C2 Construction Materials

C2.1 Introduction

The materials investigation for the fill-type dam was carried out in 1979/1980 by the British consulting firm, Engineering and Power Development Consultants (EPDC), as a part of the investigation works for the Kiambere Feasibility study. Additional investigation was done in 1986/1987 by UNDP/World Bank/Acres. The investigation results are described in the following reports respectively:

a) Kiambere Hydroelectric Development Feasibility study,
Geology Report, Part 3 (A), April 1980
Tana River Development Company Ltd, Kenya/EPDC

b) Kenya National Power Development Plan, 1986-2010
Appendix Vol. 2, June 1987
UNDP/World Bank/Acres

In this study (1994~1995), following the above previous study and the preliminary review, and based upon the field reconnaissance made so far, the investigation of construction materials was planned as to cover the maximum quantities of required materials in case of the rock-fill type of dams. In addition, the concrete aggregates survey and tests for concrete dams and relevance structures, which have something in common with filter materials, were carried out for comparative studies of dam types, reliability of material sources and cost etc. The test items for the construction materials are tabulated in Table C2.4.1 (1) to (5).

The construction materials required for the dams and their relevant structures are obtainable from the following sources;

Embankment materials		
Impervious core material	:	Residuals soils near the site
Filter and drain material	:	River bed deposits and/or producing from rock quarry
Rock material (Inner shell)	:	Weathered rock coming from general excavation, spillway and tunnel spoil
Rock material (Outer shell)	:	Rock quarry and/or fresh rock from spillway and tunnel excavation
Concrete aggregates	:	River bed deposits and/or producing from rock quarry

There are a lot of the river bed deposits in the seasonal rivers in economical distance, which mostly drain the right bank side of the Tana river.

The residual soils originated gneisses and granitic mother rocks, which showed to have on appropriate quality as the impervious core materials in the previous study, exist widely on the both banks of the river. However, the thickness of above promising

layers is very thin in general. Rock quarry can be found rather easily in both project areas. Gneisses and granitic rocks which have a sufficient required quality are available. The proposed locations of borrow areas and quarry sites for the Mutonga project and Grand Falls project are shown in Figures C2.2.1, C2.2.2 and C2.2.3, and C2.3.1, C2.3.2 and C2.3.3 respectively.

C2.2 Mutonga Project

C2.2.1 Embankment Materials

(1) Required materials and their quantities

The required quantities for each of the construction material in case of rockfill type of dam are estimated as follows;

Table Required Material Quantity for Center Core Rockfill Dam

Material	Required quantity (m^3)
Impervious core material	171,000
Filter and drain material	81,500
Inner shell (weathered rock material)	49,200
Outer shell (fresh rock material)	508,000

The JICA Study Team selected three borrow areas for the impervious core material, five river bed deposit borrows and one quarry site for the filter, rock materials and concrete aggregate within about 5 km distance from the proposed dam site as shown in the Figures C2.2.1 and C2.2.2.

(2) Impervious core materials

Residual soils widely develop in the surrounding area of the proposed dam site. Test pit investigation was conducted by EPDC (1979) and UNDP/World Bank/Acres (1987) for their selected three borrow areas. The investigation results are shown in Table C2.4.2. The test pit investigation in this stage (1994/1995) was made for the same three borrow areas as the previous study and some extension area of the Kanjiya Hill borrow area, namely Borrow MC-1, MC-2 and MC-3.

The 12 test pits were dug by the hand pick and 24 samples from the above test pits were tested by the Mowlem Construction Company (East Africa) Limited, and the results are shown in the attached Table 3.4.3. The representative gradation curves are shown in Table C2.4.4 and Figure C2.4.3. The sample number tested is as follows:

a) Natural moisture content : 24 samples
b) Specific gravity : 24 samples
c) Particle size analysis : 24 samples
d) Liquid limit test : 24 samples

e)	Plastic limit test	:	24 samples
f)	Compaction test	:	8 samples
g)	Triaxial compression test (CU test)	:	3 samples
h)	Permeability test	:	8 samples

All the above tests were based on ASTM Standard or BS standard. For the permeability test and the triaxial compression test (CU test), the test samples were prepared at the optimum moisture content and at the dry density of the 98 % maximum dry density.

Engineering Judgement on Soil Material

a) Physical properties

The soil materials in Borrow MC-1, MC-2 and MC-3 are the residual soils originated from weathered gneisses and granitic rocks with some coarse grains, consequently having low moisture content and generally very thin layer (about 1.0 to 1.5 m thick) favourable for use to the impervious core material.

The natural moisture content of soils from the above three Borrows ranges from 1.1 % to 10.1 % being averaged at 5.2 %. But those samples were taken under dry condition in the dry season. Therefore it may be wetted in the rainy season by 2 or 3 %. The optimum moisture content is 12.8 % on an average, therefore it means strong operation by sprinkle watering will be required for embankment of core zone.

The plasticity index (P.I) of those soils ranges from 7 to 16 % being averaged at 12 %. It can be classified into low to medium plasticity soils resistible enough against piping action. The content rate of gravel (over 2.0 mm), sand (2.0 ~ 0.074 mm) silt (0.074 ~ 0.005 mm) and clay (less 0.005 mm) is 10.9, 48.3, 15.2 and 25.6 % on an average respectively. The maximum grain size is 4 mm to 63 mm which are decomposed to some extent.

Those materials have low moisture content and stiff condition, even so, it can be easily excavated by bulldozer with ripper. The above soils from Borrow MC-1, MC-2 and MC-3 are mostly classified into CL or ML in the Unified Soil Classification System. Apparently gravely materials in the lower depth can be easily compacted and crushed into CL class soils due to its weathering conditions.

b) Mechanical properties

The compaction test was carried out in accordance with ASTM D698, Method A. The materials used for this test were mines No. 4 sieve.

Table Compaction Test Result

Borrow Area	MDD (g/cm^3)	OMC (%)
MC-1 (TP 95-1)	1,960 ~ 2,040	9.3 ~ 11.8
MC-2 (TP 95-6)	1,900 ~ 1,920	12.3 ~ 15.1
MC-3 (TP 95-9)	1,870 ~ 1,940	13.0 ~ 15.0
Average	1,939	12.8

Notes : MDD : maxinum dry density
OMC : optimum moisture content

As shown in the above table, the maximum dry densities of the soil materials taken from Borrow MC-1, MC-2 and MC-3 are very high and it means the soil material when compacted at the optimum moisture content has good strength and deformation properties.

The permeability test made on the compacted samples under the optimum moisture content and at the 98 % maximum dry density clarified that those samples have very low permeability in an order of less than 10^{-8} cm/sec which assures sufficient water tightness of the core zone. In addition, the triaxial test made on the same samples clarified that those materials have a good strength such as 28.5 to 33.5 degree (average, 30.7 degree) of internal friction angle and 0.3 to 1.4 t/m^2 (average, 1.0 t/m^2) of cohesion both in terms of effective stress.

From all the above engineering point of view, those residual soil materials in Borrow MC-1, MC-2 and MC-3 will offer very suitable materials which have good strength and deformation, and low permeability for embankment of core zone for a rockfill dam.

Judging from the excavated pit depth by hand pick, the available soils for embankment of core zone are very thin such as 0.5 to 1.2 m in depth and the estimated available quantities for each borrow area are summarized as follows;

Table Estimated Available Quantity of Core Material

Location	Area (m^2)	Average thickness of soil (m)	Estimated quantity (m^3)
Borrow MC-1 (Mutonga/Tana confluence borrow area)	37,000	0.5	18,500
Borrow MC-2 (Right bank borrow area)	80,000	1.2	96,000
Borrow MC-3 (Kanjiya Hill borrow area and extension)	190,000	0.8	152,000
Total available quantity			266,500

The quantity is also sufficient even for the maximum requirement.

(3) Filter and drain material

River bed deposits, sand with some gravels and boulders, are available in the following four seasonable rivers in the Tana river right bank at the dam site as shown in Figures C2.2.1 and C2.2.3. The results of a test pit investigation performed by EPDC(1979) and UN/World Bank/Acres (1987) are shown in Table C2.4.5. The condition of deposit and the estimated available quantity are summarized as follows;

Mur War Wanda river :
This river flows down from the left bank, joining to the Tana mainstream at a location of about 300 m upstream of the dam site. The river is very small and narrow, and the deposit distributes in the river bed with 5 to 10 m wide in general and about 200 m long. The thickness is estimated to be 1 to 2 m which could not be confirmed exactly because of shallow ground water (about 0.5 m deep) existing in the deposit. The deposit is formed by mainly sand, rarely gravels and boulders. The available quantity is estimated to be 2,000 ~ 2,500 m^3 only.

Tana river right bank at dam site:
This is the river bed deposit of the Tana river mainstream. According to the bore hole M95-3, the surface layer with a thickness of about 1 m is formed by medium to coarse sand, with rare gravels and boulders, and next lower layer it about 1.5 m in thickness is formed by silty to clayey sand. The area is 20 to 30 m wide and 150 m long approximately. The available quantity is estimated about 4,000 ~ 5,000 m^3 which include silty to clayey sand layer existing in the bottom of the deposit.

Mukindu river :
This river joints to the Tana mainstream from the right bank, south of the dam site. In the lower reach of the Mukindu river, in the section of about 2 km from the Tana river, the deposit is very thin and narrow, and not favourable for material source. However thick and wide deposit is seen in the middle reach of the Mukindu river, in the section between 2 and 3 km from the confluence with the Tana river, where the deposit distributes with an area of 50 m in width and 1,000 m in length approximately. The thickness of the available deposit will be 1 to 2 m. The deposit is formed by mainly medium to coarse sand, with rare gravels and boulders.

The available quantity is estimated to be about 25,000 ~ 30,000 m^3 in the middle reach section and the transportation distance between this source and the dam site is about 2.5 km. The three samples, namely MS-1, MS-2 and MS-3 in the promising borrow section in the Mukindu river were taken from approximately each 0.5 ~ 1.0 m depth and tested to check the availability for concrete aggregates and/or filter materials.

Kanyaka river :

This river drains the right bank side of the Tana mainstream, joining the downstream of the Mukindu river. The area with relatively thick and wide deposits is located at about 3 to 4 km distance, east of the dam site. The deposit is 10 to 30 m wide, 1.5 km or more long approximately.

The thickness of deposit may be 1 to 2 m, and the deposit is formed by mainly medium to coarse sand, with rare gravels and boulders, which are very similar to the Mukindu river deposit respectively. The available quantity is estimated to be about 45,000 ~ 50,000 m^3. The three samples, namely MS-4, MS-5 and MS-6 were taken and tested.

Konyu river :

This river flows down from the right bank, joining to the Tana mainstream downstream of the Kanyaka river. The area promising filter and concrete aggregate source is located at about 4.5 ~ 5.5 km east of the dam site. The deposit is 40 to 60 m wide, 2 km or more long approximately. The quality and thickness of the deposit is also very similar to those of the Mukindu and Konyu rivers. The four samples, namely MS-7, MS-8, MS-9 and MS-10 were taken and tested.

Engineering Judgement on Filter Materials

About 90,000 m^3 of filter and drain materials will be required in case of a rockfill dam at the maximum. The above promising river deposits, 10 samples of sand and gravels are checked by the standard requirement of filter materials as mentioned below.

The standard criteria for filter materials are as follows:

(a) $\dfrac{\text{15 \% particle size of filter material (F15)}}{\text{15 \% particle size of core material (C15)}} > 5$

(b) $\dfrac{\text{15 \% particle size of filter material (F15)}}{\text{85 \% particle size of core material (C85)}} < 5$

(c) It is desirable that gradation curve of filter materials is approximately in parallel with that of the core materials.

(d) If the core materials contain coarse materials, the above conditions a) and b) shall be applied to the materials under 25 mm size.

(e) Filter materials shall not be cohesive and shall not contain more than 5 % of finer particles passing No. 200 (0.074 mm) sieve.

According to the results of tests on core materials (Borrow MC-1, MC-2 and MC-3), the value of C15 ranges between 0.0001 to 0.01 mm and that of C85 falls within 0.8 to 15.0 mm. Then the sand and gravel gradation tests (MS-1 to MS-10) revealed that the value of F15 is in a range from 0.8 to 2.5 mm. This F15 range fully satisfies the above conditions (a) and (b).

The gradation curves of sand and gravel shown in Figure C2.2.5 is not so parallel with that of core material shown in Figure C2.2.4, however, in the section of both finer particles the representative gradation curves satisfies nearly the condition (c).

The content of the finer particles than 0.074 mm in the materials tested is all less than 5 %, which satisfies the above condition (e).

Physical and chemical test results are discussed in the section of concrete material. The sand and gravel materials from MC-1 to MC-10 can be used for the filter materials with sufficient safety. However, it should be noted that coarse filter zone (transition zone) produced from quarry rocks may be necessary between the above filter zone and rock zone.

(4) Rocks materials

As for the rock materials to be used for a rockfill dam, abundant excavated materials, such as the weathered and fresh granite intrusion, granite gneiss, mafic and semi-felsic gneisses from the spillway, diversion tunnel and dam foundation etc. around the dam site offers good sources of rock materials. Weathered rocks from these excavations could be used in a zoned rockfill, namely inner shell.

Fresh rocks mainly from the tunnel and spillway excavation which estimated more than 1,000,000 m^3, could be used in an inner shell material as well as sources of concrete aggregates.

Drilling investigation was made in the small hill located about 1 km south of the dam site for the purpose of a reserve quarry and for the quality check. The results of the drilling investigation and laboratory test are as follows;

Table : Drilling Investigation at Mutonga Quarry Site

MQ95-1 (Total Depth : 30 m) Hole mouth : EL. 609.51 m

Depth	Thickness (m)	Geology	Rock class
0.00 - 5.10	5.10	Sandy silt - decomposed rocks	D
5.10 - 8.40	3.30	Granitic gneiss	CH
8.40 - 17.85	9.45	Mafic gneiss	CH
17.85 - 19.10	1.25	Granitic gneiss	CH
19.10 - 20.50	1.40	Mafic gneiss	CH
20.50 - 27.50	7.00	Granitic gneiss	CH
27.50 - 28.35	0.85	Dolerite	CH
28.35 - 30.00	1.65	Mafic gneiss	CH

Table : Test Results of Boring Core

Sampling		Specific Gravity Test		Absorp. Test	Na_2SO_4 Durability Test		Strength
Log No.	Depth (m)	SSD	APP	(%)	+No.4	-No.4	(kg/cm^2)
MQ95-1	7.5 to 7.8	2.64	2.66	0.5	1.3	3.0	1,220
MQ95-1	8.5 to 9.0	2.79	2.84	1.1	3.1	7.3	345
MQ95-1	20.0 to 20.7	2.78	2.80	0.7	2.0	6.3	553
MQ95-1	23.0 to 24.0	2.60	2.63	0.6	1.9	2.4	766

Note : SSD : saturated surface dry basis APP : apparent specific gravity

As observed in the above tables the fresh rock has a quite sufficient strength as high as more than 300 kg/cm^2. The values of specific gravity, absorption test and durability test show that those fresh rocks have enough soundness for use in any rockfill zones.

The weathered rock materials are considered almost same as that shell materials used for Kiambere Dam. The ripped migmatite, a non-plastic grey sandy gravel of the shell material in Kiambere Dam has the following properties which are very useful for the design value of the inner shell zone of this project.

In-site moisture content :	1 ~ 2.5 %
Specific gravity :	2.73 ~ 2.86
Maximum dry density :	2.08 ~ 2.26 t/m^3
Effective cohesion C' :	0.6 t/m^2
Effective friction angle ϕ' :	36° ~ 38°
Coefficient of permeability :	0.3 ~ 1.0 x 10^{-4} cm/sec.

C2.2.2 Concrete Aggregate

Laboratory test results are summarized in Table C2.4.6.

(1) Fine aggregate

River deposits distributed in the seasonal rivers will be usable as concrete fine aggregates. Natural river sand contains coarse aggregates with more than 100 mm diameter. After screening the coarse aggregates, the calculated gradation curve is ranged in the allowable gradation band as shown in Table C2.4.7 and Figure C2.2.5.

Specific gravity and absorption tests are made as routine investigations for concrete aggregates. Test results of sand and gravel from MS-1 to MS-10 are more satisfactory with respect to soundness and strength such as higher specific gravity of a minimum value of 2.60 and low absorption value of a maximum value of 0.8 %. The sodium sulphate soundness test results ranges between 3.6 and 7.4 % which generally implies to have acceptable durability of sand and gravels. Alkali chemical test indicates that the sand material is innocuous as shown in Figure C2.2.6.

(2) Coarse aggregate

There are no noticeable distribution of gravel deposits near the project area. Gravels are found only in the seasonal river. Available quantity in these deposits does not seem to meet the required quantity. Therefore, coarse aggregate shall be produced through a crushing plant, being sourced from the quarry site. The material from the quarry site is also so sound physically and chemically that it is suitable for concrete aggregates.

Some gravels are seen in the residual soil layers. Because these gravels are mostly highly to moderately weathered, however, they seem to be useless for concrete aggregates.

C2.3 Grand Falls Project

C2.3.1 Embankment Materials

(1) Required materials and their quantities

The required quantities for each of the construction material in case of rockfill type dam are estimated as follows:

Table Required Material Quantity for Center Core Rock fill dam

Material	Required quantity (m^3)	
	Low Scale	High Scale*
Impervious core material	860,000	2,900,000
Filter and drain material	373,000	1,180,000
Inner shell (weathered rock material)	292,000	650,000
Outer shell (fresh rock material)	3,850,000	17,400,000

Note : * including saddle dam.

According to the field reconnaissance and reviewing the previous study, the JICA Study Team selected four borrow areas for the impervious material, two river bed deposit borrows and one quarry site for the filter, rock materials and concrete aggregates within about 10 km distance from the proposed dam site as shown in Figures C2.2.3, C2.3.1, C2.3.2 and C2.3.3.

(2) Impervious core material

Residual soils also widely develop in the surrounding upstream area of the proposed dam site, which is very similar to the residual soils reviewed in the Mutonga project. Following the test pit investigation conducted by EPDC (1979) and UN/World Bank/Acres (1987) as shown in Table C2.4.8, total 62 test pits and 30 auger borings were carried out in the selected 4 borrow areas, namely Borrow GC-1, GC-2, GC-3 and GC-4 in the upstream area of the dam site in this stage (1994/1995). The investigation results are shown in Table C2.4.9.

Total 36 samples from the above test pits were tested by the Mowlen Construction Company (East Africa) Limited and the results are summarized in Table C2.4.10 and the representative gradation test results are tabulated in Table C2.4.11 and shown in Figure C2.3.4. The sample number tested is as follows:

a)	Natural; moisture content	:	36 samples
b)	Specific gravity	:	36 samples
c)	Particle size analysis	:	35 samples
d)	Liquid limit test	:	36 samples
e)	Plastic limit test	:	36 samples

f)	Compaction test	:	12 samples
g)	Triaxial compression test (CU test)	:	6 samples
h)	Permeability test	:	12 samples

All the above tests were based on ASTM standard or BS standard. For the permeability test and the triaxial compression test (CU test), the test samples were prepared at the optimum moisture content and the 98 % maximum dry density.

Engineering Judgement on Soil Material

a) Physical properties

The soil materials in Borrow GC-1, GC-2, GC-3 and GC-4 are very similar to the Mutonga soil materials which are also the residual soils originated from the decomposed gneisses and granitic rocks, and only 1.0 to 1.5 m thin layers are favourable for use to the impervious core material.

The natural moisture content of soils from the above four Borrows ranges from 0.5 % to 6.0 % being averaged at 3.3. % which are rather more dry condition than the Mutonga soils. On the contrary the optimum moisture content is 12.1 % on an average (12.8 %, in Mutonga), therefore it means strong watering operation will be required for embankment of core zone.

The liquid limit ranges widely from non-plasticity to 35 % and the plasticity index (P.I) of those soils ranges from non plasticity to 18 % being averaged at about 13 %. It can be classified into low to medium plasticity soils resistible enough against piping action by using at well mixture and wet condition.

The maximum grain size is 4 mm to 63 mm which are decomposed to some extent. The content rate of gravel (2.0 mm over), sand (2.0 ~ 0.074 mm), silt (0.074 ~ 0.005 mm) and clay (less 0.005 mm) is 26.1, 42.3, 11.5 and 20.1 % on an average respectively.

The above soils from Borrow GC-1, GC-2, GC-3 and GC-4 are mostly classified into CL and ML in the Unified Soil Classification System and have low moisture content and staff condition in general, even so, it can be easily excavated by bulldozer with ripper. Apparently gravely materials in the lower depth and less weathered, can be easily crushed and compacted into CL or ML class soils due to its weathering conditions.

b) Mechanical properties

The compaction test was carried out in accordance with ASTM D698, Method A. The materials used for this test were minus No. 4 sieve.

Borrow Area	MDD (g/cm^3)	OMC (%)
GC-1 (TP95-2)	1,890 ~ 2,070	11.2 ~ 13.0
GC-2 (TP95-10)	1,940 ~ 2,040	10.2 ~ 13.0
GC-3 (TP95-14)	1,900 ~ 2,110	10.2 ~ 13.7
GC-4 (TP95-16)	1,860 ~ 2,090	11.0 ~ 15.8
Average	1,990	12.1

Notes: MDD : maximum dry density
OMC : optimum moisture content

As shown in the above table, the dry densities compacted at the optimum moisture content are very high and it means the compacted materials have good strength and good deformation properties.

The permeability test made on the compacted samples under the optimum moisture contestant and at the 98 % maximum dry density clarified that those samples have very low permeability in an order of less than 10^{-8} cm/sec of coefficient of permeability which assures sufficient water tightness of core zone. In addition, the triaxial compression test made on the samples clarified that those samples have a good shearing strength such as 26.5 to 35.0 degree (average 30.8 degree) of internal friction angle in terms of effective stress and on an average of 0.5 t/m^2 of cohesion in terms of effective strange.

From all the above engineering point of view, the residual soil materials in Borrow GC-1 to GC-4 will offer very suitable materials for the impervious core which have sufficient shear strength and trafficability, good deformation properties and low permeability.

The only serious drawback of the above Borrows is thin layer available to the impervious core, such as only 1.0 m or more in depth mostly. This means that wide borrow areas are necessary and shall be selected inside of the submerged reservoir to avoid the scenery and environment problem. The estimated available quantities in the reservoir for each borrow area are summarized as follows;

Table Estimated Available Quantity of Core Material

Location	Area (m^2)	Average thickness of soil (m)	Estimated quantity
Borrow GC-1 (Right bank)	1,500,000	0.9	1,350,000
Borrow GC-2 (Right bank)	2,000,000	0.5	1,000,000
Borrow GC-3 (Left bank)	600,000	0.8	480,000
Borrow GC-4 (Left bank)	1,000,000	0.8	800,000
Total available quantity			3,630,000

(3) Filter and drain materials

Pit investigation results in the previous study are listed in Table C2.4.12. River bed deposits, sand with some gravels and boulders, are available in the following two seasonable rivers within economical distance from the dam site as shown in Figures C2.2.3 and C2.3.1. The condition of deposit and the estimated available quantity are summarized as follows;

Ngoru river

This river flows down from the right bank, joining to the Tana mainstream downstream of the dam site. The area with thick and wide deposit is located about 1 to 2 km east of the dam site. The deposit is 40 to 50 m wide and 2.5 km or more long approximately. The thickness of deposit may be 1 to 2 m and formed by mainly medium to coarse sand, with rare gravels and boulders. The available quantity is estimated to be 330,000 m^3 or more. The four samples, namely GS-1-1 to GS-1-4 in the above promising borrow area in the Ngoro river (Borrow GS-1) were taken from approximately each 0.5 ~ 1.0 m depth and tested to check the availability for concrete aggregates and/or filter materials.

Karange river

This river joints to the Tana mainstream from the right bank, south of Tharaka village. The area with thick and wide deposit is located about 9 km south and upstream of the dam site. The deposit may be available in 50 to 100 m wide, 3 km or more long approximately. The thickness of deposit may be 1 to 2 m as same as the Ngoru river deposit and formed by mainly medium to coarse sand, with rare gravels and boulders. The available quantity is estimated to be 330,000 m^3 or more. The six samples, namely GS-2-1 to GS-2-6 were taken and tested.

Engineering Judgement on Filter Materials

Total 10 samples from Borrow GS-1 (Ngoru river) and Borrow GS-2 (Karange river) were tested and their results are discussed in the concrete material.

The gradation curves of the above results are shown in Figure C2.3.5. The above representative sand and gravel materials are checked by the standard criteria for filter material as mentioned before. Comparing with the gradations of core material (Borrow GC-1, GC-2, GC-3 and GC-4), the sand and gravel materials from Borrow GS-1 and GS-2 fully satisfies the above criteria.

In addition, judging from the test results of specific gravity, absorption test and sodium sulphate soundness test, all the promising sand and gravels from Borrow GS-1 and GS-2 can be used for the filter material with sufficient safety against core material. However, if the coarse filter materials or transition materials against rock materials (outer shell) are necessary, the suitable materials shall be produced from quarry rocks.

(4) Rock materials

Rock materials, weathered and fresh rocks can be obtained from the various open and tunnel excavations required for the dam and the relevant structures. In addition to those, rock quarry for the outer shell or concrete coarse aggregate will be required. Many rock ridges or knobs exist around the dam site, especially in the downstream area, such as Tiamber hill and Kamuwongu hill, etc. The Tiamber and Kamuwongu hills located on the right bank of the Tana river are formed by mainly granitic gneisses which have suitable quality for the rock materials. There is a small hill in the right abutment of the dam which is formed by granitic gneiss and semi-felsic gneiss, partly mafic gneiss. These materials are also suitable for the rock materials, while the available quantity is much less than the other hills mentioned above.

The bore hole GQ95-1 was drilled at the top of the small hill near the right abutment of the dam. The results are summarised below:

Table : Drilling Investigation for Grand Falls Quarry Site

GQ95-1 (Depth:30.25 m)		Hole mouth : EL. 572.15 m	
Depth	Thickness (m)	Geology	Rock class
0.00 - 2.65	2.65	Sandy silt-decomposed rocks	D
2.65 - 6.60	3.95	Granitic gneiss, decomposed	CL, partly CM
6.60 - 15.50	8.90	Semi-felsic gneiss	B
15.50 - 30.25	14.75	Granitic gneiss	B

In the bore hole GQ95-1, rocks are granitic gneiss and semi-felsic gneiss, which have foliation faintly and massive, with very rare joint structures (RQD; 100 % in most section) and the rock classification of CL to B in general. The rock condition shows applicable to use for the rock material. The available quantity in this hill is estimated to be 6,000,000 m^3 or more.

Boring core samples from GQ95-1 and the dam site boring G95-8 and G95-10 were tested and the results are as follows;

Table Test Results of Boring Core

Sampling		Specific Gravity Test		Absorp. Test	Durability Test		Strength
Log No.	Depth (m)	SSD	APP	(%)	+No.4	-No.4	(kg/cm^2)
GQ95-1	3.5 to 4.0	2.60	2.65	1.2	5.4	8.0	82
GQ95-1	26.5 to 27.0	2.65	2.68	0.6	1.7	5.5	649
G95-8	10.7 to 11.0	2.94	2.98	0.6	-	-	441
G95-8	18.6 to 19.1	2.83	2.87	0.7	-	-	913
G95-10	14.2 to 14.5	2.64	2.67	0.7	-	-	683

Notes; SSD : saturated surface-dry basis
APP : apparent specific gravity

As observed in the above tables, the fresh rock has a sufficient strength and the values of specific gravity, absorption test and durability test show that fresh rocks of semi felsic and granite gneiss have sufficient soundness for use in any rockfill zones.

The design engineering properties of fresh and hard semi-felsic and granitic gneiss rocks for outer shell are conceivable from the previous study as follows;

Density : $\gamma wet = 1.90\ t/m^3$, $\gamma sat = 2.12\ t/m^3$
Shearing strength : $C' = 0\ t/m^2$, $\phi' = 43.0°$
(compacted by vibratory roller)

Where,

γwet : wet density
γsat : saturated density
C' : cohesion in terms of effective stress
ϕ' : internal friction angle in terms of effective stress

The abundant weathered rock materials produced from the dam site such as spillway excavation shall be used for inner shell zone or transition zone as much as possible. Referring to the past test and experience such as Kiambere Dam project, the following engineering properties may be applicable as follows;

Density : $\gamma wet = 2.02\ t/m^3$,
Shearing strength : $C' = 0$, $\phi' = 37.0°$
Coefficient of permeability : $k = 0.5 \times 10^{-4}$cm/sec.

C2.3.2 Concrete Aggregate

Laboratory test results are summarized in Table 3.4.13.

(1) Fine aggregate

River deposits distributed in the seasonal rivers as discussed in the section of dam filter material will be usable as concrete fine aggregates. Natural river sand contains coarse aggregates with more than 100 mm diameter. After screening the coarse aggregates, the calculated gradation curve is ranged in the allowable gradation band as shown in Figure C2.3.5. Physical and chemical properties such as specific gravity, absorption and durability are all within allowable range. Alkali chemical test indicates that the sand material is innocuous as shown in Figure C2.3.6.

(2) Coarse aggregate

There are no noticeable distribution of gravel deposits near the project area. Gravels are found only in the seasonal river. Available quantity in these deposits does not seem to meet the required quantity. Therefore, coarse aggregate shall be produced through a

crushing plant, being sourced from the quarry site. The material from the quarry site is also so sound physically and chemically that it is suitable for concrete aggregates.

Some gravels are seen in the residual soil layers. Because these gravels are mostly highly to moderately weathered, however, they seem to be useless for concrete aggregates.

Table C2.4.1 (1) Construction Material Investigation Performed in 1994-1995

1. Mutonga Project

(A) Concrete aggregate and filter materials

Sampling location and quantity

Mukindu river: 3 samples
(located in the right bank, downstream of the dam)

Kamonyoni river: 3 samples
(located in the right bank, downstream of Mukindu river)

Konyu river: 4 samples
(located in the right bank, downstream of Kamonyoni river)

10 samples in total.

(B) Test pit excavation and sampling for impervious core material

Test pit (MC1 at Left bank)

No.	Depth (m)	Sampling (nos)
TP95-1	2.60	2
TP95-2	1.10	2
TP95-3	1.20	2
Total		6

Test pit (MC2 at right bank)

No.	Depth (m)	Sampling (nos)
TP95-4	1.60	2
TP95-5	1.90	2
TP95-6	1.40	2
Total		6

Test pit (MC3 at Right bank)

No.	Depth (m)	Sampling (nos)
TP95-7	2.60	2
TP95-8	1.10	2
TP95-9	1.20	2
TP95-10	1.60	2
TP95-11	1.90	2
TP95-12	1.40	2
Total		12

Note

The test pit excavation was done at 12 locations in total. A total of 24 nos. of samples were collected from those test pits.

Table C2.4.1 (2) Construction Material Investigation Performed in 1994-1995

(C) Laboratory Test (Mutonga: 1995)

i) Concrete aggregate and filter materials

Test item	Test quantity
Gradation test (ASTM C138)	10
Specific gravity and absorption test (ASTM C127, C128)	10
NA_2SO_4 durability test (ASTM C88)	10
Los Angeles test (ASTM C131)	10
Alkali aggressive chemical test (ASTM C289)	2

ii) Impervious core materials

Test item	test quantity
Particle size analysis (ASTM D422)	30
Specific gravity test (ASTM D854)	30
Moisture content (ASTM D2216)	30
Liquid limit test (ASTM D423)	30
Plastic limit test (ASTM D424)	30
Compaction test (ASTM D698)	10
Tri-axial compression test (CU)	5
Permeability test	10

iii) Rock materials

Test item	Test quantity
Specific gravity and absorption test (ASTM C127, C128):	4 samples.
Uni-axial compression test (ASTM D2938-86):	4 samples.
Na2SO4 durability test (ASTM C88):	4 samples

Sample: Depth between 7.50m and 7.80m in bore hole No.MQ95-1
Depth between 8.50m and 9.00m in bore hole No.MQ95-1
Depth between 20.00m and 20.70m in bore hole No.MQ95-1
Depth between 23.00m and 24.00m in bore hole No.MQ95-1
(MQ95-1; located in the proposed quarry site.)

Table C2.4.1 (3) Construction Material Investigation Performed in 1994-1995

2. Grand Falls Project

(A) Test pit excavation and sampling for impervious core material (1994)

i) Test pit (Right bank)

No.	Depth (m)
TP94-1	2.60
TP94-2	1.10
TP94-3	1.20
TP94-4	1.10
TP94-5	1.30
TP94-6	1.30
TP94-7	1.80
TP94-8	1.90
TP94-9	0.60
TP94-10	1.30
TP94-21	1.40
TP94-22	1.40
TP94-23	1.40
TP94-24	1.10
TP94-25	1.30
TP94-26	1.60
TP94-27	1.70
TP94-28	1.25
TP94-29	1.05
TP94-30	0.70
TP94-31	1.10
TP94-32	0.80
AB94-1	0.60
AB94-2	0.60
AB94-3	0.50
AB94-4	1.00
AB94-5	1.40
AB94-6	0.60
AB94-7	0.60
AB94-8	1.20
AB94-9	1.20
AB94-10	*
AB94-11	*
AB94-12	0.60
AB94-13	0.45
AB94-14	0.70
AB94-15	*
Total (m)	38.45

ii) Test pit (Left bank)

No.	Depth (m)
TP94-11	1.60
TP94-12	1.90
TP94-13	1.40
TP94-14	1.40
TP94-15	1.55
TP94-16	1.15
TP94-17	1.60
TP94-18	1.75
TP94-19	1.60
TP94-20	1.90
TP94-33	2.00
TP94-34	0.80
TP94-35	1.70
TP94-36	1.50
TP94-37	1.90
TP94-38	1.40
TP94-39	1.30
TP94-40	1.50
TP94-41	1.20
TP94-42	1.20
TP94-43	1.80
TP94-44	2.10
AB94-16	2.30
AB94-17	1.90
AB94-18	2.40
AB94-19	1.80
AB94-20	*
AB94-21	1.50
AB94-22	1.00
AB94-23	1.80
AB94-24	1.40
AB94-25	1.40
AB94-26	1.90
AB94-27	1.80
AB94-28	1.30
AB94-29	1.10
AB94-30	1.40
Total (m)	57.25

Note
* shows that soil layer is very thin.

Table C2.4.1 (4) Construction Material Investigation Performed in 1994-1995

(B) Concrete aggregate and filter materials

Sampling location and quantity
Ngoru river: 4 samples
(located in the left bank, downstream of the dam)

Karange river: 6 samples
(located in the left bank, south of Tharaka village)

10 samples in total

(C) Test pit excavation and sampling for impervious core material (1995)

Test pit (Right bank)

No.	Depth (m)	Sampling (nos.)
TP95-1	2.60	2
TP95-2	1.10	2
TP95-3	1.20	2
TP95-4	1.10	2
TP95-5	1.30	2
TP95-6	1.30	2
TP95-7	1.80	2
TP95-8	1.90	2
TP95-9	0.60	2
TP95-10	1.30	2
Total		20

Test pit (Left bank)

No.	Depth (m)	Sampling (nos)
TP95-11	1.60	2
TP95-12	1.90	2
TP95-13	1.40	2
TP95-14	1.40	2
TP95-15	1.55	2
TP95-16	1.15	2
TP95-17	1.60	2
TP95-18	1.75	2
Total		16

Note
The test pit excavation was done at 18 locations in total. 36 nos. of samples in total were collected from those test pits.

Table C2.4.1 (5) Construction Material Investigation Performed in 1994-1995

(D) Laboratory Test (Grand Falls: 1995)

i) Concrete aggregate and filter materials

Test item	Test quantity (Nos.)
Gradation test (ASTM C138)	10
Specific gravity and absorption test (ASTM C127, C128)	10
NA_2SO_4 durability test (ASTM C88)	10
Los Angeles test (ASTM C131)	10
Alkali aggressive chemical test (ASTM C289)	3

ii) Impervious core materials

Test item	Test quantity (Nos.)
Particle size analysis (ASTM D422)	30
Specific gravity test (ASTM D854)	30
Moisture content (ASTM D2216)	30
Liquid limit test (ASTM D423)	30
Plastic limit test (ASTM D424)	30
Compaction test (ASTM D698)	10
Tri-axial compression test (CU)	5
Permeability test	10

iii) Rock materials

Test item	Test quantity (Nos.)
Specific gravity and absorption test (ASTM C127, C128):	2 samples.
Uni-axial compression test (ASTM D2938-86):	2 samples.
Na2SO4 durability test (ASTM C88):	2 samples.

Sample: Depth between 3.50m and 4.00m in Bore hole No.GQ95-1
Depth between 26.20m and 27.00m in bore hole No.GQ95-1
(GQ95-1; located in the proposed quarry site.)

Table C2.4.2 Results of Test Pit Investigation for Core Materials (Mutonga)

A) Results in the Report of EPDC (1980)

Pit No.	Depth of soil (m)	Total depth(m)
DR1	*	1.60
DR2	1.00	1.80
DR3	0.80	1.20
DR4	2.00	3.00
DR5	1.80	3.00
DR6	1.00	1.50
DR7	1.80	2.00
DR8	1.00	2.50
DR9	1.20	1.50
DR10	1.20	1.30
DR11	1.20	2.50
DR12	1.80	2.30
DR13	2.30	2.40
DR14	1.70	1.95
DR15	1.50	1.90
DR16	1.30	1.80
DR17	1.20	2.00
DR18	1.75	1.90
DR19	1.00	1.90
DR20	0.50	1.35
DR21	1.20	1.45
DR22	0.70	1.30
DR23	1.80	1.90
DR24	0.30	1.00
DR25	1.00	1.50
DR26	1.10	1.85
DR27	1.60	1.60
DR28	2.00	2.15
DR29	1.40	1.50
DR30	0.85	1.00
DR31	1.05	1.30
DR32	0.80	1.05
DR33	0.50	1.60
	40.35	58.60

Right bank borrow area
Total excavation depth 58.60 m
Average thickness of soil 1.22 m

Pit No.	Depth of soil (m)	Total depth(m)
M1	0.80	0.80
M2	0.10	0.50
M3	0.10	2.00
M4	0.40	1.30
M5	0.30	1.80
M6	0.75	1.65
M7	1.70	1.80
M8	0.80	1.60
M9	0.00	0.30
M10	0.40	0.70
M11	1.20	1.50
M12	0.00	1.40
M13	0.80	1.70
M14	0.50	1.15
M15	0.80	1.35
M16	0.50	0.90
M17	0.60	1.05
M18	0.30	1.40
M19	0.10	1.50
M20	0.00	0.50
M21	no-data	
M22	0.10	1.40
M23	0.20	0.70
M24	0.25	0.80
	M25 0.40	1.50
	11.10	29.30

Mutonga/Tana confluence borrow area
Total excavation depth 29.30 m
Average thickness of soil 0.46 m

(B) Results in the Report of UN/World Bank (1987)
Kanjiya Hill borrow area

Pit No.	Depth of soil(m)	Total depth(m)
TP-301	0.80	1.80
TP-302	0.65	2.00
TP-303	0.60	1.50
TP-304	0.60	0.90
TP-305	1.10	1.55
TP-306	0.85	1.20
	4.60	8.95

Total excavation depth 8.95 m
Average thickness of soil 0.76 m

Table C2.4.3 Soil Test Summary Sheet (Mutonga)

	Test Pit Sampling		Gradat.	Specific Gravity	Natural Moisture Content	Atterberg Test		Compaction Test		Tri-axial Test		Permeab.
	Pit No.	Depth(m)	Test	Test	(%)	L.L	P.I	MDD (kg/m3)	OMC (%)	C' (t/m2)	ø' (deg.)	k 10^{-9} cm/s
MC1	TP95-1	0 to 0.3	Yes	2.66	2.9	27	11	1,960	11.8			4.4
	TP95-1	0.3 to 0.4	Yes	2.64	1.1	24	9	2,040	9.3			30.0
	(Mix)							1,970	11.4	0.3	33.5	3.5
	TP95-2	0 to 0.75	Yes	2.67	2.3	N.P						
	TP95-2	0.75 to 0.9	Yes	2.70	1.9	27	13					
	TP95-3	0 to 0.3	Yes	2.62	4.5	21	8					
	TP95-3	0.3 to 0.85	Yes	2.64	3.0	24	11					
MC2	TP95-4	0 to 1.1	Yes	2.60	5.8	28	13					
	TP95-4	1.1 to 1.6	Yes	2.58	6.0	24	7					
	TP95-5	0 to 0.7	Yes	2.57	5.7	33	16					
	TP95-5	0.7 to 1.2	Yes	2.51	5.3	N.P						
	TP95-6	0 to 1.0	Yes	2.60	3.0	27	14	1,900	15.1			3.7
	TP95-6	1.0 to 2.0	Yes	2.55	9.1	28	9	1,920	12.3			5.4
	(Mix)									1.4	30.0	3.5
MC3	TP95-7	0 to 1.0	Yes	2.59	4.1	N.P						
	TP95-7	1.0 to 2.35	Yes	2.54	6.6	29	10					
	TP95-8	0 to 0.3	Yes	2.48	5.6	27	12					
	TP95-8	0.3 to 0.9	Yes	2.57	4.9	N.P						
	TP95-9	0 to 0.6	Yes	2.56	4.6	30	15	1,910	13.0			1.7
	TP95-9	0.6 to 1.2	Yes	2.55	5.3	29	12	1,940	14.2			2.8
	(Mix)							1,870	15.0	1.2	28.5	1.5
	TP95-10	0 to 0.25	Yes	2.67	2.6	23	8					
	TP95-10	0.25 to 0.47	Yes	2.56	10.1	27	9					
	TP95-11	0 to 0.6	Yes	2.57	9.2	34	16					
	TP95-11	0.6 to 0.7	Yes	2.59	7.5	31	14					
	TP95-12	0 to 0.3	Yes	2.63	6.0	32	13					
	TP95-12	0.3 to 0.6	Yes	2.61	7.9	31	14					
	Max.			2.70	10.1	34	16	2,040	15.1	1.4	33.5	30.0
	Min.			2.48	1.1	21	7	1,870	9.3	0.3	28.5	1.5
	Avg.			2.59	5.2	28	12	1,939	12.8	1.0	30.7	6.3

Notes;

- L.L : Liquid Limit
- P.I : Plasticity Index
- MDD : Maximum Dry Density
- OMC : Optimum Moisture Content
- C' : Cohesion in terms of effective stress
- ø' : Internal Friction Angle in terms of effective stress
- k : Coefficient of permeability

Table C2.4.4 Soil Gradation Test Results, Mutonga

Upper Layer (Residual Soil)

	Sampling	(Sieve unit : n								Grading (%, Passing)									
Test Pit No.	Depth (m)	63	50	38	28	20	14	10	6.3	5	4	2	1	0.6	0.5	0.4	0.3	0.2	0.1
MC1, TP95-1	0.0 - 0.3	100	100	100	100	100	100	100	100	99	99	95	90	85	82	78	72	48	41
MC1, TP95-2	0.0 - 0.75	100	100	100	100	100	100	100	100	100	100	99	92	83	79	76	69	49	38
MC1, TP95-3	0.0 - 0.3	100	100	100	100	100	100	100	100	100	100	97	91	86	83	78	72	54	41
MC2, TP95-4	0.0 - 1.1	100	100	100	100	100	100	100	100	100	100	99	95	87	83	79	73	57	50
MC2, TP95-5	0.0 - 0.7	100	100	100	100	100	100	99	98	98	98	95	91	85	82	78	73	54	47
MC2, TP95-6	0.0 - 1.0	100	100	100	100	100	100	100	100	100	100	99	94	87	82	78	72	53	46
MC3, TP95-7	0.0 - 1.0	100	100	100	100	100	100	100	100	100	100	100	95	86	77	71	61	34	30
MC3, TP95-8	0.0 - 0.3	100	100	100	100	100	100	98	97	97	96	93	88	81	77	73	68	59	52
MC3, TP95-9	0.0 - 0.6	100	100	100	100	100	100	100	100	100	100	99	93	86	81	77	72	56	43
MC3, TP95-10	0.0 - 0.25	100	100	100	100	100	100	100	100	100	100	98	93	87	83	77	68	45	33
MC3, TP95-10	0.0 - 0.6	100	100	100	100	100	100	100	100	100	100	98	93	88	86	83	79	69	60
MC3, TP95-10	0.0 - 0.3	100	100	100	100	100	100	100	99	99	99	96	90	85	82	79	73	60	55
	Average	100	100	100	100	100	100	100	100	99	99	97	92	86	81	77	71	53	45

Lower Layer (Gravelly Soil)

	Sampling	(Sieve unit : n								Grading (%, Passing)									
Test Pit No.	Depth (m)	63	50	38	28	20	14	10	6.3	5	4	2	1	0.6	0.5	0.4	0.3	0.2	0.1
MC1, TP95-1	0.3 - 0.4	100	100	99	98	97	96	96	94	93	91	80	69	60	54	50	43	28	22
MC1, TP95-2	0.75 - 0.9	100	100	100	100	99	99	97	94	92	90	76	64	57	54	51	47	39	32
MC1, TP95-3	0.3 - 0.85	100	100	100	99	95	93	91	88	85	81	72	67	62	58	54	50	37	32
MC2, TP95-4	1.1 - 1.6	100	96	89	88	84	83	80	73	70	66	54	48	44	42	40	37	31	25
MC2, TP95-5	0.7 - 1.2	100	100	98	96	94	91	88	81	77	74	63	55	51	48	44	38	27	24
MC2, TP95-6	1.0 - 2.0	100	100	100	100	100	100	100	99	99	98	95	89	84	81	78	69	53	48
MC3, TP95-7	1.0 - 2.35	100	100	100	100	100	100	100	100	100	99	96	90	82	76	73	66	52	44
MC3, TP95-8	0.3 - 0.9	100	100	100	97	97	95	93	88	86	79	65	52	45	40	36	30	18	18
MC3, TP95-9	0.6 - 1.2	100	100	100	100	100	100	99	99	98	97	89	83	79	76	70	66	49	41
MC3, TP95-10	0.25 - 0.47	100	100	100	100	100	100	99	99	98	98	94	88	81	78	75	70	56	47
MC3, TP95-10	0.6 - 0.7	100	100	100	100	100	99	98	97	96	95	93	88	83	78	75	72	61	55
MC3, TP95-10	0.3 - 0.6	100	100	100	99	97	95	95	94	93	93	92	86	81	79	74	69	55	54
	Average	100	100	99	98	97	96	95	92	91	88	81	73	67	64	60	55	42	37

Mixture (Upper 50 % + Lower 50 %)

	Sampling																		
Test Pit No.	Depth (m)	63	50	38	28	20	14	10	6.3	5	4	2	1	0.6	0.5	0.4	0.3	0.2	0.1
MC1, TP95-1	0.0 - 0.4	100	100	100	99	99	98	98	97	96	95	88	80	73	68	64	58	38	32
MC1, TP95-2	0.0 - 0.9	100	100	100	100	100	100	99	97	96	95	88	78	70	67	64	58	44	35
MC1, TP95-3	0.0 - 0.85	100	100	100	100	98	97	96	94	93	91	85	79	74	71	66	61	46	37
MC2, TP95-4	0.0 - 1.6	100	98	95	94	92	92	90	87	85	83	77	72	66	63	60	55	44	38
MC2, TP95-5	0.0 - 1.2	100	100	99	98	97	96	94	90	88	86	79	73	68	65	61	56	41	36
MC2, TP95-6	0.0 - 2.0	100	100	100	100	100	100	100	100	100	100	98	93	84	77	72	64	43	37
MC3, TP95-7	0.0 - 2.35	100	100	100	100	100	100	100	100	100	100	98	93	84	77	72	64	43	37
MC3, TP95-8	0.0 - 0.9	100	100	100	99	99	98	96	93	92	88	79	70	63	59	55	49	39	35
MC3, TP95-9	0.0 - 1.2	100	100	100	100	100	100	100	100	99	99	94	88	83	79	74	69	53	42
MC3, TP95-10	0.0 - 0.47	100	100	100	100	100	100	100	100	99	99	96	91	84	81	76	69	51	40
MC3, TP95-10	0.0 - 0.7	100	100	100	100	100	100	99	99	98	98	96	91	86	82	79	76	65	58
MC3, TP95-10	0.0 - 0.6	100	100	100	100	99	98	98	97	96	96	94	88	83	81	77	71	58	55
	Average	100	100	99	99	98	98	97	96	95	94	89	83	76	73	69	63	48	41

Table C2.4.5 Results of Test Pit Investigation for Filter Materials (Mutonga)

(A) Results in the Report of EPDC (1980)

i) Mur war wanda (Lct bank, upstream of dam)

Pit No.	Depth of sand(m)	Total depth(m)
MSL1	0.85	0.85
MSL2	1.20	1.20
MSL3	1.30	1.50
MSL4	1.30	1.50
MSL5	1.20	1.20
MSL6	0.80	0.80
MSL7	0.85	0.85
MSL8	0.45	0.45
Total excavation depth		8.35 m
Average thickness of sand		0.99 m

ii) Mukindu (Right bank, downstream of dam)

Pit No.	Depth of sand(m)	Total depth(m)
MSR1	1.50	1.50
MSR2	1.60	1.60
MSR3	1.30	1.30
MSR4	1.00	1.00
MSR5	0.40	0.40
MSR6	1.10	1.10
Total excavation depth		6.90 m
Average thickness of sand		1.15 m

iii) Tana river (Dam site)

Pit No.	Depth of soil(m)	Total depth(m)
MST1	1.70	1.70
MST2	1.30	1.30
MST3	1.60	1.60
Total excavation depth		4.60 m
Average thickness of sand		1.53 m

(B) Results in the Report of UN/World Bank (1987)

i) Mukindu (Right bank, down stream of dam)

Pit No.	Depth of sand(m)	Total depth(m)
TP-101	0.50	0.50
TP-102	0.50	0.50
Total excavation depth		1.00 m
Average thickness of sand		0.50 m

ii) Kamonyoni (Right b. downst. of Mukindu)

Pit No.	Depth of sand(m)	Total depth(m)
TP-201	1.40	1.80

Note

Excavation was stopped at the depths because of water seepage in TP-101 & 102.

Table C2.4.6 Concrete Material Test Summary Sheet, Mutonga

	Sampling		Gradat.	Specific Gravity Test		Absorp. Test	Na2SO4 Durability Test		Alkali Chem.	Strength
	Log No.	Depth(m)	Test	SSD	APP	(%)	+No.4	-No.4	Test	(kg/cm2)
Boring Core										
	MQ95-1	7.5 to 7.8		2.64	2.66	0.5	1.3	3.0		1,220
	MQ95-1	8.5 to 9.0		2.79	2.84	1.1	3.1	7.3		345
	MQ95-1	15.0 to 16.5								
	MQ95-1	16.5 to 18.0								
	MQ95-1	20.0 to 20.7		2.78	2.80	0.7	2.0	6.3		553
	MQ95-1	21.2 to 22.3								
	MQ95-1	23.0 to 24.0		2.60	2.63	0.6	1.9	2.4		766
	MQ95-1	25.5 to 27.0								
	M95-3	4.9 to 5.4		2.77	2.81	0.9				297
	M95-3	21.8 to 22.5		2.94	2.98	0.6				954
	M95-4	9.8 to 10.3		2.76	2.79	0.5				487
	Max.			2.94	2.98	1.1	3.1	7.3		1,220
	Min.			2.60	2.63	0.5	1.3	2.4		297
	Avg.			2.75	2.79	0.7	2.1	4.8		660
River Sand/Gravel										
MS1			Yes	2.69	2.71	0.4		4.4		
MS2			Yes	2.70	2.71	0.3		4.6		
MS3			Yes	2.77	2.79	0.3		5.2		
MS4	500 m		Yes	2.69	2.70	0.3		5.0		
MS5	1,000 m		Yes	2.89	2.90	0.1		3.6	Yes	
MS6	200 m		Yes	2.95	3.00	0.8		5.5	Yes	
MS7	750 m		Yes	2.69	2.70	0.2		7.4	Yes	
MS8	250 m		Yes	2.70	2.71	0.3		4.7	Yes	
MS8	250 m		Yes	2.80	2.83	0.6		5.6	Yes	
MS10	750 m		Yes	2.74	2.75	0.2		3.6	Yes	
	Max.			2.95	3.00	0.8		7.4		
	Min.			2.69	2.70	0.1		3.6		
	Avg.			2.76	2.78	0.4		5.0		

Table C2.4.7 River Sand Gradation Test Results, Mutonga

Sampled Material

River Name	Pit No.	50	37.5	20	10	5	2.36	1.18	0.6	0.3	0.15
Mukind	MS-1	100	100	99	97	95	89	69	42	12	2
	MS-2	100	100	99	98	96	91	76	42	9	2
	MS-3	100	100	97	94	92	83	60	28	5	1
Kamonyoni	MS-4	100	100	85	77	72	65	51	28	8	1
	MS-5	100	100	100	99	98	96	85	50	12	2
	MS-6	100	100	99	98	95	90	76	43	11	1
Konyu	MS-7	100	100	98	97	96	93	80	54	18	5
	MS-8	100	100	100	99	97	94	75	44	13	3
	MS-9	100	100	100	100	99	95	77	42	11	2
	MS-10	100	100	100	100	99	95	73	38	13	3

After Cutting Particles Over 10 mm

River Name	Pit No.	50	37.5	20	10	5	2.36	1.18	0.6	0.3	0.15
Mukind	MS-1				100	98	92	71	43	12	2
	MS-2				100	98	93	78	43	9	2
	MS-3				100	98	88	64	30	5	1
Kamonyoni	MS-4				100	94	84	66	36	10	1
	MS-5				100	99	97	86	51	12	2
	MS-6				100	97	92	78	44	11	1
Konyu	MS-7				100	99	96	82	56	19	5
	MS-8				100	98	95	76	44	13	3
	MS-9				100	99	95	77	42	11	2
	MS-10				100	99	95	73	38	13	3
Lower Limit					100	90	80	50	25	10	2
Upper Limit					100	100	100	90	65	35	10

Table C2.4.8 Results of Test Pit Investigation for Impervious Core Materials (Grand Falls)

Results of UN/World Bank, 1987

i) Right bank borrow area, upstream of dam

Pit No.	Depth of soil(m)	Total depth(m)
TP-101	1.22	1.70
TP-102	0.55	2.00
TP-103	1.00	1.60
TP-104	1.15	1.80
TP-105	1.23	1.90
Total excavation depth		9.00 m
Average thickness of soil		1.03 m

ii) Right bank borrow area, downstream of dam

Pit No.	Depth of soil(m)	Total depth(m)
TP-201	0.23	1.80
TP-202	1.00	1.90
TP-203	0.60	1.20
TP-204	0.25	2.00
Total excavation depth		6.90 m
Average thickness of soil		0.52 m

iii) Left bank borrow area, downstream of dam

Pit No.	Depth of soil(m)	Total depth(m)
TP-301	1.15	2.20
TP-302	0.35	1.20
TP-303	0.70	0.70
TP-304	1.05	1.40
TP-305	1.00	1.90
TP-306	0.55	2.00
Total excavation depth		9.40 m
Average thickness of soil		0.80 m

iv) Left bank borrow area, upstream of dam

Pit No.	Depth of soil(m)	Total depth(m)
TP-401	0.50	1.80
TP-402	0.75	1.10
TP-403	0.40	2.00
TP-404	0.40	2.00
TP-405	0.55	1.80
Total excavation depth		8.70 m
Average thickness of soil		0.52 m

Table C2.4.9 Results of Test Pit Investigation for Impervious Core Materials Performed in 1994 (Grand Falls)

i) Right bank borrow area, upstream of dam

Pit No.	Depth of soil(m)	Total depth(m)
TP94-1	1.60	2.60
TP94-2	0.70	1.10
TP94-3	1.00	1.20
TP94-4	0.90	1.10
TP94-5	0.70	1.30
TP94-6	0.30	1.30
TP94-7	0.90	1.80
TP94-8	1.10	1.90
TP94-9	0.50	0.60
TP94-10	0.95	1.30
TP94-21	0.90	1.40
TP94-22	0.90	1.40
TP94-23	0.60	1.40
TP94-24	1.10	1.10
TP94-25	0.70	1.30
TP94-26	1.60	1.60
TP94-27	1.50	1.70
TP94-28	1.00	1.25
TP94-29	0.70	1.05
TP94-30	0.70	0.70
TP94-31	0.90	1.10
TP94-32	0.80	0.80
AB94-1	0.60	0.60
AB94-2	0.60	0.60
AB94-3	0.50	0.50
AB94-4	0.80	1.00
AB94-5	1.00	1.40
AB94-6	0.60	0.60
AB94-7	0.60	0.60
AB94-8	0.60	1.20
AB94-9	1.20	1.20
AB94-10		*
AB94-11		*
AB94-12	0.60	0.60
AB94-13	0.45	0.45
AB94-14	0.70	0.70
AB94-15		*
Total excavation depth		38.45 m
Average thickness of soil		0.83 m

ii) Left bank borrow area, upstream of dam

Pit No.	Depth of soil(m)	Total depth(m)
TP94-11	0.60	1.60
TP94-12	1.90	1.90
TP94-13	0.60	1.40
TP94-14	0.90	1.40
TP94-15	1.55	1.55
TP94-16	0.70	1.15
TP94-17	1.30	1.60
TP94-18	0.70	1.75
TP94-19	0.70	1.60
TP94-20	1.10	1.90
TP94-33	1.60	2.00
TP94-34	0.40	0.80
TP94-35	1.20	1.70
TP94-36	1.10	1.50
TP94-37	0.80	1.90
TP94-38	1.30	1.40
TP94-39	0.70	1.30
TP94-40	0.90	1.50
TP94-41	0.70	1.20
TP94-42	0.70	1.20
TP94-43	1.80	1.80
TP94-44	1.70	2.10
AB94-16	1.60	2.30
AB94-17	0.90	1.90
AB94-18	1.00	2.40
AB94-19	0.90	1.80
AB94-20		*
AB94-21	0.90	1.50
AB94-22	1.00	1.00
AB94-23	0.90	1.80
AB94-24	0.40	1.40
AB94-25	0.80	1.40
AB94-26	0.90	1.90
AB94-27	1.20	1.80
AB94-28	0.75	1.30
AB94-29	0.70	1.10
AB94-30	1.40	1.40
Total excavation depth		57.25 m
Average thickness of soil		1.01 m

Note
Depth of soil includes gravely layers.

Table C2.4.10 Soil Test Summary Sheet (Grand Falls)

	Test Pit Sampling		Gradat.	Specific Gravity	Natural Moisture Content	Atterberg Test		Compaction Test		Tri-axial Test		Permeab.
	Pit No.	Depth(m)	Test	Test	(%)	L.L	P.I	MDD (kg/m3)	OMC (%)	C' (t/m2)	φ' (deg.)	k_{10} cm/s
Grand Falls Dam Site												
GC1	TP95-1	0 to 0.8	Yes	2.73	4.9	25	9					
	TP95-1	0.8 to 1.6	Yes	2.68	4.9	28	10					
	TP95-2	0 to 0.5	Yes	2.64	5.0	30	15	1,890	13.0	0.7	28.5	1.1
	TP95-2	0.5 to 1.1	Yes	2.70	2.9	25	8	2,070	11.2	0.9	35.0	1.2
	(Mix)							2,000	11.8	0.0	33.0	1.2
	TP95-3	0 to 0.4	Yes	2.65	4.2	25	12					
	TP95-3	0.4 to 1.5	Yes	2.62	3.3	NP						
	TP95-4	0 to 0.3	Yes	2.55	4.7	31	17					
	TP95-4	0.3 to 0.6	Yes	2.53	2.0	35	13					
	TP95-5	0 to 0.3	Yes	2.55	3.1	30	15					
	TP95-5	0.3 to 0.7	Yes	2.57	2.8	34	14					
	TP95-6	0 to 0.2	Yes	2.57	4.0	31	12					
	TP95-6	0.2 to 0.5	Yes	2.58	2.9	31	18					
GC2	TP95-7	0 to 0.35	Yes	2.56	2.1	27	11					
	TP95-7	0.35 to 0.8	Yes	2.58	3.7	28	11					
	TP95-8	0 to 0.5	Yes	2.60	6.0	31	16					
	TP95-8	0.5 to 1.15	Yes	2.57	3.7	27	12					
	TP95-9	0 to 0.25	Yes	2.61	4.0	29	15					
	TP95-9	0.25 to 0.65	Yes	2.66	3.0	24	11					
	TP95-10	0 to 0.25	Yes	2.66	4.2	25	12	2,000	10.8			2.8
	TP95-10	0.25 to 0.5	Yes	2.66	2.5	29	12	2,040	10.2			2.8
	(Mix)							1,940	13.0			2.6
GC3	TP95-11	0 to 0.6	Yes	2.68	3.4	29	14					
	TP95-11	0.6 to 1.2	Yes	2.76	1.3	NP						
	TP95-12	0 to 0.55	Yes	2.70	2.2	24	10					
	TP95-12	0.55 to 1.3	Yes	2.65	1.3	NP						
	TP95-13	0 to 0.85	Yes	2.65	3.2	34	16					
	TP95-13	0.85 to 1.7	Yes	2.64	1.8	NP						
	TP95-14	0 to 0.4	Yes	2.60	3.5	31	15	2,020	12.5	0.7	26.5	1.6
	TP95-14	0.4 to 0.8	Yes	2.61	0.5	29	14	1,900	13.7	0.0	35.0	32.0
	(Mix)							2,110	10.2	0.9	27.0	2.9
	TP95-15	0 to 0.4	Yes	2.60	2.8	26	11					
	TP95-15	0.4 to 0.85	Yes	2.57	1.7	29	15					
GC4	TP95-16	0 to 0.55	Yes	2.59	5.0	31	16	1,860	15.8			2.0
	TP95-16	0.55 to 1.3	Yes	2.56	4.1	31	14	2,090	11.0			30.0
	(Mix)							1,960	12.1			1.6
	TP95-17	0 to 0.3	Yes	2.68	2.3	NP						
	TP95-17	0.3 to 0.5			4.0	NP						
	TP95-18	0 to 0.9	Yes	2.59	3.8	31	16					
	TP95-18	0.9 to 1.7	Yes	2.66	4.1	NP						
	Max.			2.76	6.0	35	18	2,110	15.8	0.9	35.0	32.0
	Min.			2.53	0.5	24	8	1,860	10.2	0.0	26.5	1.1
	Avg.			2.62	3.3	29	13	1,990	12.1	0.5	30.8	6.8

Notes;

L.L : Liquid Limit
P.I : Plasticity Index
MDD : Maximum Dry Density
OMC : Optimum Moisture Content
C' : Cohesion in terms of effective stress
φ' : Internal Friction Angle in terms of effective stress
k : Coefficient of permeability

Table C2.4.11 Soil Gradation Test Results, Grand Falls

Upper Layer (Residual Soil)

	Sampling (Sieve unit : mi	Grading (%, Passing)																	
Test Pit No.	Depth (m	63	50	38	28	20	14	10	6.3	5	4	2	1	0.6	0.5	0.4	0.3	0.2	0.1
GC1, TP95-1	0.0 - 0.8	100	100	100	100	100	100	100	100	100	100	99	93	84	80	73	65	42	33
GC1, TP95-2	0.0 - 0.5	100	100	100	100	100	100	100	100	99	99	96	88	82	80	76	71	57	51
GC1, TP95-3	0.0 - 0.4	100	100	100	100	100	100	99	99	99	98	95	88	82	80	74	69	52	42
GC1, TP95-4	0.0 - 0.3	100	100	100	100	100	100	99	99	99	98	93	84	77	75	71	66	52	46
GC1, TP95-5	0.0 - 0.3	100	100	100	100	99	99	99	98	98	98	95	89	84	82	79	75	62	58
GC1, TP95-6	0.0 - 0.2	100	100	100	99	98	96	93	86	83	78	65	56	51	49	46	42	32	28
GC2, TP95-7	0.0 - 0.35	100	100	96	94	90	83	76	64	58	53	44	40	38	37	35	33	26	22
GC2, TP95-8	0.0 - 0.5	100	100	100	100	100	100	100	99	99	99	97	93	88	86	82	78	62	54
GC2, TP95-9	0.0 - 0.25	100	100	100	100	100	100	98	95	93	91	84	78	73	71	69	65	45	45
GC2, TP95-1	0.0 - 0.25	100	100	100	100	99	97	96	94	93	93	91	86	80	77	72	65	51	48
GC3, TP95-1	0.0 - 0.6	100	96	87	78	71	63	56	48	45	42	37	35	32	31	29	27	21	17
GC3, TP95-1	0.0 - 0.55	100	100	100	98	94	93	92	90	89	88	82	75	66	62	57	52	44	29
GC3, TP95-1	0.0 - 0.85	100	100	100	97	93	87	78	68	64	59	54	49	45	43	41	39	34	31
GC3, TP95-1	0.0 - 0.4	100	100	100	100	100	100	100	100	100	100	98	93	88	87	83	79	65	55
GC3, TP95-1	0.0 - 0.4	100	100	100	100	100	100	100	100	99	99	97	91	84	81	77	70	48	37
GC3, TP95-1	0.0 - 0.55	100	100	100	100	100	100	100	100	100	100	98	92	87	85	81	76	68	58
GC3, TP95-1	0.0 - 0.3	100	100	100	100	99	97	95	93	92	91	87	81	74	71	67	60	40	26
GC3, TP95-1	0.0 - 0.9	100	100	100	100	100	100	100	99	99	98	95	90	83	79	75	69	52	44
	Average	100	100	99	98	97	95	93	91	89	88	84	78	72	70	66	61	47	40

Lower Layer (Gravelly Soil)

	Sampling (Sieve unit : mi	Grading (%, Passing)																	
Test Pit No.	Depth (m	63	50	38	28	20	14	10	6.3	5	4	2	1	0.6	0.5	0.4	0.3	0.2	0.1
GC1, TP95-1	0.8 -1.60	100	100	98	96	94	91	86	79	71	59	52	47	44	43	38	34	26	22
GC1, TP95-2	0.5 - 1.10	100	100	100	99	97	96	95	90	88	85	75	63	53	49	45	39	28	22
GC1, TP95-3	0.4 - 1.50	100	100	100	100	99	98	97	96	95	93	87	80	73	68	61	54	33	27
GC1, TP95-4	0.3 - 0.6	100	100	97	90	85	79	74	64	60	56	47	41	40	38	36	34	28	26
GC1, TP95-5	0.3 - 0.7	100	100	100	95	87	81	76	69	66	61	50	43	40	39	38	36	32	30
GC1, TP95-6	0.2 - 0.5	100	100	100	100	98	95	91	83	79	74	64	56	50	46	41	37	29	25
GC2, TP95-7	0.35 - 0.8	100	100	100	94	89	81	73	62	57	52	42	37	34	33	31	29	24	19
GC2, TP95-8	0.5 - 1.15	100	100	95	92	89	85	82	78	76	74	65	57	52	49	47	43	34	29
GC2, TP95-9	0.25 - 0.6	100	100	100	100	98	97	94	90	87	84	75	68	63	58	55	50	39	31
GC2, TP95-1	0.25 - 0.5	100	100	94	88	81	75	71	65	62	58	51	46	42	40	38	35	27	23
GC3, TP95-1	0.6 - 1.2	100	100	100	100	99	99	99	98	97	97	96	91	81	74	68	56	38	24
GC3, TP95-1	0.55 - 1.3	100	100	100	100	100	99	98	97	97	96	93	82	65	58	51	41	23	17
GC3, TP95-1	0.85 - 1.7	100	100	100	100	99	97	97	95	94	92	84	73	57	51	44	34	17	12
GC3, TP95-1	0.4 - 0.8	100	100	96	91	83	76	68	57	54	50	41	36	34	33	32	30	24	20
GC3, TP95-1	0.4 - 0.85	100	96	83	79	75	69	64	58	55	53	48	44	41	39	37	34	25	21
GC3, TP95-1	0.55 - 1.3	100	100	89	88	82	78	73	65	61	56	48	42	38	37	35	33	28	25
GC3, TP95-1	0.9 - 1.7	100	100	96	90	87	84	81	79	78	76	72	65	55	48	42	33	21	17
	Average	100	100	97	94	91	87	83	78	75	72	64	57	51	47	43	38	28	23

Mixture (Upper 50 % + Lower 50 %)

	Sampling																		
Test Pit No.	Depth (m	63	50	38	28	20	14	10	6.3	5	4	2	1	0.6	0.5	0.4	0.3	0.2	0.1
GC1, TP95-1	0.0 - 1.6	100	100	99	98	97	96	93	90	86	80	76	70	64	62	56	50	34	28
GC1, TP95-2	0.0 - 1.1	100	100	100	100	99	98	98	95	94	92	86	76	68	65	61	55	43	37
GC1, TP95-3	0.0 - 1.5	100	100	100	100	100	99	98	98	97	96	91	84	78	74	68	62	43	35
GC1, TP95-4	0.0 - 0.6	100	100	99	95	93	90	87	82	80	77	70	63	59	57	54	50	40	36
GC1, TP95-5	0.0 - 0.7	100	100	100	98	93	90	88	84	82	80	73	66	62	61	59	56	47	44
GC1, TP95-6	0.0 - 0.5	100	100	100	100	98	96	92	85	81	76	65	56	51	48	44	40	31	27
GC2, TP95-7	0.0 - 0.8	100	100	98	94	90	82	75	63	58	53	43	39	36	35	33	31	25	21
GC2, TP95-8	0.0 - 1.15	100	100	98	96	95	93	91	89	88	87	81	75	70	68	65	61	48	42
GC2, TP95-9	0.0 - 0.65	100	100	100	100	99	99	96	93	90	88	80	73	68	65	62	58	42	38
GC2, TP95-1	0.0 - 0.5	100	100	97	94	90	86	84	80	78	76	71	66	61	59	55	50	39	36
GC3, TP95-1	0.0 - 1.2	100	98	94	89	85	81	78	73	71	70	67	63	57	53	49	42	30	21
GC3, TP95-1	0.0 - 1.3	100	100	100	99	97	96	95	94	93	92	88	79	66	60	54	47	34	23
GC3, TP95-1	0.0 - 1.7	100	100	100	99	96	92	88	82	79	76	69	61	51	47	43	37	26	22
GC3, TP95-1	0.0 - 0.8	100	100	98	96	92	88	84	79	77	75	70	65	61	60	58	55	45	38
GC3, TP95-1	0.0 - 0.85	100	98	92	90	88	85	82	79	77	76	73	68	63	60	57	52	37	29
GC3, TP95-1	0.0 - 1.3	100	100	95	94	91	89	87	83	81	78	73	67	63	61	58	55	48	42
GC3, TP95-1	0.0 - 0.3	100	100	100	100	99	97	95	93	92	91	87	81	74	71	67	60	40	26
GC3, TP95-1	0.0 - 1.7	100	100	98	95	94	92	91	89	89	87	84	78	69	64	59	51	37	31
	Average	100	100	98	96	94	91	89	85	83	80	75	68	62	59	55	50	38	32

Table C2.4.12 Results of Test Pit Investigation for Filter Materials (Grand Falls)

(A) Results in the Report of UN/World Bank (1987)

Right bank, downstream of dam

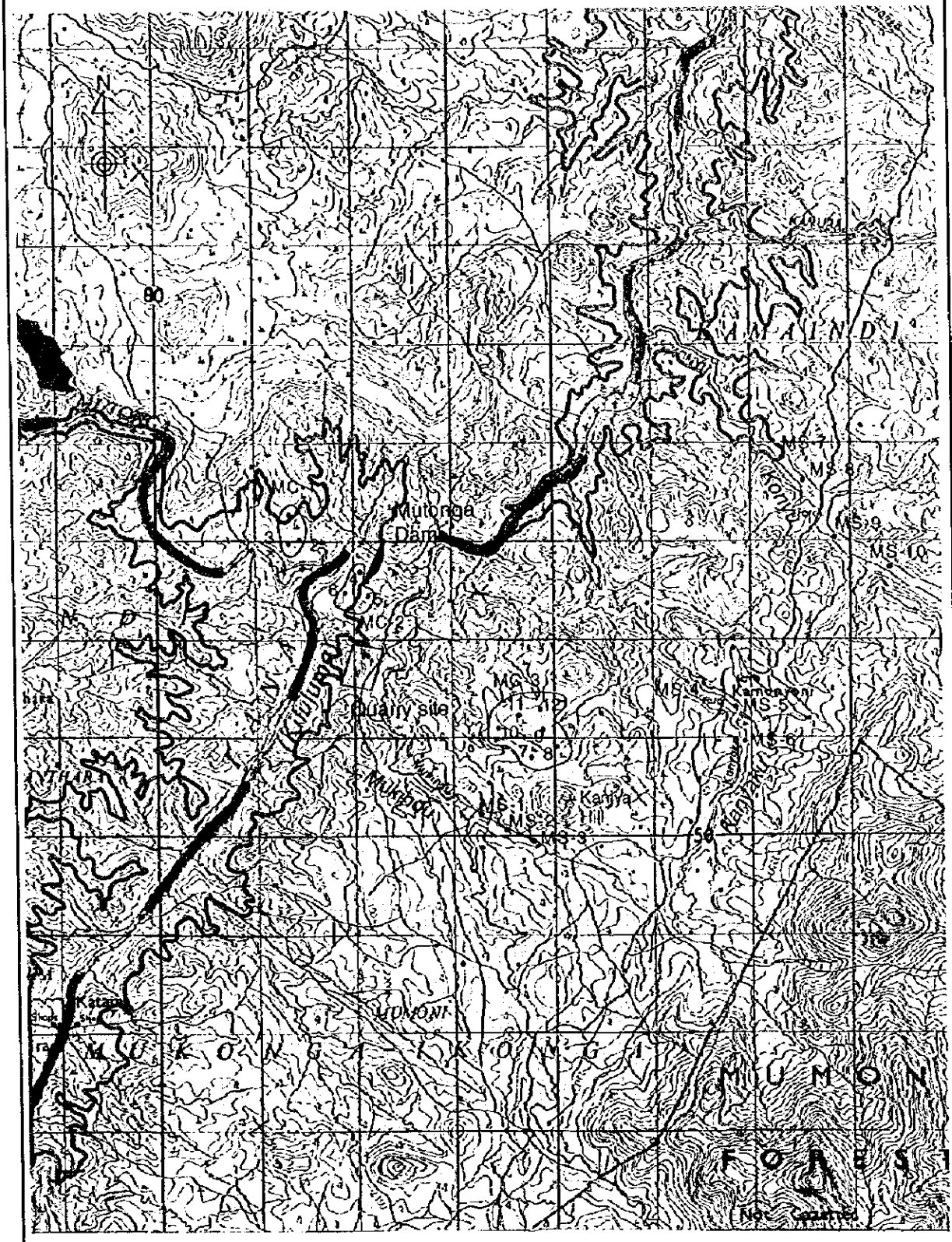
Pit No.	Depth of sand(m)	Total depth(m)
TP-501	0.80	0.80
TP-502	0.70	0.70
TP-503	0.60	0.60
TP-601	0.40	0.40 (Location is not clear)

Note

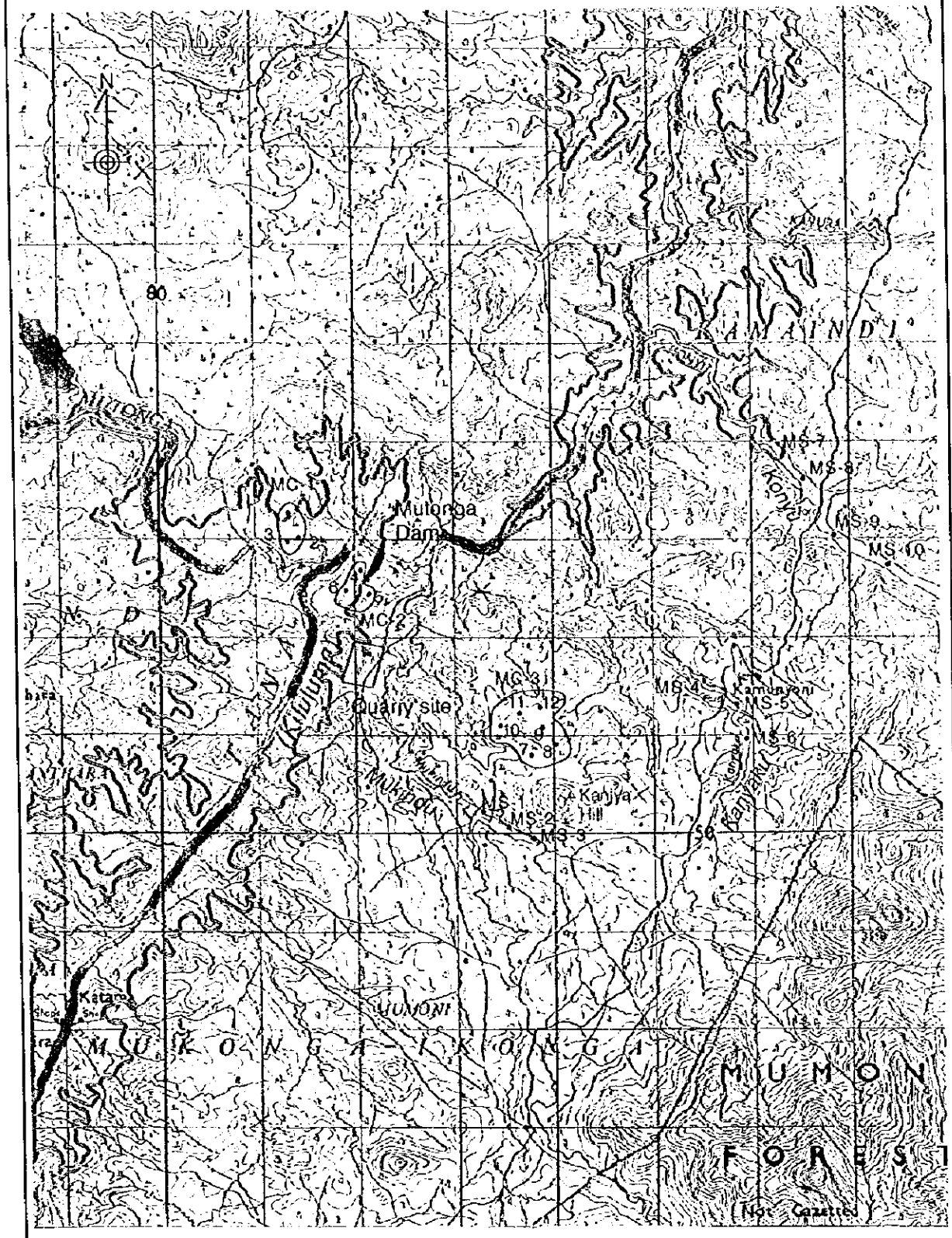
Excavation was stopped at the above depths because of water seepage for all the pits).

Table C2.4.13 Concrete Material Test Summary Sheet (Grand Falls)

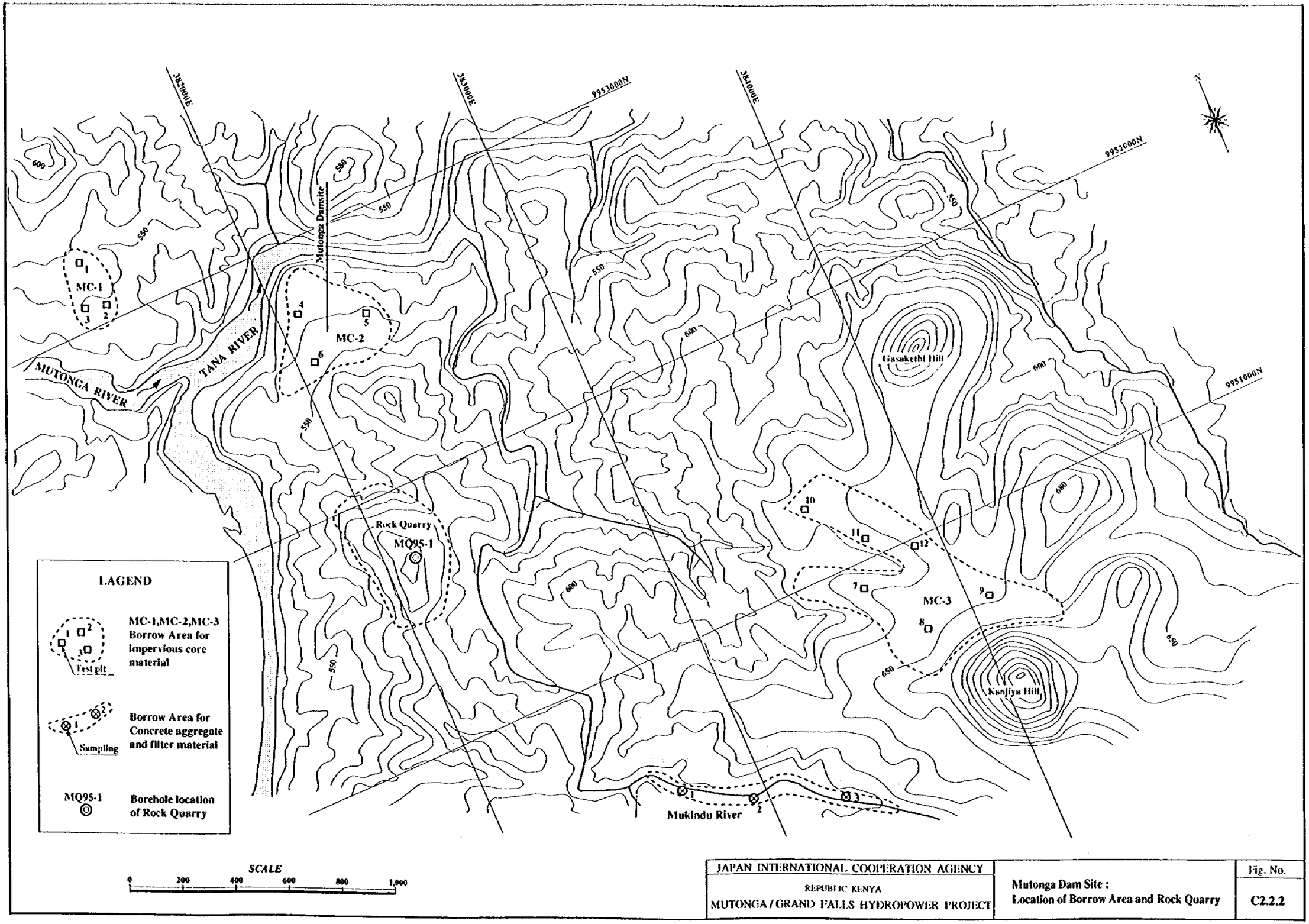
	Sampling Log No.	Depth(m)	Gradat. Test	Specific Gravity Test SSD	APP	Absorp. Test (%)	Na2SO4 Durability Test +No.4	-No.4	Alkali Chem. Test	Strength (kg/cm2)
Boring Core										
	GQ95-1	3.5 to 4.0		2.60	2.65	1.2	5.4	8.0		82
	GQ95-1	26.5 to 27.0		2.65	2.68	0.6	1.7	5.5		649
	G95-8	10.7 to 11.0		2.94	2.98	0.6				441
	G95-8	18.6 to 19.1		2.83	2.87	0.7				913
	G95-10	14.2 to 14.5		2.64	2.67	0.7				683
	M95-3	4.9 to 5.4		2.77	2.81	0.9				297
	M95-3	21.8 to 22.5		2.94	2.98	0.6				954
	M95-4	9.8 to 10.3		2.76	2.79	0.5				487
	Max.			2.94	2.98	1.2	5.4	8.0		954
	Min.			2.60	2.65	0.5	1.7	5.5		82
	Avg.			2.77	2.80	0.7	3.6	6.8		563
River Sand/Gravel										
GS1	100 m, Gravel		Yes	2.69	2.70	0.2	15.8	4.8	Yes	
	500 m, Sand		Yes	2.70	2.71	0.3		4.5	Yes	
	1,000 m, Sand		Yes	2.70	2.71	0.3		4.4	Yes	
	1,500 m, Sand		Yes	2.72	2.76	0.8		4.8	Yes	
GS2	0 m, Sand		Yes	2.69	2.70	0.2		2.7	Yes	
	800 m, Gravel		Yes	2.60	2.64	1.1	5.5	4.2	Yes	
	1,500 m, Sand		Yes	2.69	2.70	0.3		4.3	Yes	
	10 m, Sand		Yes	2.67	2.68	0.3		2.9	Yes	
	700 m, Gravel		Yes	2.73	2.76	0.5	2.7	4.2		
	1,500 m, Sand		Yes	2.73	2.74	0.2		3.9	Yes	
	Max.			2.73	2.76	1.1	15.8	4.8		
	Min.			2.60	2.64	0.2	2.7	2.7		
	Avg.			2.69	2.71	0.4	8.0	4.1		



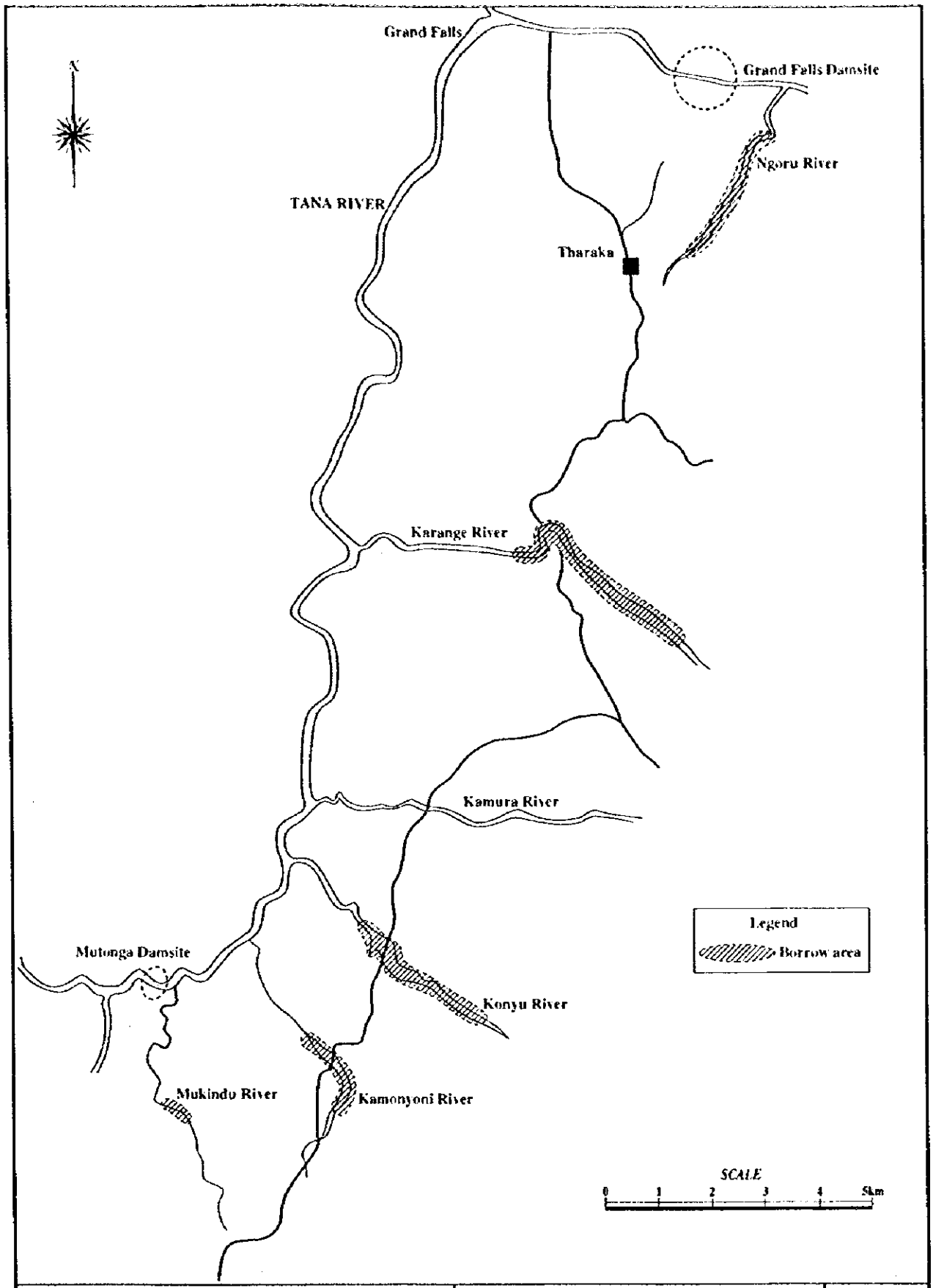
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Mutonga Dam Site : Location of Borrow Area and Quarry Site	Fig. No. C2.2.1



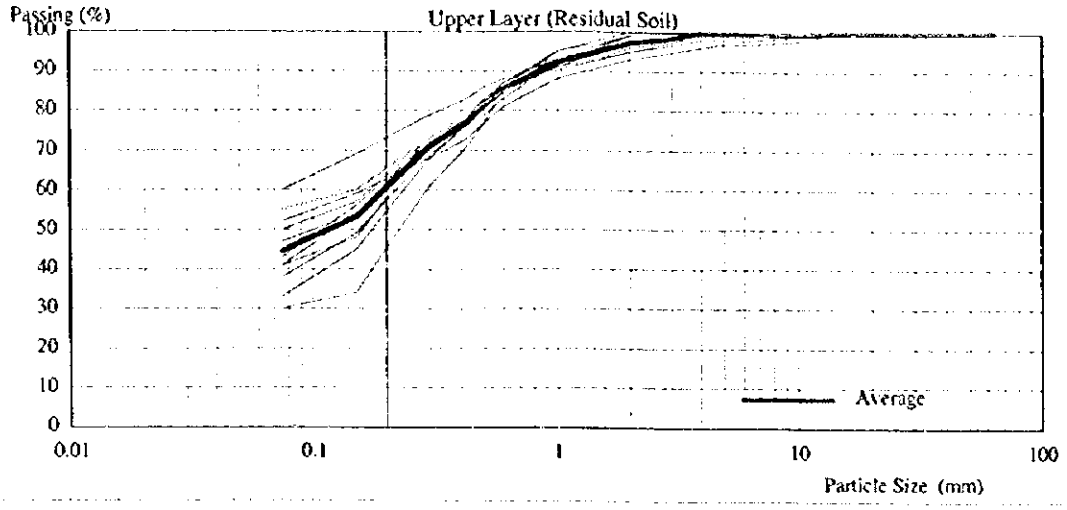
JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Mutonga Dam Site : Location of Borrow Area and Quarry Site	Fig. No. C2.2.1

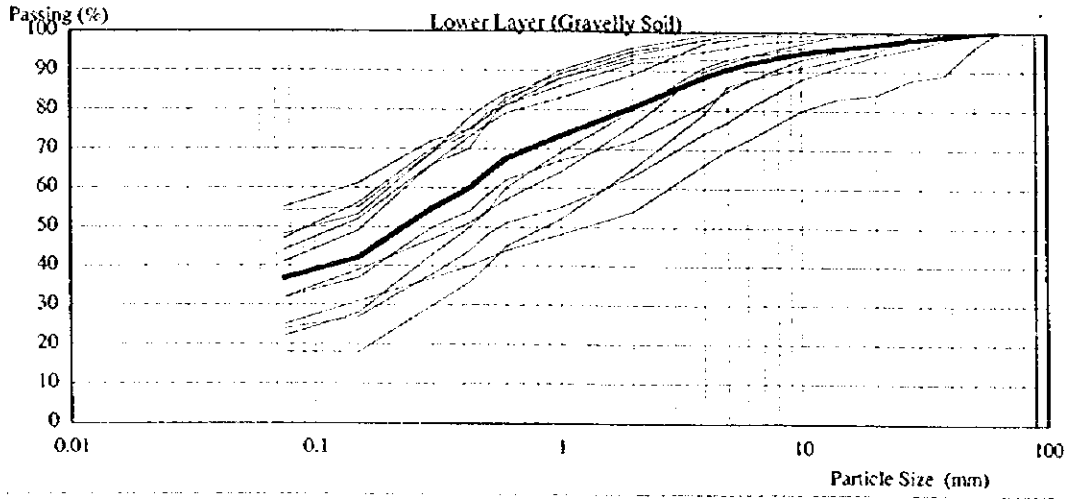


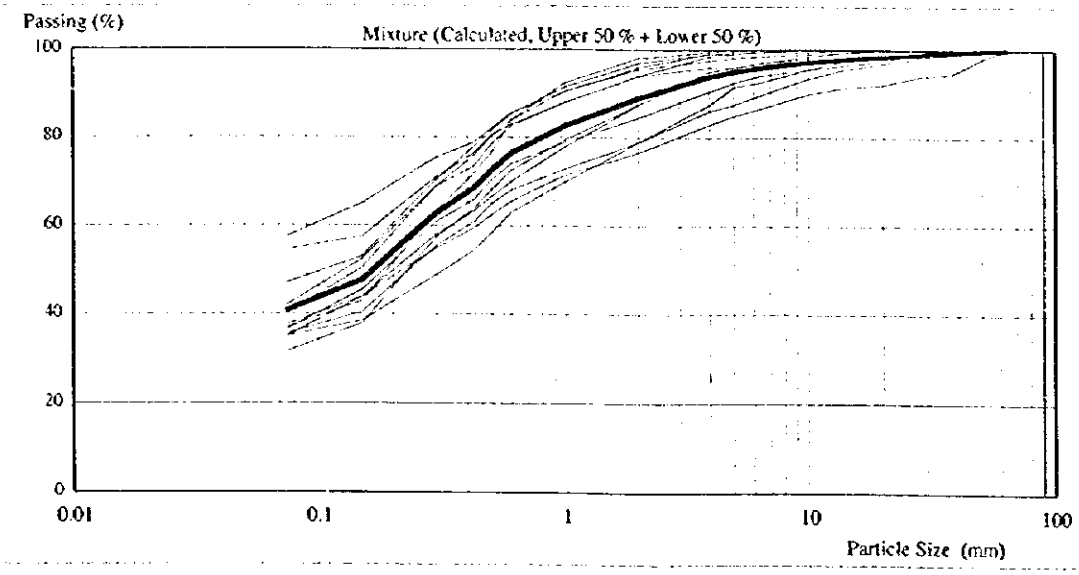
JAPAN INTERNATIONAL COOPERATION AGENCY		Fig. No.
REPUBLIC KENYA MUTONGA / GRAND FALLS HYDROPOWER PROJECT	Mutonga Dam Site : Location of Borrow Area and Rock Quarry	C2.2.2



JAPAN INTERNATIONAL COOPERATION AGENCY		Fig. No.
REPUBLIC KENYA MUTONGA / GRAND FALLS HYDROPOWER PROJECT	**Location Map of Borrow Area for the Concrete Aggregate and Filter Material**	**C2.2.3**

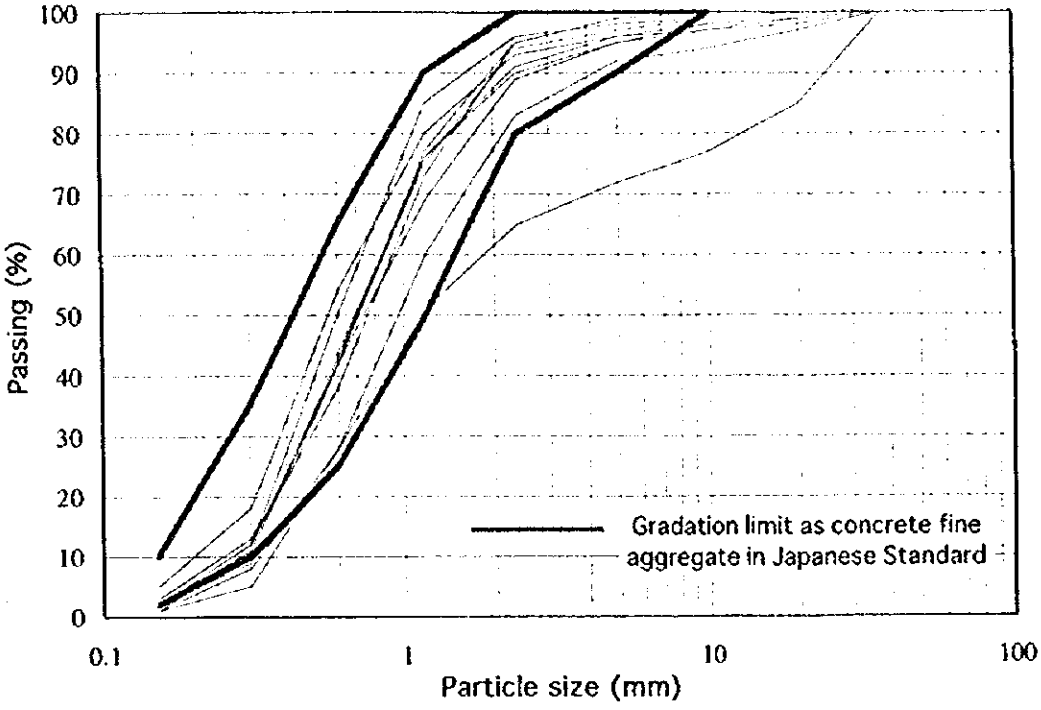




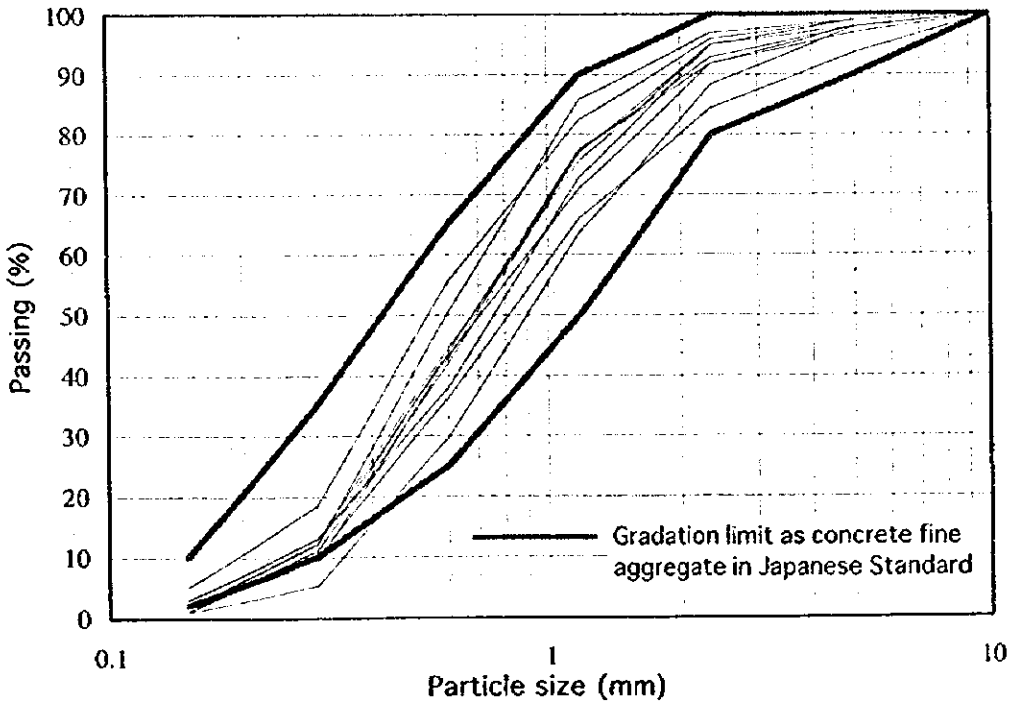


JAPAN INTERNATIONAL COOPERATION AGENCY	Representative Soil Gradation Curve (Mutonga)	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		C2.2.4

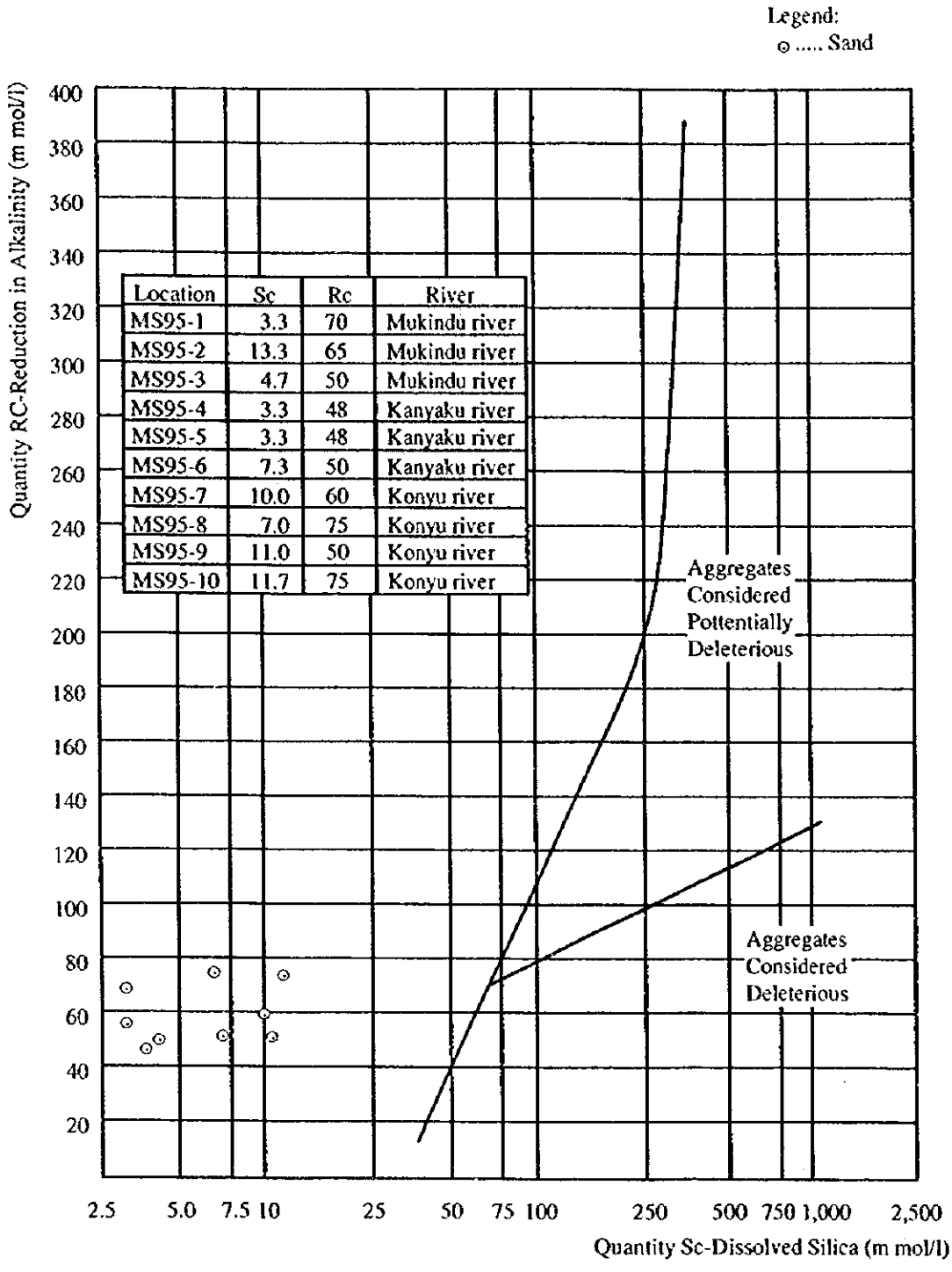
Sampled Material



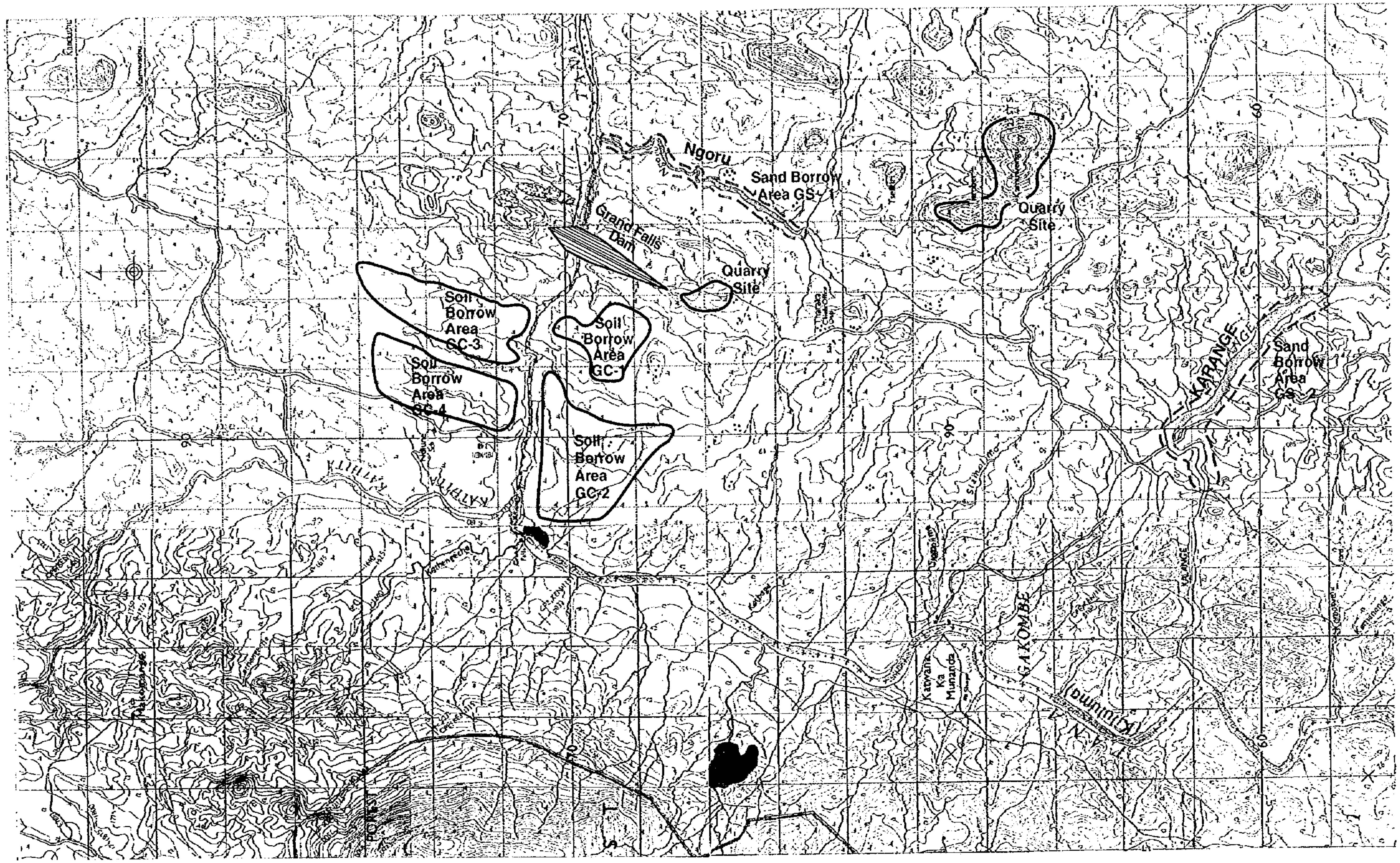
After Cutting Particles over 10 mm



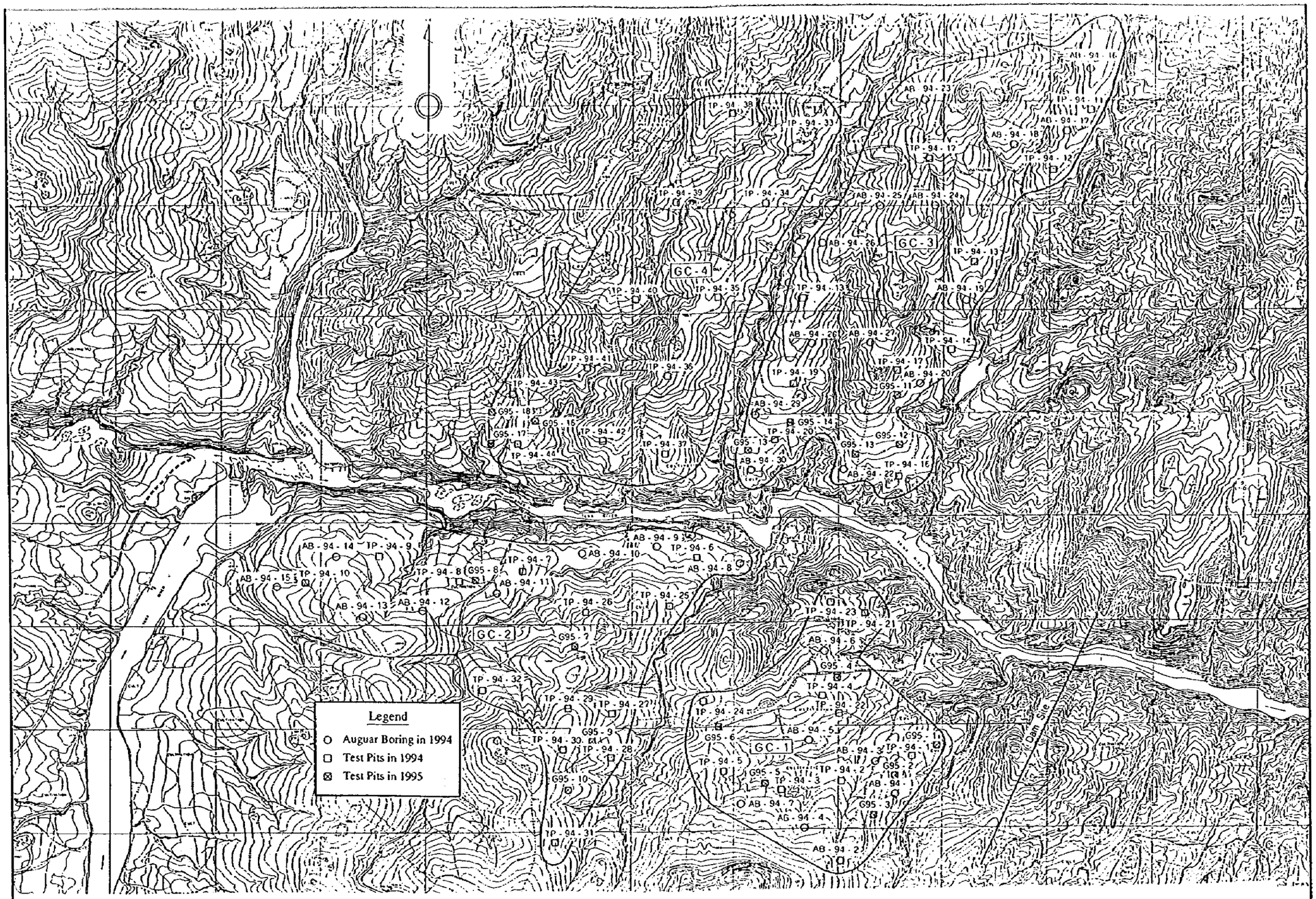
JAPAN INTERNATIONAL COOPERATION AGENCY	Sand Gradation Curve (Mutonga)	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		C2.2.5



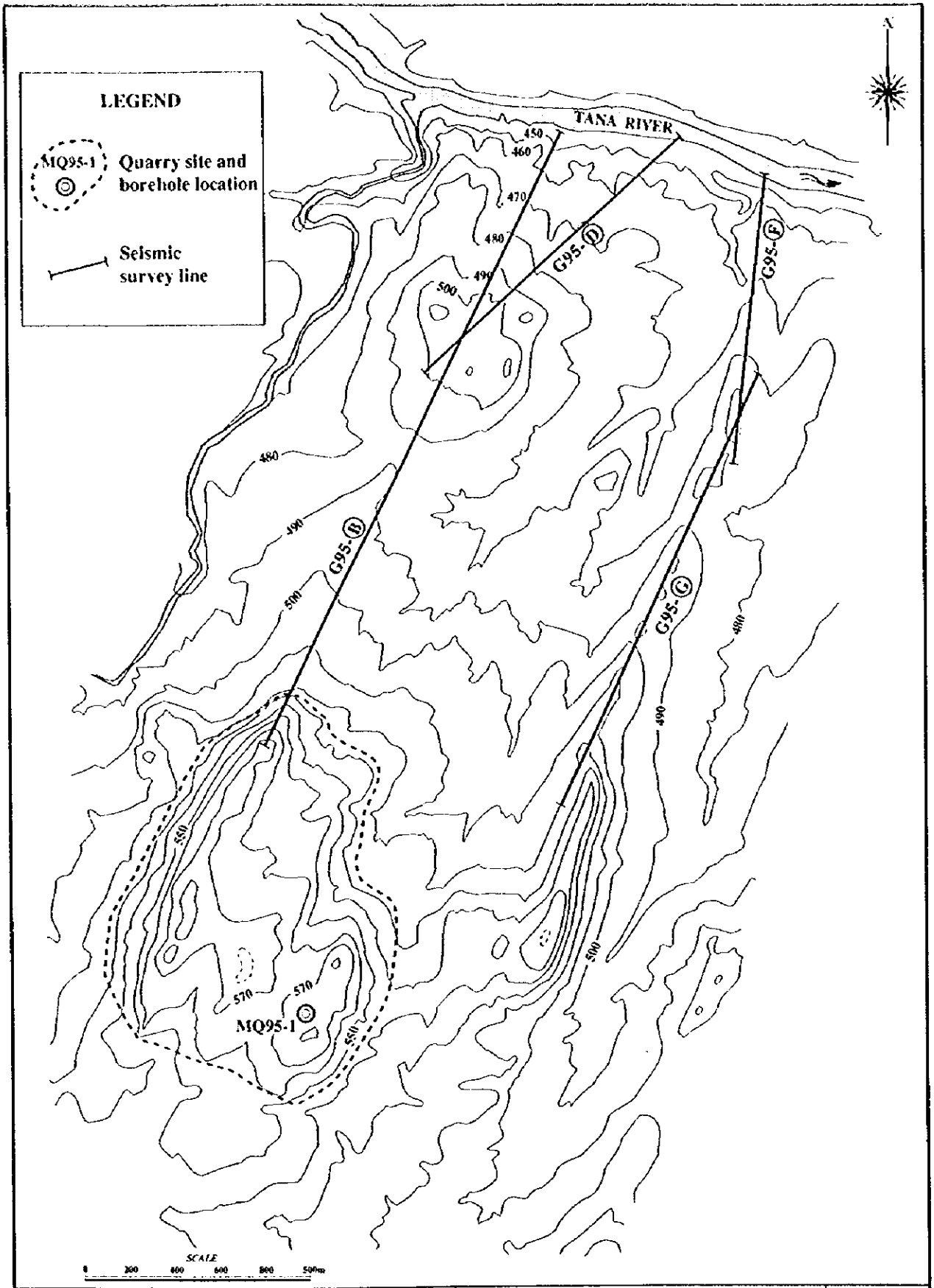
JAPAN INTERNATIONAL COOPERATION AGENCY	Alkali Aggressive Chemical Test Results (Montonga)	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		C2.2.6



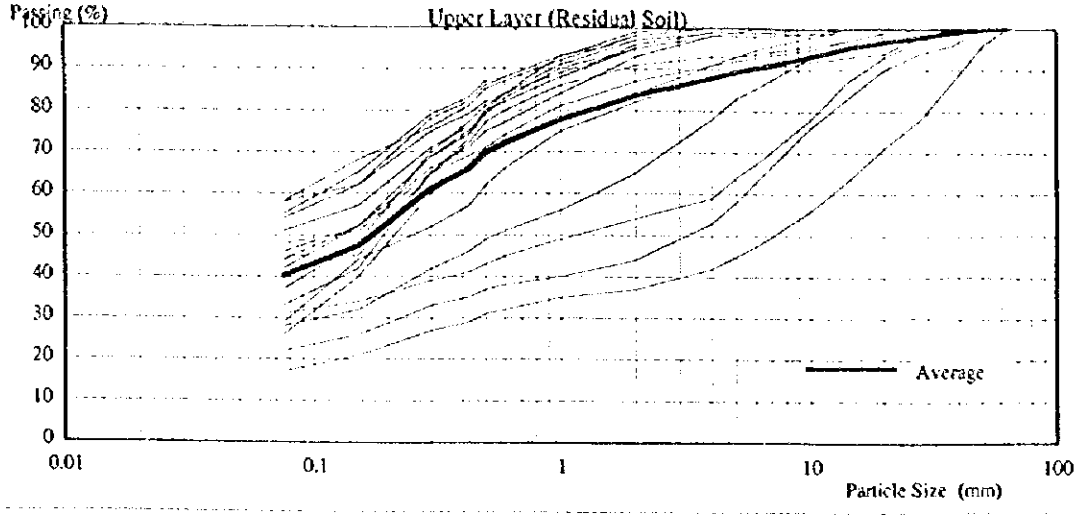
JAPAN INTERNATIONAL COOPERATION AGENCY	Grand Falls Dam Site : Location of Borrow Area and Quarry Site	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		C2.3.1

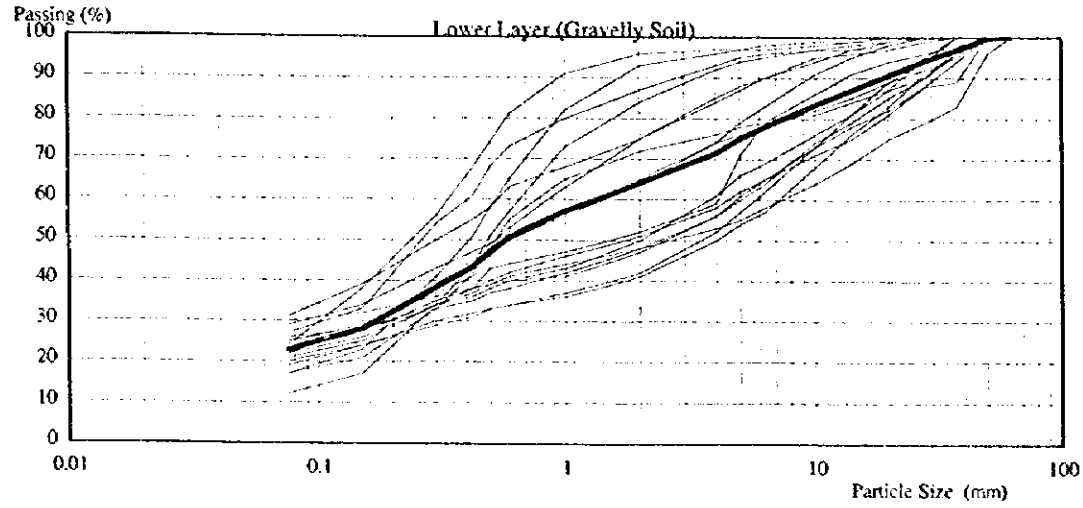


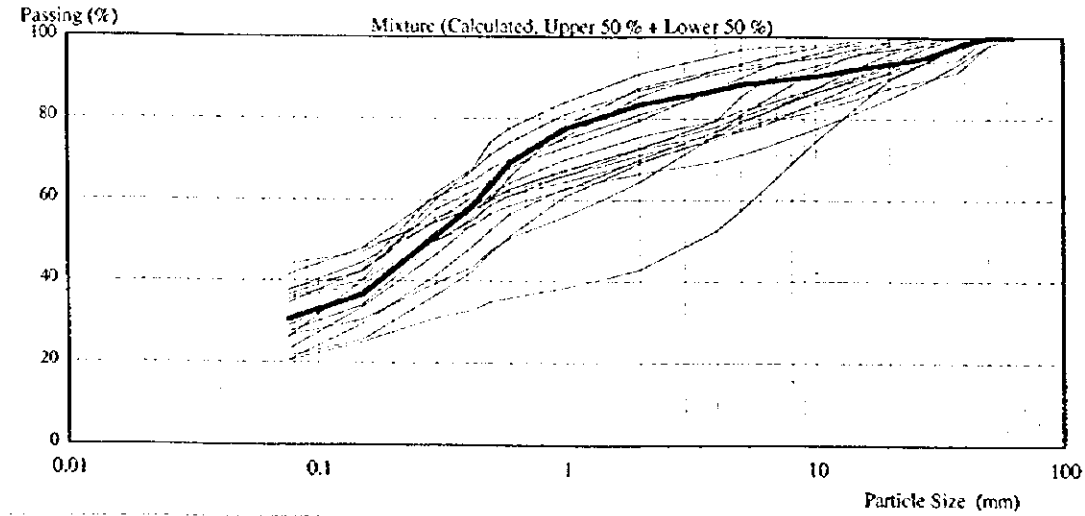
JAPAN INTERNATIONAL COOPERATION AGENCY	Grand Falls Dam Site : Location of Borrow Area for Core Material	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		C2.3.2



JAPAN INTERNATIONAL COOPERATION AGENCY	Grand Falls : Location of Quarry Site	Fig. No.
REPUBLIC KENYA MUTONGA / GRAND FALLS HYDROPOWER PROJECT		C2.3.3

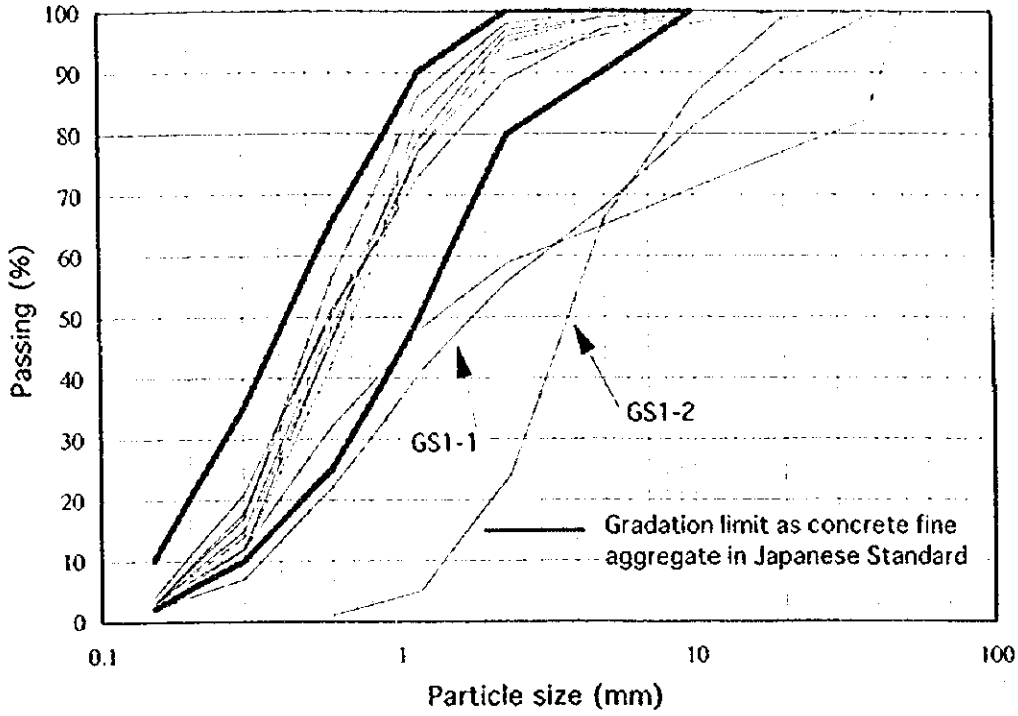




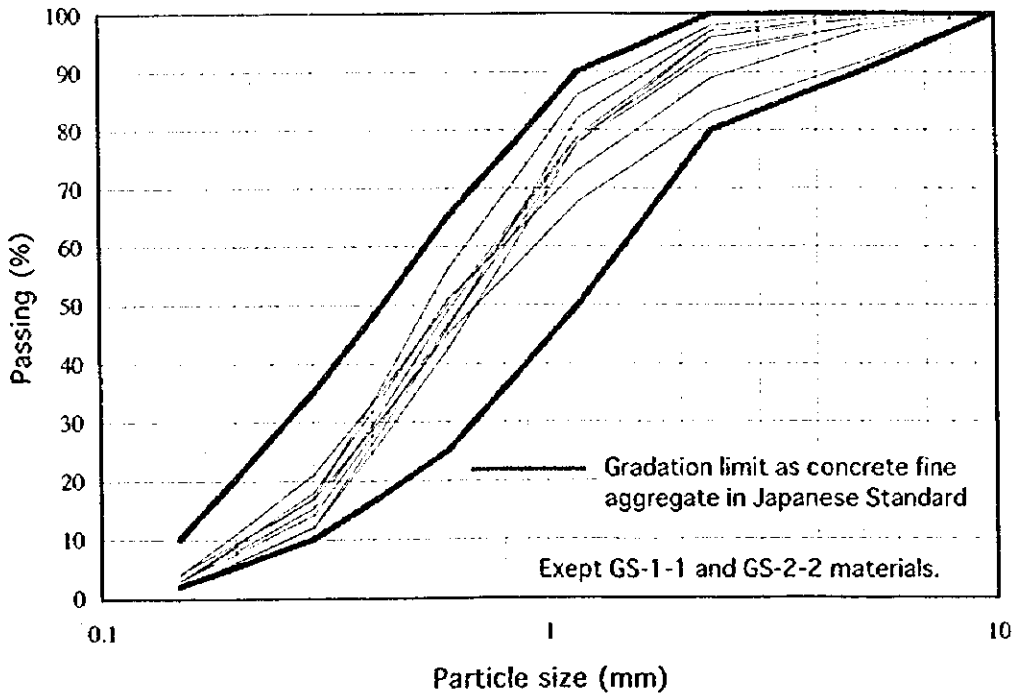


JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Representative Soil Gradation Curve (Grand Falls)	Fig. No. C2.3.4

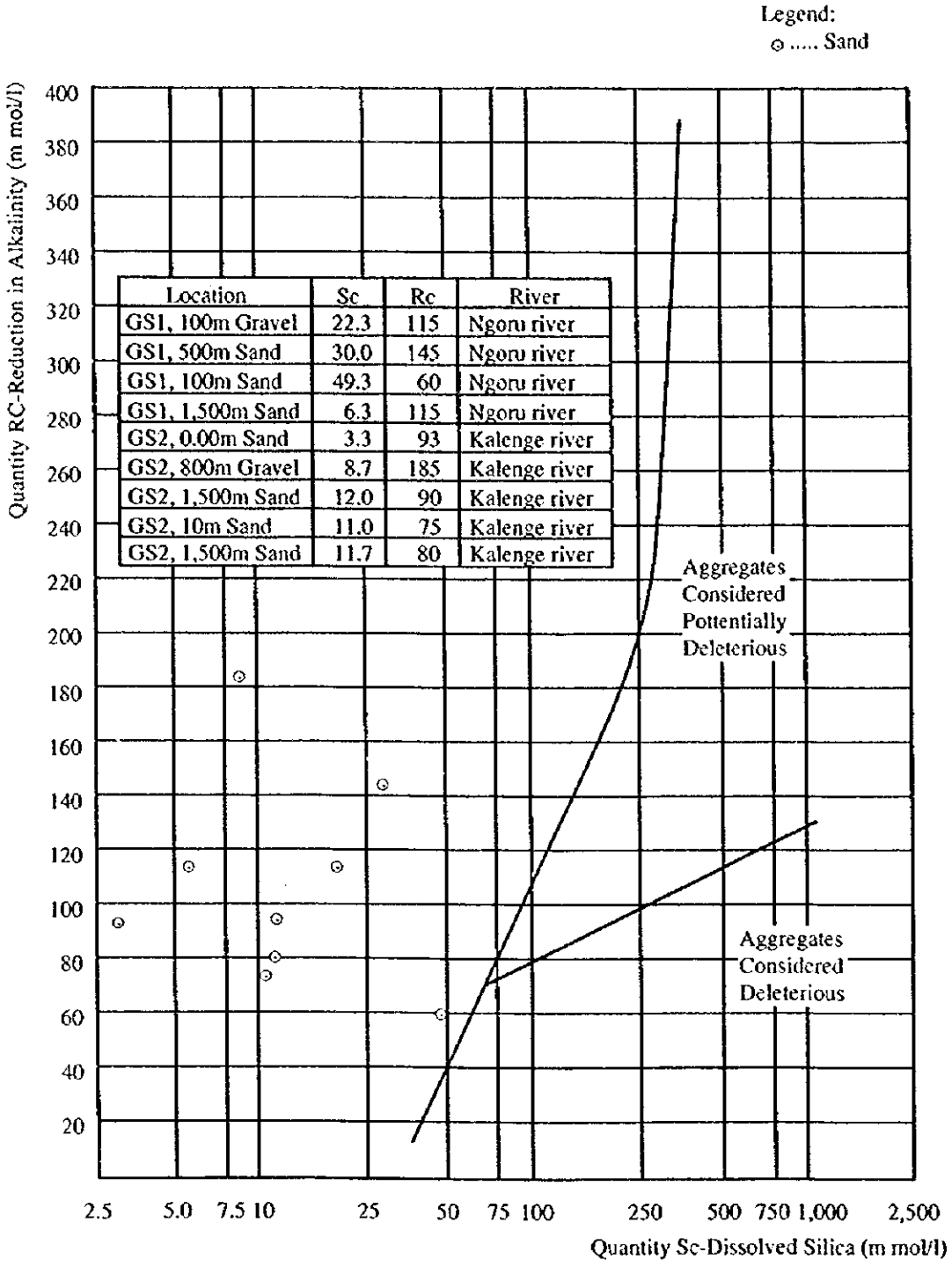
Sampled Material



After Cutting Particles over 10 mm



JAPAN INTERNATIONAL COOPERATION AGENCY	Sand Gradation Curve (Grand Falls)	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		C2.3.5



JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Alkali Aggressive Chemical Test Results (Grand Falls)	Fig. No. C2.3.6