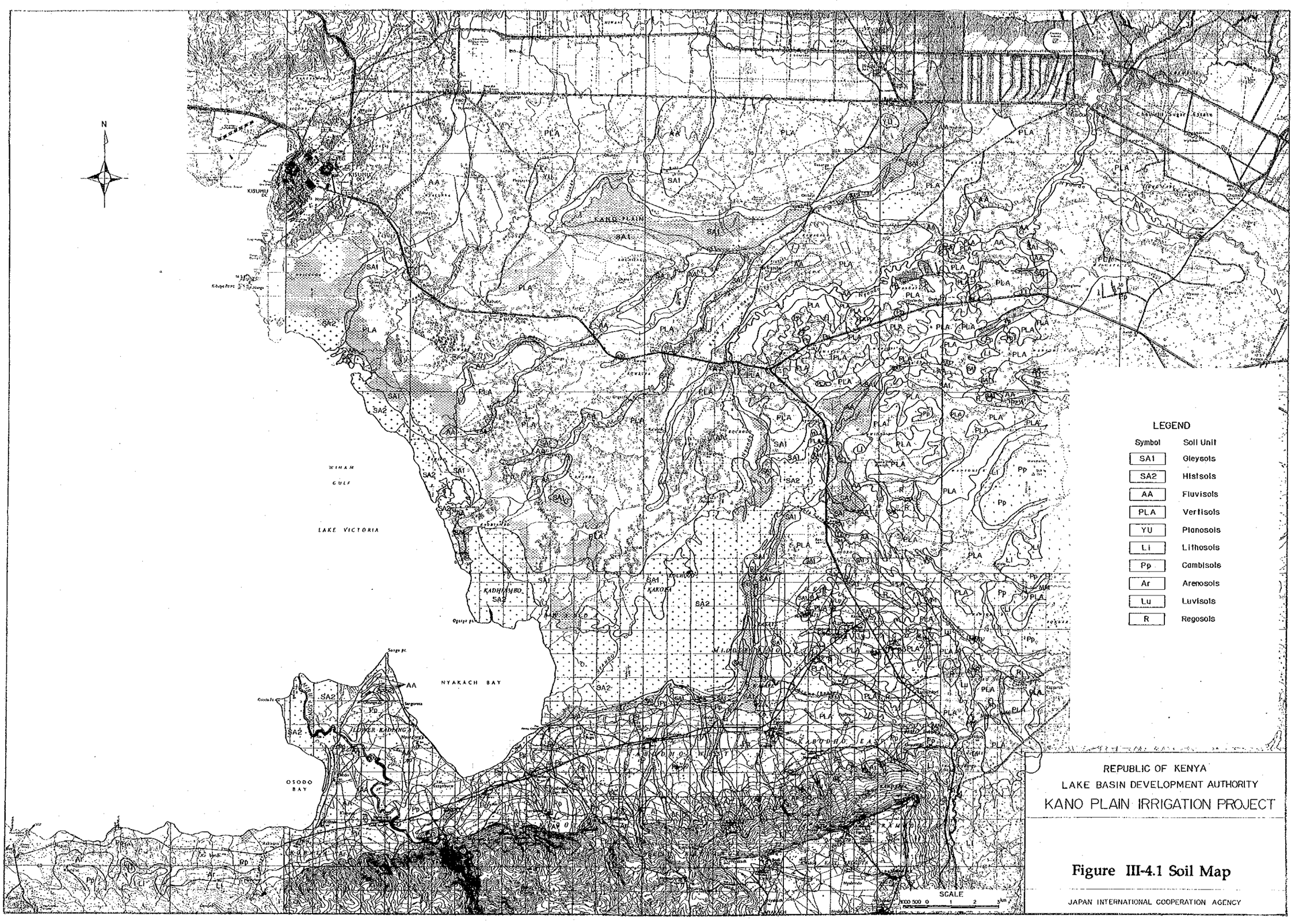
for upland crops

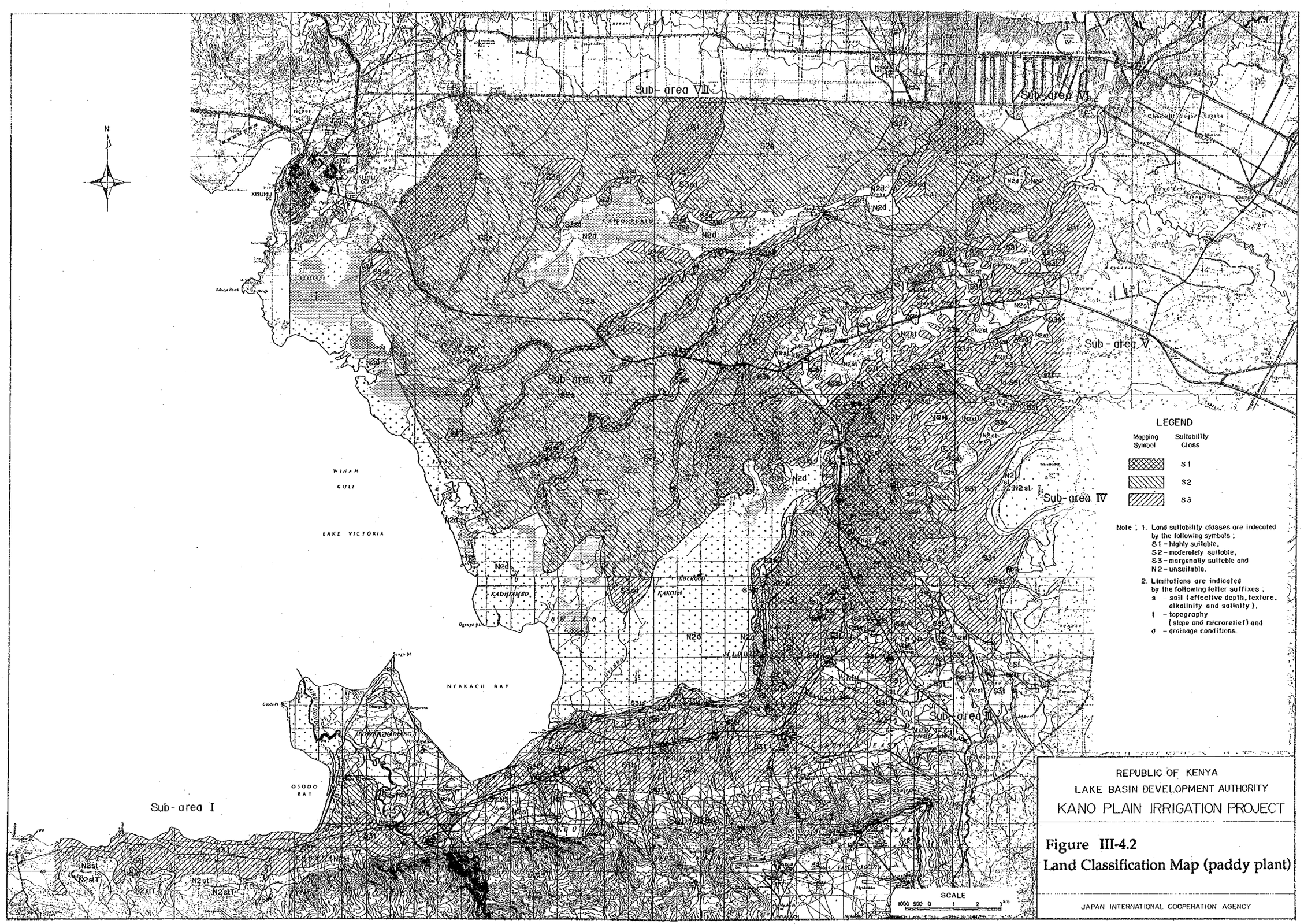
(Unit:ha)

	I	II	III	IV	V	VI	VII	VIII	Total
S1	0	770	510	0	800	770	0	0	2,850
S2	1,060	3,580	1,650	1,500	1,490	2,100	650	1,920	13,950
S3	380	810	2,110	4,760	4,380	7,250	3,570	13,640	36,900
N	810	2,520	830	620	8,600	960	230	4,710	19,280
Total	2,250	7,680	5,100	6,880	15,270	11,080	4,450	20,270	72,980

Source: Prepared by JICA Study Team

Figures


N
KISUMU
KANO PLAIN
WINAM GULF
LAKE VICTORIA
KADHIAMBO
KAKOLA
NYAKACH BAY
OSODO BAY
ABUOMO EAST
KAMPENE
SCALE
LEGEND
Symbol Soil Unit
SA1 Gleysols
SA2 Histsols
AA Fluvisols
PLA Vertisols
YU Planosols
Li Lithosols
Pp Cambisols
Ar Arenosols
Lu Luvisols
R Regosols
REPUBLIC OF KENYA
LAKE BASIN DEVELOPMENT AUTHORITY
KANO PLAIN IRRIGATION PROJECT
Figure III-4.1 Soil Map
JAPAN INTERNATIONAL COOPERATION AGENCY


Sub- area VIII
Sub- area VI
Sub - area V
Sub-area VII
Sub-area IV
Sub-area III
Sub-area II
Sub-area I
KISUMU
KANO PLAIN
LAKE VICTORIA
NYAKACH BAY
KADHIAMBO
KAKOLA
OSODO BAY
WINAM GULF
Chemelil Sugar Estate
LEGEND
Mapping Symbol
Suitability Class
S1
S2
S3
Note ; 1. Land suitability classes are indicated by the following symbols ;
S1 - highly suitable,
S2 - moderately suitable,
S3 - marginally suitable and
N2 - unsuitable.
2. Limitations are indicated by the following letter suffixes ;
s - soil (effective depth, texture, alkalinity and salinity),
t - topography (slope and microrelief) and
d - drainage conditions.
SCALE
1000 500 0 1 2 3 km
REPUBLIC OF KENYA
LAKE BASIN DEVELOPMENT AUTHORITY
KANO PLAIN IRRIGATION PROJECT
Figure III-4.2
Land Classification Map (paddy plant)
JAPAN INTERNATIONAL COOPERATION AGENCY