(4) Situation of devastated land area

In the Paraiba Highland, at present, slided land containing diabasic and andesitic cap rocks is observed in the region of Santa Barbara facing the Ribeirao, a tributary of the Rio Paraibuna. Slided Land is also found in the region of mica schists and quartz schists near the original flow of the Rio Paraibuna flowing from Kunha to the south.

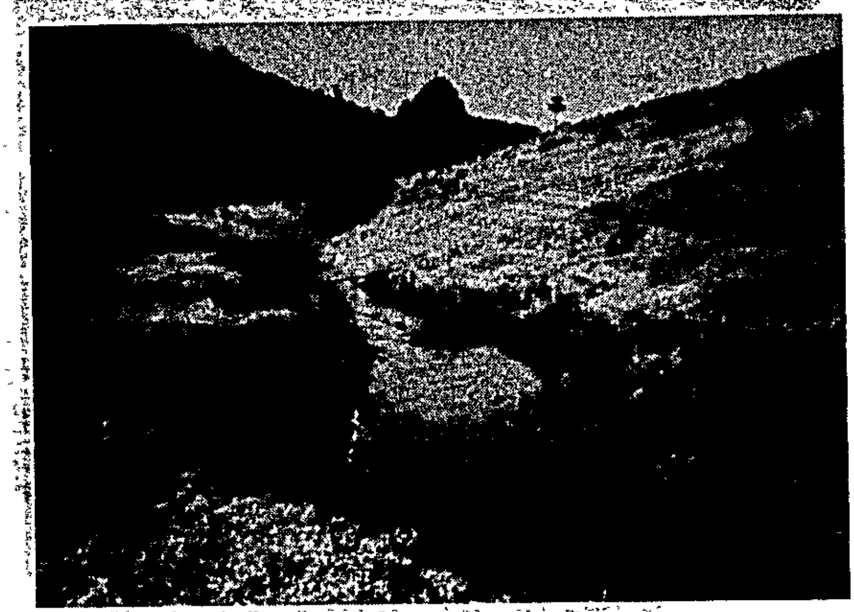
In the watershed of the Rio Una, devastated land like gullies is observed, and land creeping collapse occurred on a steep slope in the region of mica schists, near the reservoir in the lower reaches of the Rio Paraiba.

However, in general, there are not so many devastated areas, except artificial steep slopes such as the cut faces and refilled faces of roads, etc.

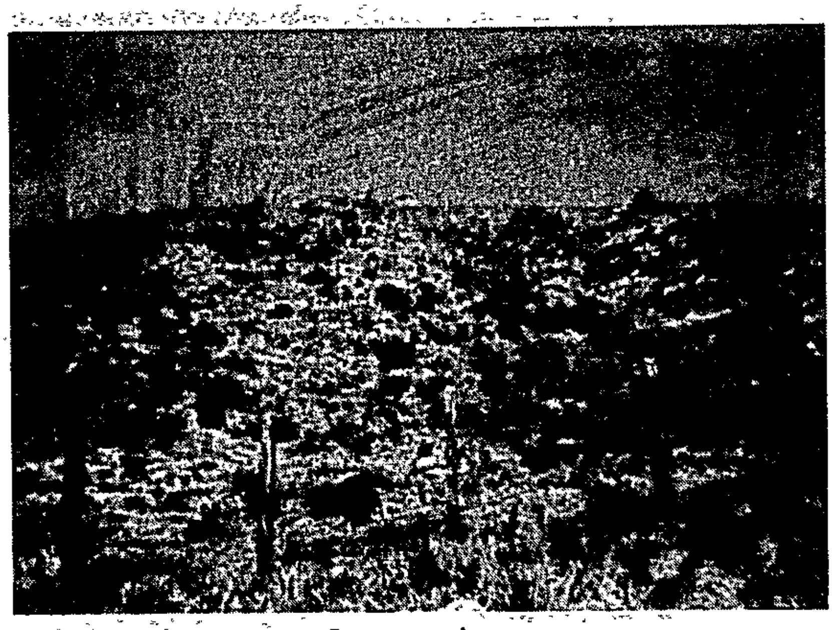
This area has geologically a deep saprolite layer, and the soils mainly comprise coarse sand and clay, and little gravels, indicating so-called discontinous weathering. Thus, forest vegetation is lost, and if humus runs off, soil erosion by overland flow, and erosion landslide by the piping phenomenon of interflow, etc. are liable to occur easily.

A matter of primary concern in watershed management is the potential transition to devastation caused by the breaking of soil layers by over-grazing in pastures and by the deterioration of infiltration capacity due to the loss of humic layer (A horizon) on slopes of more than 20 degrees and the acidifying of soils.

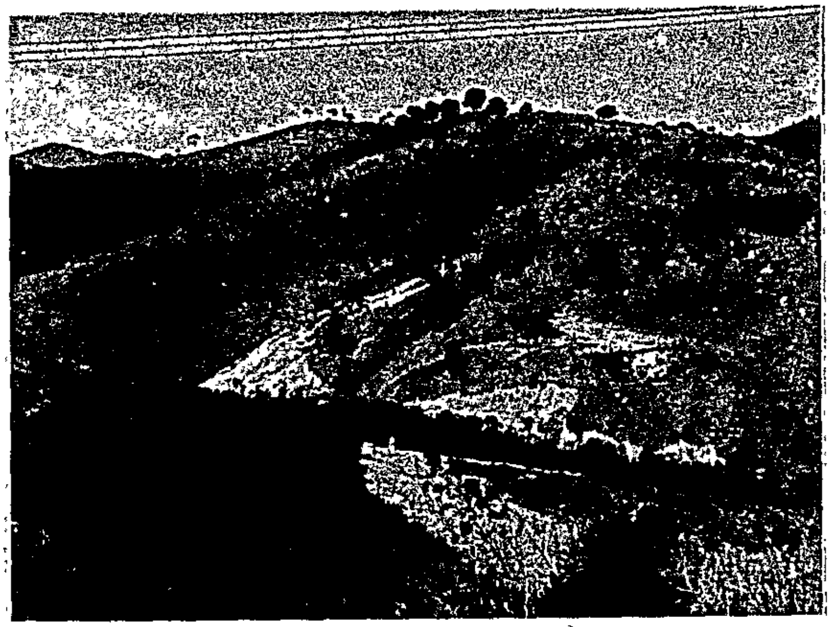
To cut the vicious cycle of loss of humus → turning infertile → topsoil runoff → devastation, it is required to promote careful comprehensive policies consistent in forest administration and agricultural administration, covering the studies on tree species and forest types with high function of soil conservation, periodical switching between forest and pasture, intensive utilization of land by grazing forest or improved pasture with high productivity, proper classification of land use according to topographic features and soil texture, construction of simple soil conservation facilities and terracing, etc.



Denuded pasture land in the upper reaches of the Paraibuna

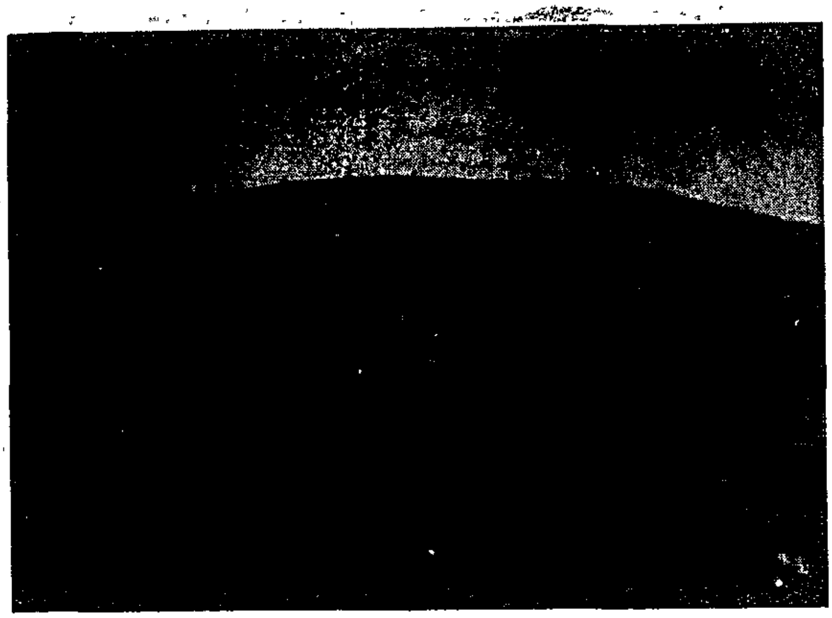


Same as above

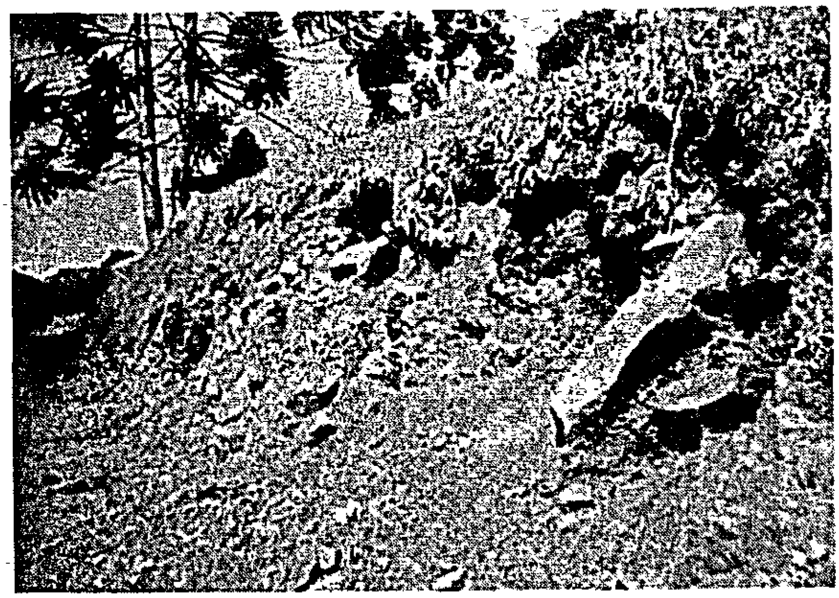


Denuded pasture land in the upper reaches
of the Paraibuna. Can an ant-hill be an
indicator of denudation?

Same as above
Denudation starts from the cattle path



Diabase section of Santa Barbara on the
left bank of the Riviera, a branch of
·the Paraibuna   Denuded pasture land on
a steep slope

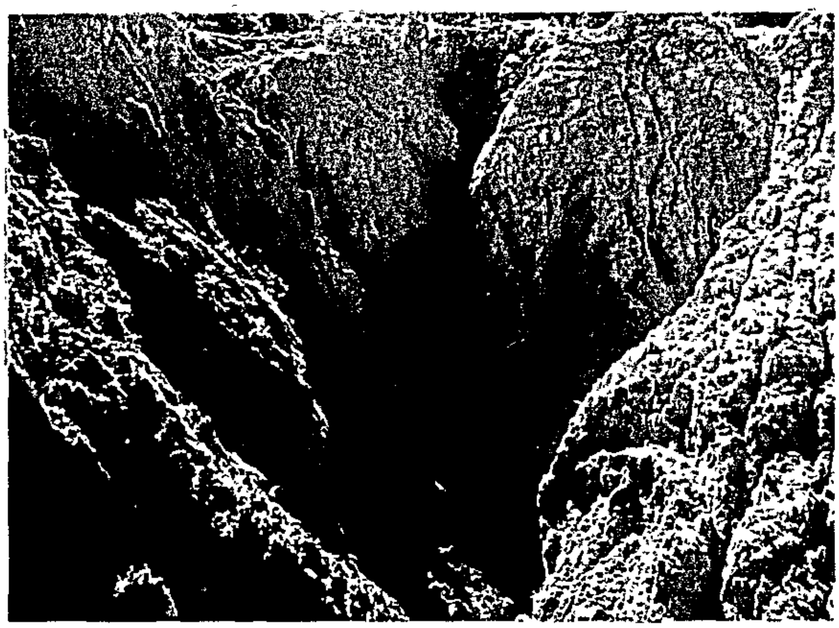


Same as above
Degradation of the terrace (cutting face)

Upper reaches of the Paraibuna
Denudation due to excessive grazing

Same as above
Ant-hill and the cattle path

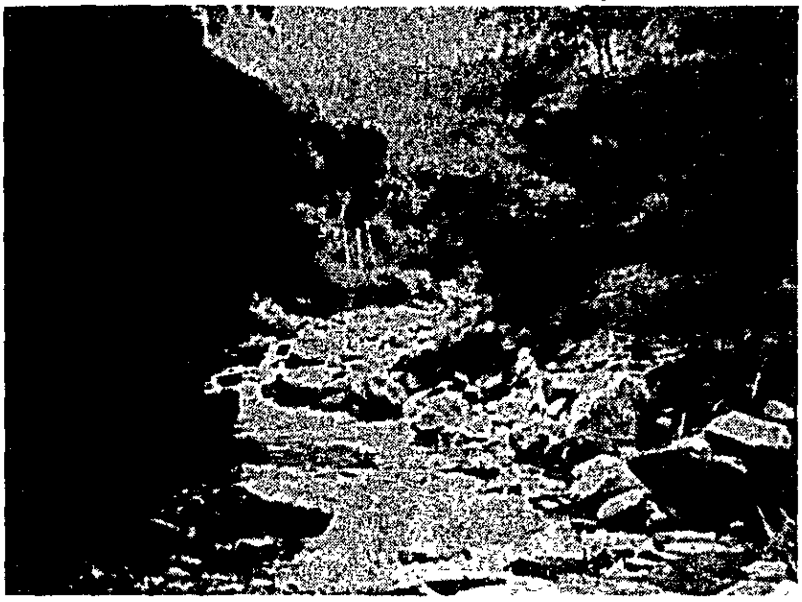
Headwaters of the Paraibuna Gully erosion of the embankment Geology: migmatite, soil, red-yellow podzol



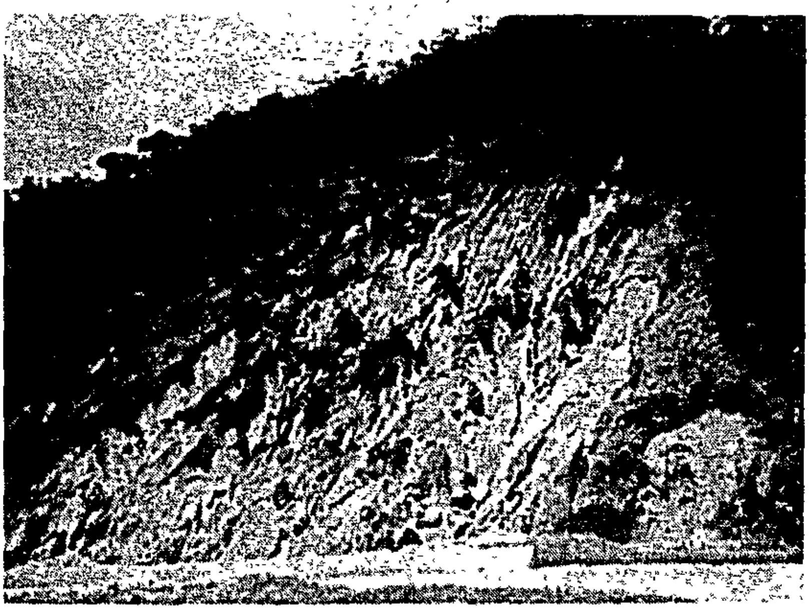
A gully-erosion Same as above

Denuded mountain area of the Una basin
Tertiary period, Daubate stratum
(sand stone, siltstone)

Same as above (planted forest)

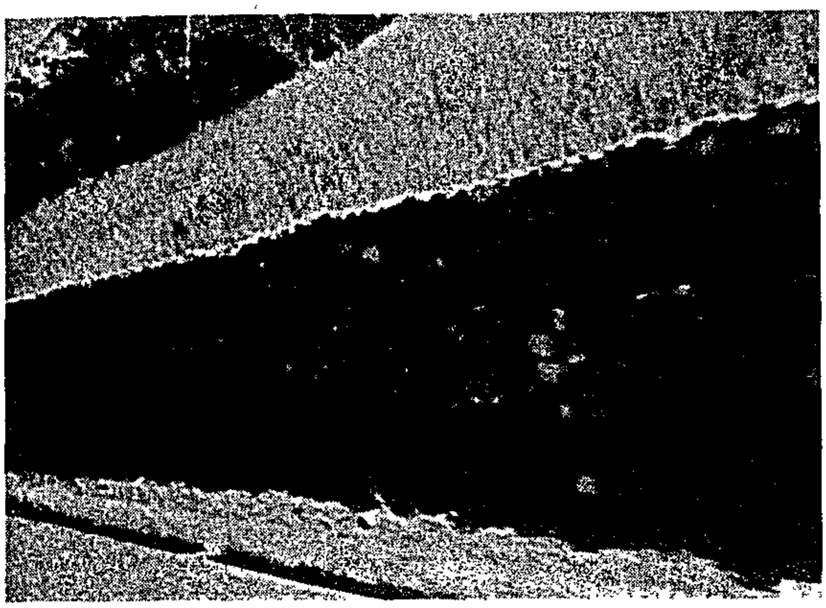


Devastated stream in the Una basin

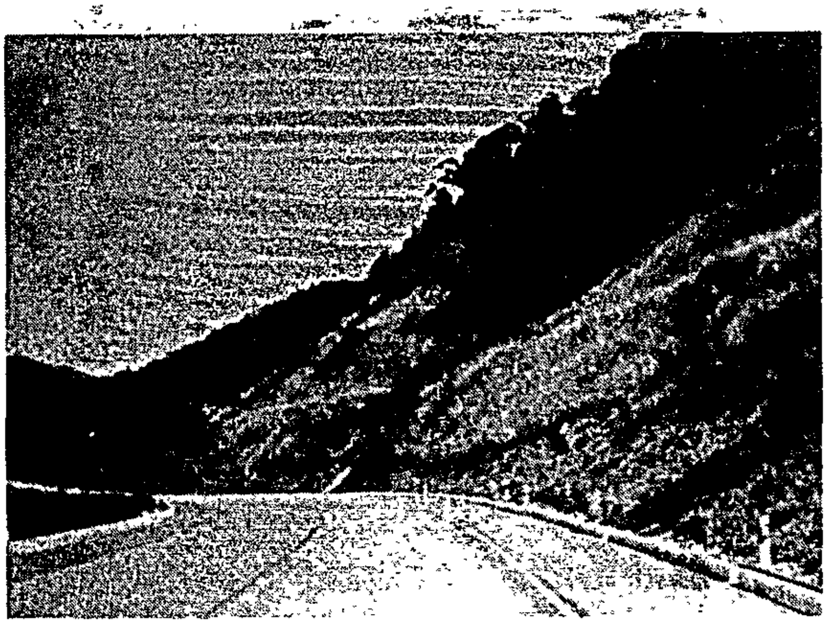


Degradation of the cutting face in the Una basin
Tertiary period, siltstone (Taubate stratum)

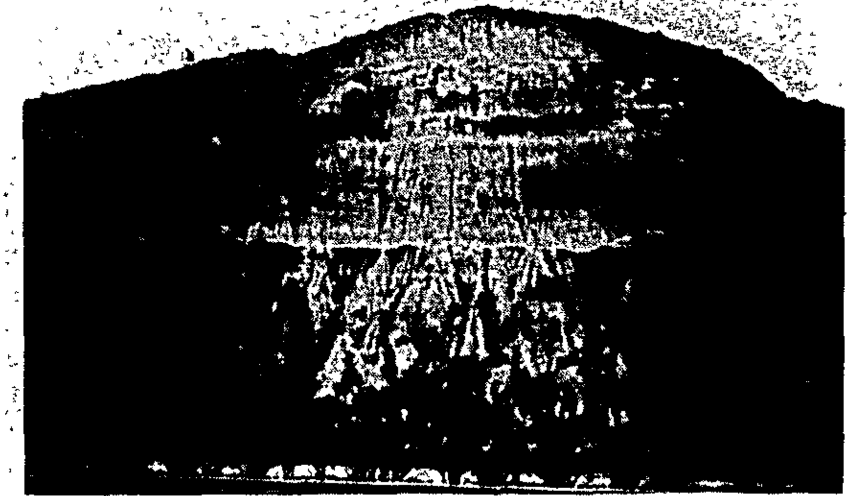
Denuded mountain area of the Una basin
Tertiary period Siltstone, sandy stone
(Taubate stratum)



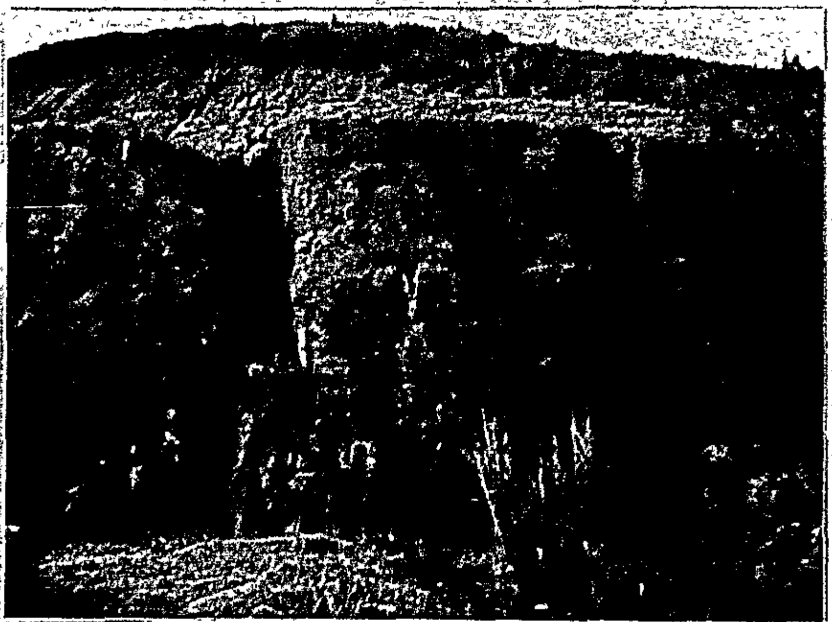
Section of migmatite caused by landslide degradation around the dam in the middle reaches of the Paraiba River



Line formed on the cutting face
Horizontal stairs



In the vicinity of Taubate
Erosion of the cutting face of the Taubate stratum (siltstone) Form of erosion varies from section to section: center (silt), upper and lower sections (sandy)



Upper reaches of the Paraiba River
Gully erosion of the cutting face

1.4 General Conditions of the Watershed of the Rio Una

The Rio Una is a tributary of the Rio Paraiba, being a river system important for watershed management, which joins the Rio Paraiba on the right bank of the latter.

With regard to this water system, Dr. Walter Emmerich of the Forestry Institute and Dr. Hidenori Nakano investigated and submitted a paper to the 3rd Forest Conference held in Manaus in December, 1978. The summary is quoted below.

(1) General

This watershed serves to supply water to Taubate City which is located between the two largest economic centers of Brazil, São Paulo and Rio de Janeiro. Therefore this area is especially important in terms of geography and economy.

This watershed is located on the right side of the Rio Paraiba, between Taubate City and Pindamonhangaba City, and the geographical position is lat. 23° S, long. 45°30' W.

The watershed of the Rio Paraiba has an area of 57,000km^2, and of it, 13,5000km^2 is located in São Paulo Province, 20,900km^2, in Minas Geraes Province, and 22,600km^2, in Rio de Janeiro Province.

Since the beginning of the previous century, this area developed mainly based on large-scale cultivation of coffee.

About 1840, the watershed of the Rio Paraiba produced 80% of coffee production of the entire São Paulo Province, and 37% of agricultural production of the province.

However, this golden age did not last until the end of the century.

The land which had developed rapidly became impoverished, and the sole factor which had made this area attractive, the slave labor, was abolished.

The watershed of the Rio Una has an area of $400km^2$, and originates from the Serra Quebra Cangalha which has much rainfall.

The lower stream of the river is characterized by mild climate (gentle wind, sunshine and humidity).

(2) Topography

The watershed of the Rio Una extends to the northwest from an altitude of 500m to 900m of the Serra Quebra Canghalha, and in the southeast, it borders the Serra Janbeiro.

In this area, the Rio Paraibuna, another tributary of the Rio Paraiba flows, and the river originates from the Serra Mar at an elevation of 1,700m.

At an intermediate altitude of 900m of the Serra Mar, there is a crotch of the river.

The relief directly affects the microclimate, the mesoclimate of the watershed, the mode of inland water, and the formation of vegetation and soils of the watershed.

The contribution to silviculture and livestock farming area is directly connected with the relief.

The relief is also a factor to regulate mechanization and tree planting.

Also in city planning, this relief affects the locations of buildings and the cost of construction.

Also in the field of outdoor amusement and recreation, the relief attracts people greatly.

(3) Geological structure

The strate in the watershed of the Rio Una comprise limestones quartz and rocks of the Tertiary period.

The stratum of the Tertiary is dominant in the central portion of the watershed of the Rio Paraiba.

This 20km wide stratum crosses the watershed of the Rio Una, and extends from the slopes of the Itain runnel and the head of the Rio Una and far to lowland.

On the slopes of the head in the southwest area, gneiss forms the stratum, in the middle to east zone, rocks of Predevonian period and in the north, quartz.

The gneiss layer is generally acid.

Limestones are crystalline schists formed by mixing with plutonic rocks, and contain 19% of magnesium, being like dolomites.

(4) Soils

The soils in the watershed of the Rio Una have a trend of "Red-Yellow Podzolic Soils".

Since the rocks producing the soils of the watershed contain, as a major component, gneiss including mica schists, the soils can be said to be of Salmolan (soils formed by partial decomposition of micas and feldspars) and Massape (black and fertile clayey land) type.

In lowland, the soils are 3m deep, and the upper soils and subsoils are substantially clay.

The soils on the middle slopes are 1.5m deep, reaching Chorizon.

The upper soils comprise sandy muddy clay or sandy clay, and the subsurface soils (subsoils) comprise sandy clay and clay.

The amount of organic materials contained in the soils is 1.7 times the carbon content.

The upper soils of lowland contain 4.3% of organic materials, and those of slopes contain 2.0%.

These factors of geologic structure and soils directly influence vegetation by affecting the amount of available fertilizer.

These factors also affect relief, mode of inland water and microclimate through soil erosion, runoff, evapotranspiration and vegetation.

(5) Climate

The factor of climate also directly affects the surface vegetation of watershed and the inland water mode of rivers.

In a long period of time, it also affects the formation of soils and relief.

In the rainy season from December to March, the highest temperatures on the watershed of the Rio Una are 27 to 32.6 degrees on the average.

The lowest temperatures are 15 to 18.2 degrees on the average.

Throughout the year, wind is generally gentle, and wind velocity is in a range of 0 to 4m/sec.

In a short period of time, the wind velocity in the watershed may be in a range of 4 to 7m/sec.

There is ample sunshine with clear bule sky to provide an extensive view in dry climate.

The relative humidity is in a range of 73.2% to 75.9%.

The mean annual rainfall is 1304mm.

In recent years, hail has fallen unexpectedly, damaging agricultural products to some extent.

For a few days during winter season the temperature may fall below zero but this has no negative effect on agriculture.

In the early morning and from afternoon till night, a dense fog often sets in.

(6) Vegetation

The original vegetation in the Rio Una watershed exterminated by the coffee cultivation at the end of the previous century.

In 1972, Hueck said that this vegetation was "semi-dry forest of the Paraiba canyon".

The reason was that the vegetation at the foot of the Serra Quebra Cangalha had became a dry isolated area.

However, in difficult to invade by coffee cultivation, the traces of original vegetation are still preserved.

2. Annual Experiment Programs of Watershed Control

2.1 Facilities set up programs

Of the experimental researches, for which our cooperation is requested by the state government of São Paulo, the matters concerned with the watershed management of the Rio Paraiba are as follows:

(1) Research on the tree species and working methods desirable for conservation of water and soils

(2) Research on the method of deciding importaant sites where forests should be restored for conservation of water and soils

(3) Research on the simple soil conservation works which complement the function of forests to conserve water and soils

(4) Comprehensive experiments of watershed management

Of the above, the facilities which are especially required to be set up are integrated meteorological observation equipment, horizontal lysimeters, slope flow facilities, gauging facilities, precipitation observation network and simple soil conservation model facilities. The following are planned.

(A) Integrated meteorological observation equipment (in the field) .... 4 plots

a. Coastal mountainuous region which has much rain (Kunha experimental site)

b. Westeren lowland which has little rain

c. Central undulating region

d. Eastern undulating region

Integrated meteorological observation equipment ...... Each 1 system, 4 units

Accumulative raingauge .... 4 units

Large evaporimeter .... 4 units

(B) Horizontal lysimeter (10m × 10m × 2m) .... 3 units

with gauging facilities (stage recorder)

(C) Overland facilities (20m 30m 1.2m) .... 3 units

with gauging facilities and sediment rounoff measuring facilities

(D) Gauging experimental facilities (in 3 drainage area A, B and D) .... 3 units

Gauging facilities .... 3 units

Rain recorder or accumulative raingauge
.... each 3 units, 9 units

(E) Evapo-transpiration measurement by heat balance method
.... 6 locations

Regions of Kunha area and little rain regions of west lowland (2 regions)

Respectively at 3 locations of natural forest, (incluiding secondary forest), eucalyptusspp. and pines (short rotation)

Long term actinograph	... each 3 units (including a spare), total 18 units
Long term radiograph	... each 2 units (including a spare), total 12 units
Long term hygrothemo-graph	... each 3 units (including a spare), total 18 units
Long term soil thermograph	... each 4 units (including a spare), total 24 units
Long term geothermal flow graph	... each 4 units (including a spare), total 24 units
Long term dry bulb thermograph	... each 2 units (including a spare), total 12 units
Long term wet bulb thermograph	... each 2 units (including a spare), total 12 units
Long term rain recorder	... each 3 units (including a spare), total 18 units
Long term windvane and anemograph	... each 3 units (including a spare), total 18 units

Note: In the three watershed A, B and D where gauging facilities are set up, precipitations are expected to be greatly different locally due to elevations, wind directions, etc. Therefore, rain recorders or accumulative raingauges should be set up respectively at the ridge, valley head and the site of stage recorder in each drainage area, to secure accurately precipitations.

2.2 Directions of Experiment Programs

A desirable forest in terms of water and soil conservation must be active in growth, large in the total production of dead branches, dead leaves, stems, etc. And that kind of forest allows proper conversion of dead branches, leaves, etc into humus and creates favorable forest soil. The soil is well fertilzed and excellent in aeration, water flow, water-holding capacity etc. These situations have to be maintained permanently.

The climax community of the natural forest in this area is evergreen broad-leaved trees called Mata (in highland Araucaria is also included), but since they have problems in growth, final cutting age, timber price, reproduction, etc. introduced species such as eucalyptusspp. and pines are generally planted.

Eucalyptusspp. are cut, sprouted and regenerated in 5 to 15 years, and pines are regenerated under clear cutting. But in view of maintaining the soil productivity, there is a problem of whether the working method should be improved.

Furthermore, there are problems of whether tree species excellent in terms of quality, growth, preservation of fertility, water and soil conservation, etc. are available, and whether there is any examination yet to be made including the studies on the afforestation and tending of Araucaria.

On these problems, plot experiments will be made, including introduced species and indigenous species, to study water balance, surface runoff, overland runoff, total growth of stems, dead branches and leaves, soil structure and its physicochemical change, change of soil fertility etc., by way of comparative experiments.

Thus, favorable tree species and working methods will be determined.

For this purpose, lysimeters, overland flow facilities and evapotranspitation measuring facilities are used.

Then, the approximately determined tree species and working methods will be experimented to see the actual applicability, and the functions of water and soil conservation will be compared and examined by tree species, tree age, working method etc.

For this purpose, gauging facilities in each watershed will be utilized and the survey, analysis and study on soil texture, soil type, water quality, etc. will be repeated periodically.

2.3 Annual Experiment Programs

Year	Item	Facilities and instruments	Organization in charge	Experimental and measuring program
Upto 1979	Planning of general conception (measuring methods, setup locations)			Experimental site will be located in the state forest land at the upper stream of the Rio Paraibuna, Kunha.
	Instrument platform for integrated meteorological observation	One-month hydrothermometer, 2 units	Donated	Execution of preliminary meteorological observation
	Evapotranspiration comparative experiment (lysimeter)	Jordan actinometer, 1 unit	"	
	Overland flow experiment	Three-month raingauge, 1 unit	"	
	Watershed experiment	Three-month water-gauge, 1 unit	"	
	Selection of location for determination of critical area	Current meter, 1 unit	"	
	Rio Una, a tributary of the Rio Paraiba (RIO UNA)	Field office, Research room, experiment room, and bed room, 1 building of 400m^2	Forest Institute	
		Overland flow facilities (50 × 20m), 4 units	"	
		Ribeirao Mottas, a tributary of the Rio Paraiba (RIBEIRÃO MOTTAS)	"	
1980	Forest hydrometeorological observation	Instrument platform for meteorological observation, 1 location	Forest Institute	Execution of observation
		Integrated meteorological observation equipment, 1 set	Donated	
		Small computer, 1 unit	"	Arrangement of data, determination of analysis method
	Evapotranspiration comparative experiment (lysimeter) (Water balance experiment)	Horizontal lysimeter, 1 unit	Model infrastructure	Execution of the preliminary hydrometeorological observation
		Horizontal lysimeter, 2 units	Forest Institute	
		K type stage recorder (7-days), 4 units (including a spare)	Donated	
	Overland flow experiment (slope)	Overland flow facilities, 1 unit	Model infrastructure	
		K type stage recorder, 4 units (including a spare)	Donated	
	Gauging experiment	Gauging facilities, 1 set	Model infrastructure	
		Suiken 62 type stage recorder (one-month), 3 units	Donated	
		Rain recorder or accumulative rangauge, 9 units	"	

Year	Item	Facilities and instruments	Organization in charge	Experimental and measuring program
	Simple soil conservation model facilities			Study, design and specification of simple soil conservation model facilities suitable for the field conditions.
	Incidental construction	Improvement of road (including 2 wooden bridges), 26km	Forest Institute	
		Bulldozer (4-ton), 1 unit	Donated	
		Swing dozer, 1 unit	"	
		Jaw crusher, (3t) 1 unit	"	Single toggle type with portable engine 250 × 180mm
1981	Forest hydrometeorological observation	Instrument platform for hydrometerological observation, 2 locations	Forest Institute	Execution of observation
		West lowland which has little rain		Arrangement of data, review of analysis method
		Central undulation region		
		Integrated meteorological observation equipment, 2 units	Donated	
		Accumulative raingauge, 2 units	"	
		Large evaporimeter, 2 units	"	
	Evapotranspiration comparative experiment (lysimeter) (water balance experiment)			Observation to be continued in classification of grass land, shrub and high forest.
				Determination of stage and discharge curve formula, study on methods of measurement and analysis.
	Overland flow experiment	Overland flow facilities, 2 units	Forest Institute	Observation to be continued in classification of grass land, shrub and high forest, together with the model infrastructure set in 1980.
				Preparation of stage and discharge curve table, study on methods of measurement and analysis.
	Gauging experiment	Gauging facilities (for watershed A and B, with water-gauge, etc. installed), 2 sets	Forest Institute	Preparation of stage and discharge curve formula for Area D with the facilities of 1980.

Year	Item	Facilities and instruments	Organization in charge	Experimental and measuring program
				Study on methods on methods of measurement and analysis. Analysis of relation between elevation and precipitation. Determination of survey method of site conditions
	Evapotranspiration measurement by heat balance method, including stand selection of natural forest, eucalyptuses, early growing pines (Kunha area)	Long term actinometer, 9 units	Donated	Setup of measuring instruments and determination of measurement methods
		Long term pure radiograph, 6 units	"	
		Long term hydrothermograph, 9 units	"	
		Long term soil thermograph, 12 units	"	
		Long term geothermal flow graph, 12 units	"	
		Long term dry bulb thermograph, 6 units	"	
		Long term wet bulb thermograph, 6 units	"	
		Long term rain recorder, 9 units	"	
		Long term windvane and anemometer, 9 units	"	
	Forest infiltration capacity experiment	Lysimeter	Donated	Guidance on measurement methods, study of estimation method of watershed infiltration capacity by the analysis of gauging data.
		Rinshi type,*1 1 unit	"	
		Rinshi Tohoku type,*2 1 unit	"	
		Mass-grave type 1 unit	"	
1982	Forest hydrometeorological observation	Instrument plaftform for meteorological observation, 1 location	Forest Agency	Execution of observation
		Eastern undulating region		Arrangement of data, determination of analysis method
		Integrated meteorological observation equipment, 1 unit	Donated	
		Accumulative raingauge, 2 units	"	
		Large evaporimeter, 2 units	"	

*1 Lysimeter improved by Japan Forestry Experimental Station (JFES)
*2 Lysimeter improved by JFES Tohoku branch

Year	Item	Facilities and instruments	Organization in charge	Experimental and measuring program
	Evapotranspiration comparative experiment (lysimeter)			Study on the survey and measurement of total stand growth, physicochemical properties of soils and amount of organis materials.
	Overland flow experiment			Determination of survey and analysis methods concerning the relation between forest type and water & sediment runoff, as well as relation between forest types and soil texture, soil type etc.
	Gauging experiment			Preparation of stage and discharge curve curve tables for Area A and B (contraction flow factor) Determination of water quality survey method, determination of analysis method between stand condition and water quality & outflow.
	Evapotranspiration measurement by heat balance method (west lowland which has little rain), including stand selection of secondary forest, eucalyptuses, early growing pines	Long period actinometer, 9 units	Donated	Determination of evapotranspiration measuring method and trial measurement.
		Long period pure radiograph, 6 units	"	
		Long period hydrothermograph, 9 units	"	
		Long period soil thermograph, 12 units	"	
		Long period geothermal flow graph, 12 units	"	
		Long period dry bulb thermograph, 6 units	"	
		Long period wet bulb thermograph, 6 units	"	
		Long period rain recorder, 9 units	"	
		Long period windvane and anemometer, 9 units	"	
	Selection of location for determination of critical area			Training in Japan on analysis methods by use of computer for deciding hillside collapse threatening areas, landslide threatending areas and torrent threatening areas.

Year	Item	Facilities and instruments	Organization in charge	Experimental and measuring program
	Experiment of simple soil conservation structure for local applicability			Selection of construction methods suitable for the field condition. Execution of local applicability experiment. Training in Japan to learn methods how to evaluate the effects of simple soil and water conservation on various soils, materials and works.
1983	Forest hydrometeorological observation			Continued hydrometeorological observation, and arrangement and analysis of data.
	Evapotranspiration comparative experiment (lysimeter)			"
	Suface flow experiment			"
	Gauging experiment			Continued execution of discharge observation and water quality experiment, arrangement and analysis of data.
	Evapotranspiration measurement by heat balance method			Continued execution of measurement and analysis.
	Selection of location for determination of critical area			Research and development of danger deciding method based on topographic features and soil cover condition interpreted with aerial photos, geologic data, topographic data analysed with topographic map, and multiple regression analysis and multivariate analysis between devastation and peak flood, low flow, sediment discharge etc.
	Simple forest conservation works			Determination of effective and desirable simple soil conservation works according to actual conditions of geology, slope, soil texture, devastation type, importance, etc.

3. Design of Model Facilities

3.1 Design Policy

Facilities are 3 units of water balance facilities (evapotranspiration facilities for comparative experiment - lysimeter), 3 units of overland flow facilities and 4 units of gauging facilities.

For systematic promotion of technical cooperation on watershed management, the following facilities will be set up to start observation within 1980, based on the annual programs.

1. Water balance facilities (lysimeter) .... Area D
2. Overland flow facilities .... Area D
3. Gauging facilities .... Area D

(1) Determination of setup locations and construction methods

o For lysimeters, as flatland near to the office and allowing the installation of three units, the area at the inlet of valley D on the left bank is selected, and they are arranged on a straight line at intervals of 15m.

This is to make the flora in the lysimeters as far as possible to coincide with the flora in the vicinity.

Since no leakage is allowed for operation of the lysimeters, a concrete floor is laid on top of a well pressed gravel foundation. On top of this asphalt boards are placed and in addition to this concrete side walls and floor are constructed.

o Overland flow facilities have been designed on stable slopes behind the office and at the entrance of area D. They are constructed of concrete and L-shaped 30m long, 20m wide and 1.2m deep concrete boards cover the top and on both sides at right angles to the maximum gradient line of those slopes, and at the bottom, a socket for water and soil and gauging facilities to measure overland flow (including interflow) and sediment runoff are set up.

Three units of the facilities are arranged at 10 to 15m intervals for the same reason as for the lysimeters.

o Gauging facilities were decided to be set up near the respective inlets of Area A to D, and surveying was done.

Near the inlet of Area A, rocks are exposed and formed like a fall, obtaining a head. Therefore, it was decided to construct a sediment check dam at the upper place and a gauging dam at the lower place, for measuring the discharge by a square weir with V-notch.

In Area B, foundation rocks are available, but the river bed slope is gentle, not allowing to obtain a sufficient head. Therefore, it was decided to adopt open channel type, and to construct two low dams at the upper and lower streams of the channel.

The torrent in Area C forms a wide fan-like depositional area, and the gradient is gentle. Therefore, both open channel type and weir type gauging facilities must be too large in scale, and it is difficult to close the underflow water, providing a problem of measurement accuracy. Therefore, though it was designed as an open channel type, further study is required.

Area D, being similar to Area C, forms an extruded depositional area, and the slope is gentle. But since the foundation layer (concreted sand and gravel layer) is about 2m deep, open channel type was decided to be used. And it was planned to construct a dam for soil reserving and closure (with the foundation sand and gravel layer impregnated with cement milk and bentonite for cut-off) and a regulating reservoir dam, and to make the channel as long as 20m, for raising the observation accuracy.

3.2 Constructional Standard of Facilities

The structure should allow the peak flood based on the 100-year probable precipitation calculated separately and the prompt and accurate measurement of water shortage, low flow, normal and flood discharge.

Complex system of V-notch and square weir (Bacia A) and open channel system (Bacia B, Bacia D), should be adopted according to the conditions of the local torrential bed, river bed slope, etc., and a small dam for soil reserving and ponding should be constructed together to improve the measurement accuracy.

The stage should be measured by a float type stage recorder. A scaffolding (log bridge) for measuring the mean stage and the mean velocity should be prepared to calculate the correlation formula between stage and discharge, and portable vinyl resevoir facilities (2m × 2m × 1.5m, 2 units), a hard polyvinly chloride hanging gutter for water supply, gauging chamber, etc. should be prepared for discharge measurement at the notch.

The water gauge of the open channel should be set at 2m above the end of the channel, and the scaffolding for the measurement of velocity, etc. should be provided at 1m further above the previous point.

For a lysimeter, a measuring tank with V-notch and a stage recorder should be provided for measurement of seepage water, and since water is expected to flow over the ponding area of 20cm surface area, depending upon the infiltration rate of precipitation and rainfall intensity, gauging facilities for measurement of spill should be provided additionally as required.

With regard to overland flow facilities, the same facilities as for a lysimeter should be provided for measurement of overland flow and interflow, and a soil reserving chamber should be provided for measurement of sediment runoff.

3.3 Size of Weirs, Open Channels, Etc.

The safety factor of the allowable discharge of weir or V-notch to the peak flood should be 1.0 to 1.2 as required, and the grade of an open channel should be 1%.

Considering the rise of water stage, etc. at the socket of an open channel, an allowance of 0.5m should be added to the depth of the channel, and the opening should be widened like a funnel (1m long, 45° side angle).

The details are as follows:

(1) Anticipative rainfall intensity

- o Calculation of 100-year probable daily rainfall (according to Mr. Taizo Endo)

In and around the Kunha experimental base, there are several observatories (see Fig. 5). Among the respective observation points, observation periods are different. The longest period is 18 years at El-1 (1961 to 1979), and the others are 10 years or less.

Hourly rainfalls are not recorded.

For these reasons, the maximum value of dialy rainfalls at the observation point El-1 was used, to calculate the probable daily rainfall according to Gumbel's method. (See Fig. 5 and Table 8.)

According to the results, 50-year probable daily rainfall is 356mm/day, and 100-year probable daily rainfall is 515mm/day.

According to the practice in Sãn Paulo Province, 100-year probable daily rainfall is adopted.

o Calculation of 100-year probable maximum hourly rainfall (same as above)

From the value of 100-year probable daily rainfall, the maximum rainfall for T hours (γmm/hr) can be obtained from the following equation.

$$\gamma = \frac{R}{24}\left(\frac{24}{T}\right)^{\frac{2}{3}}$$

where R: 100-year probable daily rainfall (mm/24 hours)

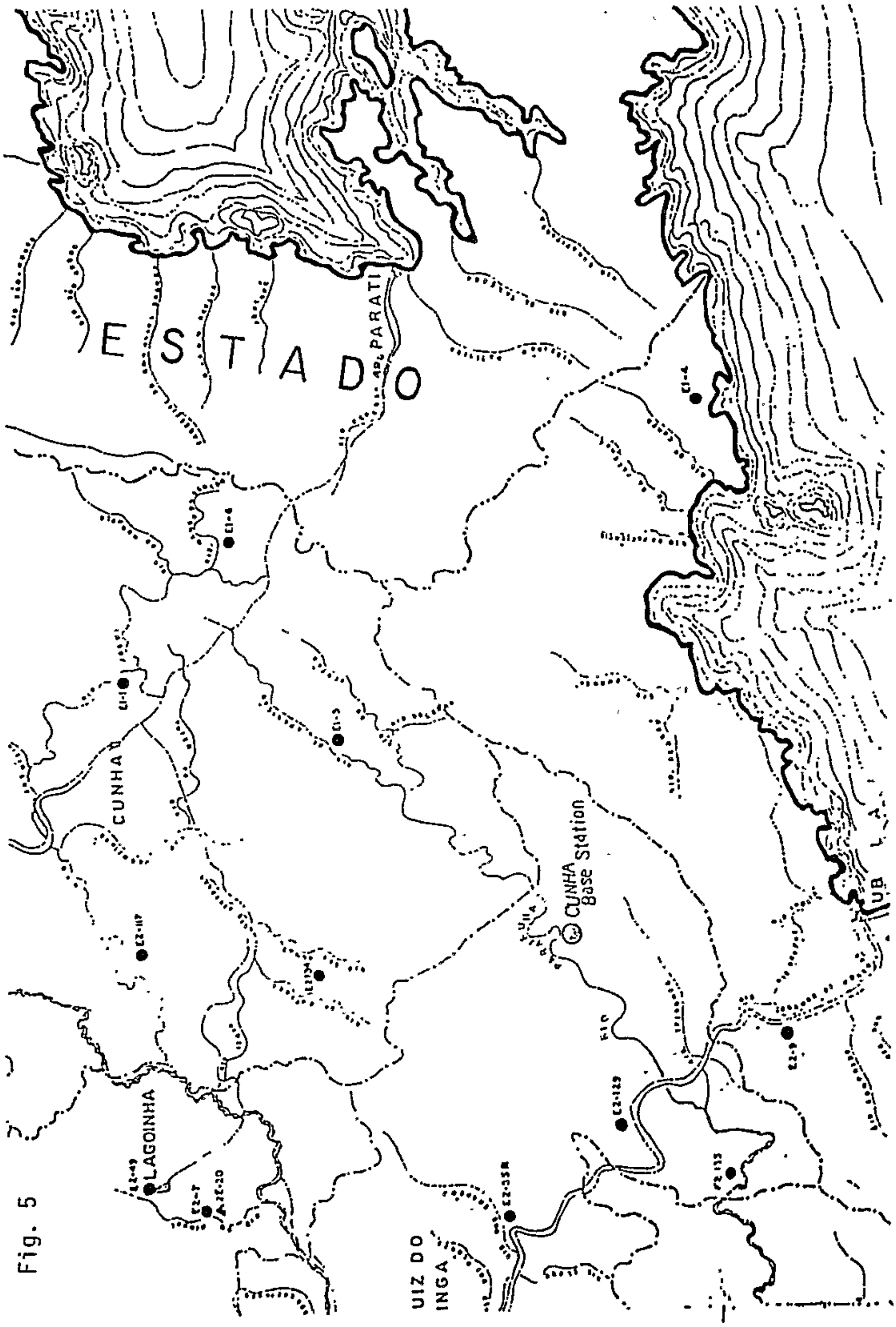

ESTADO
PARATI
CUNHA
CUNHA
Base Station
LAGOINHA
UIZ DO
INGA

Fig. 5

Table 7.1 Maximum Daily Rainfalls at the Observation Point E1-1 (mm)

MUNICIPIO
POSTO

PREFIXO: E1-1 ZONA

Month / Year	J	F	M	A	M	J	J	A	S	O	N	D	Year
1961	2099	185.5	176.0	851	172	386	196	19.0	05	854	1685	2606	12659
1962	214.6	258.5	1401	437	25.9	89	136	74.0	61.7	172.4	77.7	1649	12560
1963	1050	882	0.0	0.0	263.0	00	0.0	3.8	03	×	187.0	76.0	(7233)
1964	1866	211.1	955	42.9	49.4	31.7	251	164	56.4	1589	1037	1675	11452
1965	3309	168.8	2128	1050	462	111.3	39.5	95	46.9	1762	131.2	2155	1593.8
1966	188.3	132.8	1734	501	498	01	61	106.5	59.3	1657	290.5	2152	1439.5
1967	341.9	2636	1897	361	3.6	61.2	141	09	982	2038	200.5	169.8	1583.4
1968	197.0	77.8	111.1	1282	328	147	254	390	322	506	43.4	2726	1024.8
1969	271.8	186.4	961	681	30.8	31.7	99	52.0	281	1199	189.5	241.7	1326.0
1970	290.0	189.5	126.4	73.0	29.3	391	31.4	1250	960	713	150.8	227.6	1449.4
1971	1448	263.0	2807	641	33.3	71.4	188	47.7	623	2344	131.5	2301	15821
1972	332.1	135.4	101.4	261	15.4	6.0	57.5	673	558	851	106.4	1202	11087
1973	2440	130.0	157.1	946	896	12.4	43.9	12.3	335	951	867	2737	1272.9
1974	2485	112.2	1504	441	21.7	87.9	01	3.4	21.4	45.8	73.9	282.3	1091.7
1975	184.2	248.8	124.5	41.6	577	11.5	160	00	189	941	122.0	171.1	10904
1976	231.6	1872	154.3	1153	156.4	61.8	107.1	1018	143.0	51.9	1854	276.9	17727
1977	806	111	685	445	131	159	92	57	202	15.5	29.9	31.2	3454
1978	1336	34.6	40.9	152	33.2	283	87	91	10.8	37.3	406	44.4	4367
1979											350	35.8	
1980													
Average value													

Table 7.2

44	-	1.0799191	1.644386
53	-	0.8115044	1.7201593
53	-	0.6129273	1.7259116
59	-	0.4434958	1.7715875
61	-	0.2889324	1.7867514
63	-	0.1420895	1.8000294
64	-	0.0014721	1.8034571
68	-	0.1450286	1.8318698
68	-	0.2914030	1.8344207
71	-	0.4433944	1.8506462
76	-	0.6041408	1.8790959
76	-	0.7775458	1.8830934
81	-	0.9689280	1.906335
89	-	1.1861931	1.9489018
94	-	1.4422774	1.9722028
134	-	1.7611315	2.1258065
187	-	2.1961947	2.2723058
263	-	2.9175275	2.4199557

```
                *** KAIKI BUNSEKI ***

CASE   1

*** MOTONO HENSU LIST

    VAR.NO HENSU

       1   Y

       2   DRAIN

Y TO NICHISAIDAI URYO TO NO KANKEI(LOG(LOG-RAIN))

*** HENSU HENKAN LIST

    VAR.NO.HENSU     1   HENKAN    J

      1    Y         1      0      0

      2    DRAIN     2      5      0

*** YORIKOMI DATA   KOSU= 18

*** GOKEI TO SEKIWA
```

Calculation of annual maximum daily rainfall by Gumbel's method
(Calculation of probable daily rainfall)

$$\log(\log Q) = a + by$$

Q: Daily rainfall for random variable y (mm/24hr)

y: Normalized variable

Table 7.3

HEIKIN	0.51979840E+00	0.27642672E+00
1 Y	0.19772360E+02	0.75783456E+00
2 DRAIN	0.75783456E+00	0.30639892E-01

*** SOKAN GYORETU

	1	2
1 Y	0.99999984E+00	0.97364688E+00
2 DRAIN	0.97364688E+00	0.99999984E+00

*** GYAKU GYORETU

	1
1 Y	0.5057565E-01

*** BUNSAN BUNSEKI

SOURCE	O.F.	S.S.	M.S.	F
KAIKI	1	0.29046256E-01	0.0290	191.62
ZANSA	16	0.15936348E-02	0.0001	
ZENTAI	17	0.30639880E-01		

*** SOKAN KEISU

R 0.736 KIYO RITU 94.8 PERCENT

*** KAIKI KEISU

NO	HENSU	HYOJUN-B	B	S.E.	T	HANTEI
1	Y	0.97364704E+00	0.38327976E-01	0.22444256E-02	17.1	**

KAIKI JOSU = 0.25650392E+00

500 log(log Qmix) = 0.25650392+0.038327976y

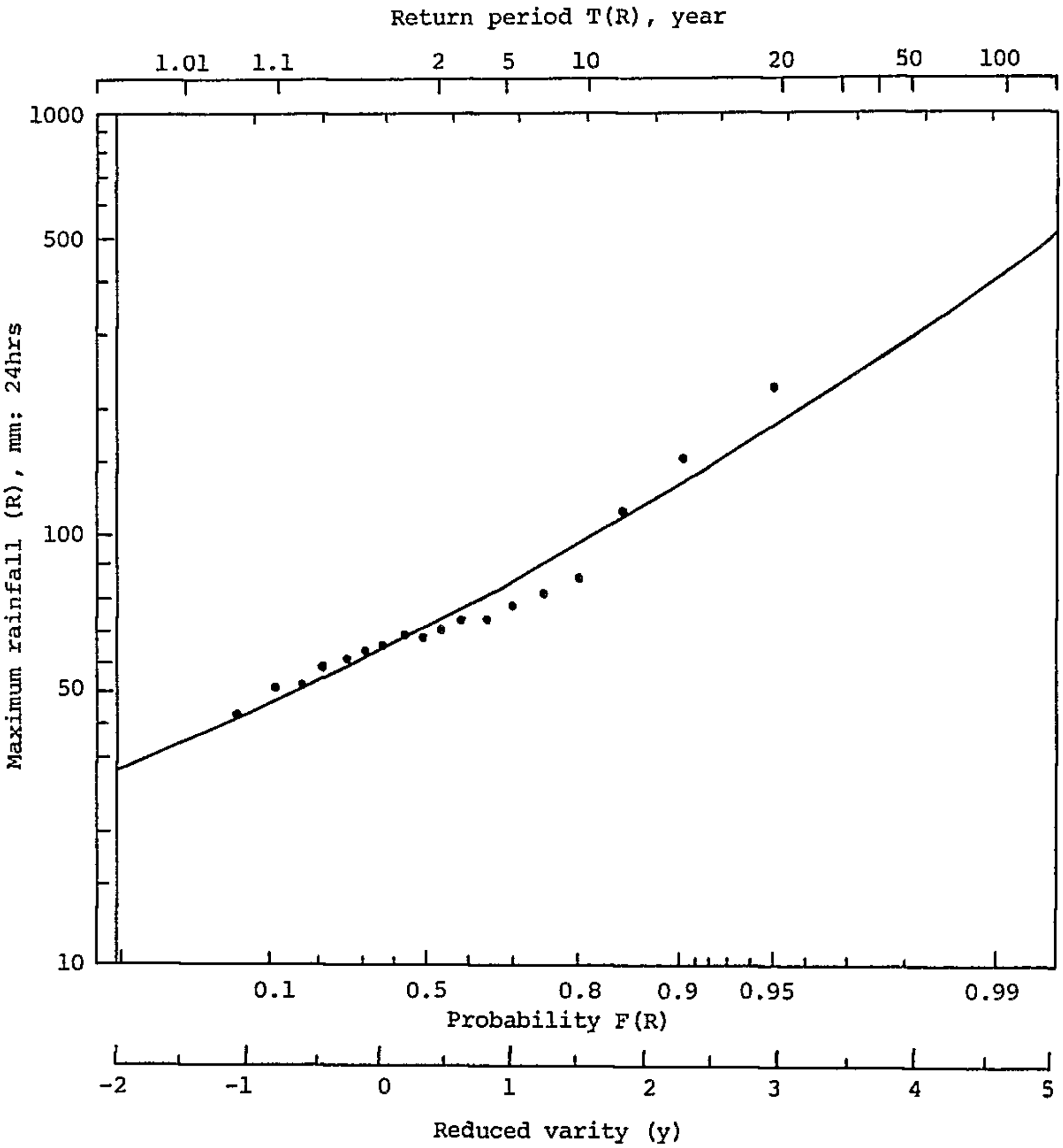
100-year probable rainfall is y = 4.6101526
log(logQ(100)) = 0.4332017
logQ(100) = 2.71145
Q(100) = 514.57mm/day

log(logQ(50)) = 0.256504+0.038328×3.921942
Q(50) = 356mm/day

y	Q	
-1	1.65265	45
0	1.805	64
1	1.9717	94
2	2.1536	142
3	2.3523	225
4	2.5693	371
5	2.7849	609
-2	0.179848	33

See Fig. 2

Fig. 6


Return period T(R), year
1.01
1.1
2
5
10
20
50
100
1000
500
100
50
10
Maximum rainfall (R), mm: 24hrs
0.1
0.5
0.8
0.9
0.95
0.99
Probability F(R)
-2
-1
0
1
2
3
4
5
Reduced varity (y)

(2) Flood peak discharge

Location	Area	100-year probable hourly rainfall	Characteristic coefficient for the same	Runoff coefficient	Peak flood	Calculation formula for the same
	A(ha)	γ (mm/hour)	β	f	Q(m³/sec)	$Q=\frac{1}{360}\times\gamma\times\beta\times f\times A$ (Rational formula)
BACIA A	37.50	179.0	30 min. 100 years 1.587	0.4	11.8	$\frac{1}{360}\times197.0\times1.587\times0.4\times37.5$
BACIA B	36.68	179.0	30 min. 100 years 1.587	0.4	11.6	$\frac{1}{360}\times179.0\times1.587\times0.4\times36.68$
BACIA C	40.73	179.0	30 min. 100 years 1.587	0.4	12.9	$\frac{1}{360}\times179.0\times1.587\times0.4\times40.73$
BACIA D	56.04	179.0	30 min. 100 years 1.587	0.43	19.0	$\frac{1}{360}\times179.0\times1.587\times0.43\times56.04$
Lysimeter R	0.01	179.0	10 min. 100 years 3.302	1.0	0.016	$\frac{1}{360}\times179.0\times3.302\times1.0\times0.01$
Runoff experiment a	Gradient 32.7% 0.06	179.0	10 min. 100 years 3.302	1.0	0.100	$\frac{1}{360}\times179.0\times3.302\times1.0\times0.06$
Runoff experiment b	Gradient 26% 0.06	179.0	10 min. 100 years 3.302	1.0	0.100	$\frac{1}{360}\times179.0\times3.302\times1.0\times0.06$
Runoff experiment c	Gradient 31.4% 0.06	179.0	10 min. 100 years 3.302	1.0	0.100	$\frac{1}{360}\times179.0\times3.302\times1.0\times0.06$

Note 1: $\gamma = \frac{R}{24}\left(\frac{24}{T}\right)^{\frac{2}{3}}$,

$$= \frac{515}{24}\left(\frac{24}{1}\right)^{\frac{2}{3}} = 179.0$$

where R: 100-year probable daily rainfall = 515mm/day

The base of calculation is as per attached sheet.

T: Duration of rainfall

Note 2: $$\beta_{100}^{30} = \frac{\frac{R}{24}\left(\frac{24}{\frac{1}{2}}\right)^{\frac{2}{3}}}{\frac{R}{24}\left(\frac{24}{1}\right)^{\frac{2}{3}}} = \left(\frac{\frac{24}{\frac{1}{2}}}{\frac{24}{1}}\right)^{\frac{2}{3}} = 2^{\frac{2}{3}} \fallingdotseq 1.587$$

where β^{30}_{100} is a characteristic coefficient for 100-year probable 30-minute rainfall.

$I_N = \beta_N \times R_N$, I: Rainfall intensity

β: Characteristic coefficient,

R: 1-hour rainfall

It was decided to calculate the peak flood, using the mean rainfall intensity within the time until precipitation reaches the observation point, and a value of 30 minutes was adopted as the time of concentration, in light of the watershed area, channel state, etc.

Note 3: β^{10}_{100} is a characteristic coefficient to obtained with the times of concentration as 10 minutes since the catchment area is small, with the same consideration as done for 2.

$$\left(\frac{\frac{24}{\frac{1}{6}}}{\frac{24}{1}}\right)^{\frac{2}{3}} = 6^{\frac{2}{3}} \fallingdotseq 3.302$$

Note 4: For f, surface conditions, gradient, soil, duration of rainfall etc. were considered, to adopt 0.4 for forest land and 0.5 for other land, hence 0.4 for Bacia A of C and 0.4 × 2/3 + 0.5 × 1/3 = 0.43 for Bacia D. For R, a, b and c, 1.0 was adopted, subject to additional calculation of overland flow and filtration flow.

(3) Size of structure

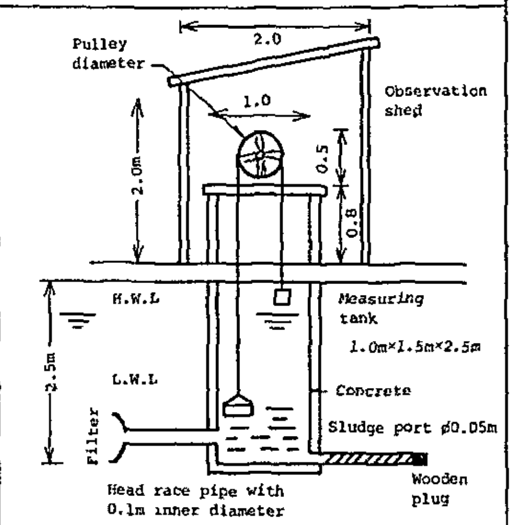
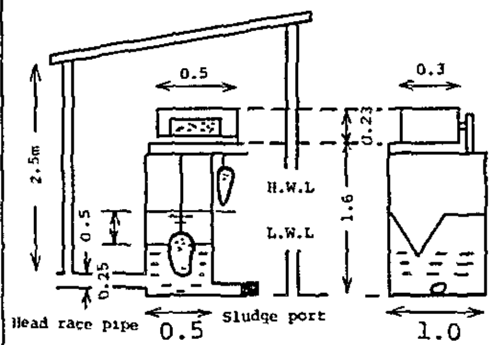
Site	Area ha	Peak flood m^3/sec	Structures of open channel, flood channel, etc.	Allowable discharge Q ..... m^3/sec
BACIA A	37.50	11.8	Flood channel of soil saving dam Bottom width B = 8.0m Top width B' = 10.0m Side slope 10% Height h = 1.0m Dam crest thickness b = 1.0m Overflow depth h' = 1.0m $\frac{h'}{b} = 1.0$	$Q = \frac{2}{15} \cdot C \cdot h \cdot \sqrt{2gh} \cdot (3 \times B + 2 \times B')$ C = Approximately decided as C = 0.6. $\frac{2}{15} \times 0.6 \times 1.0 \times \sqrt{2 \times 9.8} \times 1.0 \times (3 \times 8.0 + 2 \times 10.0) = 15.6$ Correction value for wide top dam $QC = (0.7 + 0.185 \times \frac{h'}{b}) \times Q$ $= (0.7 + 0.185 \times \frac{1.0}{1.0}) \times 15.6 = 13.8$
			Gauging dam (square weir with V-notch) • Square dam Width B = 8.0m, Straight side Height h = 1.0m Dam crest thickness b = 1.0m • V-notch $\theta = 90°$ Side length ℓ = 1.0m Height $h' = \cos\frac{\theta}{2}\ell = 0.7071m$ Top width $B' = \sin\frac{\theta}{2}\ell \times 2 = 1.414m$	$Q = \frac{2}{3} C \cdot \sqrt{2g} \times B \cdot h^{\frac{3}{2}}$ $= \frac{2}{3} \times 0.6 \times \sqrt{2 \times 9.8} \times 8.0 \times 1.0^{\frac{3}{2}} = 14.2$ Correction for wide top dam $Qc = (0.7 + 0.185 \times \frac{1.0}{1.0}) \times 14.2 = 12.6$ If water depth h = 0.7071 $Q = \frac{8}{15} \cdot C \cdot \tan\frac{\theta}{2} \sqrt{2g} \cdot h'^{\frac{5}{2}}$ $= \frac{8}{15} \cdot 0.6 \times \tan 45° \sqrt{2 \times 9.8} \times 0.7071^{\frac{5}{2}} = 0.6$ If water depth h° = 1.7071 $Q_1 = \frac{8}{15} \cdot C \cdot \tan\frac{\theta}{2} \sqrt{2g} \cdot h°^{\frac{5}{2}} - \frac{4}{15} \cdot C \cdot \sqrt{2g} \cdot \tan\frac{\theta}{2} h^{\frac{5}{2}} \times 2 - \frac{2}{3} C \sqrt{2g} \times B' \cdot h^{\frac{3}{2}}$ $= \frac{8}{15} \times 0.6 \times \tan 45° \sqrt{2 \times 9.8} \times 1.7071^{\frac{5}{2}}$ $- \frac{4}{15} \cdot 0.6 \sqrt{2 \times 9.8} \cdot \tan 45° \times 1.0^{\frac{5}{2}} \times 2$ $- \frac{2}{3} \times 0.6 \times \sqrt{2 \times 9.8} \times 1.414 \times 1.0^{\frac{3}{2}}$ $= 5.394 - 1.417 - 2.504 = 1.473$ Total discharge $Q^T = Qc + Q_1$ $= 12.6 + 1.47 \therefore 14.1 m^3/sec$

Site	Area ha	Peak flood m^3/sec	Structures of open channel, flood channel, etc.	Allowable discharge Q ..... m^3/sec
BACIA B	36.68	11.6	Open channel Bottom width B = 0.5m Top width B' = 4.5m Side slope 10% Height h = 2.0m Water depth h' = 1.5m including an allowance of 0.5m Length L = 8m Grade I = 1% = 0.01	Mean velocity $V = \frac{1}{n} \cdot I^{\frac{1}{2}} \cdot R^{\frac{2}{3}}$ (m/sec) (Manning formula) n = Coefficient of roughness = 0.015 I = Channel grade = 0.01 R = Hydraulic radius $= \frac{A}{P} = \frac{3.0}{4.74}$ = 0.633 A = Wetted area $= \frac{0.5+3.5}{2} \times 1.5$ $= 3.0m^2$ P = Wetted perimeter $= 0.5+1.5\times\sqrt{2}\times 2$ = 4.74m $V = \frac{1}{0.015} \times 0.01^{\frac{1}{2}} \times 0.633^{\frac{2}{3}} = 4.9$m/sec $Q = V \cdot A = 4.9 \times 3.0 = 14.7m^3/sec$
BACIA C	40.73	12.90	Open channel Bottom width B = 0.5m Top width B' = 4.5m Side slope 10% Height h = 2.0m Water depth h' = 1.5m including an allowance of 0.5m Length L = 20m Grade I = 1% = 0.01	Mean velocity $V = \frac{1}{n} \cdot I^{\frac{1}{2}} \cdot R^{\frac{2}{3}}$ (m/sec) (Manning formula) n = Coefficient of roughness = 0.015 I = Channel grade = 0.01 R = Hydraulic radius $= \frac{A}{P} = \frac{3.0}{4.74}$ = 0.633 A = Wetted area $= \frac{0.5+3.5}{2} \times 1.5$ = 4.74m $V = \frac{1}{0.015} \times 0.01^{\frac{1}{2}} \times 0.633^{\frac{2}{3}} = 4.9$m/sec $Q = V \cdot A = 4.9 \times 3.0 = 14.7m^3/sec$
BACIA D	56.04	19.0	Flood channel of soil reserving dam Bottom width B = 10.0m Straight side Height h = 1.2m Thickness b = 1.0m	$Q = \frac{2}{3} C \cdot \sqrt{2g} \times B \times h^{\frac{3}{2}}$ C = Approximately decided as C = 0.6. $= \frac{2}{3} \times 0.6 \times \sqrt{2 \times 9.8} \times 10.0 \times 1.2^{\frac{3}{2}} = 23.3$ Correction value for wide top dam $QC = (0.7+0.185 \times \frac{h}{b}) \times Q$ $= (0.7+0.185 \times \frac{1.2}{1.0}) \times 23.3 = 21.5$
			Flood channel and open channel of regulating reservoir dam Bottom width B = 1.0m Top width B' = 5.0m Side slope 10% Height h = 2.0 Water depth h' = 1.5m including an allowance of 0.5m	Mean velocity $V = \frac{1}{n} \cdot I^{\frac{1}{2}} \cdot R^{\frac{2}{3}}$ (m/sec) (Manning formula) n = Coefficient of roughness = 0.015 I = 0.01 R = Hydraulic radius $= \frac{A}{P} = \frac{3.75}{5.24}$ = 0.716

Side	Area ha	Peak flood m^3/sec	Structures of open channel, flood channel, etc.	Allowable discharge Q ..... m^3/sec
			Length L = 20m Grade I = 1% = 0.01.	A = Wetted area = $\frac{1.0+4.0}{2}\times 1.5$ = 3.75 P = Wetted perimeter = $1.0+1.5\times\sqrt{2}\times 2$ = 5.24 $V = \frac{1}{0.015}\times 0.01^{\frac{1}{2}}\times 0.716^{\frac{2}{3}} = 5.34$ $Q = V\cdot A = 5.34\times 3.75 = 20.0m^3/sec$
BACIA D Lysi- meter	0.01 10m×10m ×2.5m	0.016 Seapage water	Lysimeter depth 2.0m Inside top space 0.2m Soil layer depth 1.5m Bottom permeable layer 0.3m	Peak flood of seapage water Q = A×v A: Area = $100m^2$ v: Mean infiltration rate = 1×10^2cm/sec $100\times\frac{0.01}{100} = 0.01\ m^3/sec$
			Water pipe (hard polyvinyl chloride pipe) Inner diameter D = 0.1m Grade I = 3% = 0.03 (including 1% loss of head by curve, etc.)	Q = a×v a: Wetted area = $\frac{\pi D^2}{4} = \frac{3.14\times 0.1^2}{4}$ $= 8\times 10^{-3}$ v: Mean velocity $v = \frac{1}{n}R^{\frac{2}{3}}\cdot I^{\frac{1}{2}}$ n = 0.01, $R = \frac{D}{4} = \frac{0.1}{4}$ I = 0.02 ((Excluding loss of head) $= \frac{1}{0.01}\times(\frac{0.1}{4})^{\frac{2}{3}}\times 0.02^{\frac{1}{2}} = 1.2m/sec$ $Q = 8.0\times 10^{-3}\times 1.2 \fallingdotseq 0.01m^3/sec$
			V-notch θ = 60° Side length ℓ = 0.2m Height h = $\cos\frac{\theta}{2}\ell$ = 0.1732m Top width B = $\sin\frac{\theta}{2}\ell\times 2$ = Sin30°×0.2×2 = 0.2m	$Q = \frac{8}{15}\cdot C\cdot\tan\frac{\theta}{2}\sqrt{2g}\cdot h^{\frac{5}{2}}$ $= \frac{8}{15}\times 0.6\times\tan 30°\sqrt{2\times 9.8}\times 0.1732^{\frac{5}{2}}$ $= 0.01m^3/sec$
BACIA D Slope flow experi- ment Common for a, b and c	0.06 20m×30m 1.2m deep	0.1 Overland flow and inter-flow	Socket for water and soil Bottom width 0.8m Side slope 2% Height 0.8m Top width 1.12m Grade 0% Length 20.0m Total capacity $= \frac{0.8+1.12}{2}\times 0.8\times 20$ $= 15.36m^3$ Sediment shall be measured and eliminated about 6 times a year.	Sediment discharge Bare land $0.03m\times 600m^2 = 18m^3$ Grass land $0.015m\times 600m^2 = 3m^3$ Forest land $0.001m\times 600m^2 = 0.6m^3$

Side	Area ha	Peak flood m^3/sec	Structures of open channel, flood channel, etc.	Allowable discharge Q ..... m^3/sec
			V-notch $\theta = 60°$ Side length $\ell = 0.5m$ Height $h = \cos\frac{\theta}{2}\ell = 0.433m$ Top width $B = \sin\frac{\theta}{2}\ell \times 0.5m$	$Q = \frac{8}{15} \cdot C \cdot \tan\frac{\theta}{2}\sqrt{2g} \cdot h^{\frac{5}{2}}$ $= \frac{8}{15} \times 0.6 \times \tan 30° \sqrt{2 \times 9.8} \times 0.433^{\frac{5}{2}}$ $= 0.1m^3/sec$
			Water pipe (hard polyvinyl chloride) Inner diameter $D = 0.25m$ Grade $I = 3\%$ (including 1% loss of head)	$Q = a \times V$ a: Wetted area $= \frac{\pi D^2}{4} = \frac{3.14 \times 0.25^2}{4}$ $= 0.05m^2$ v: Mean velocity $v = \frac{1}{n} R^{\frac{2}{3}} \cdot I^{\frac{1}{2}}$ $n = 0.01,\ R = \frac{D}{4} = \frac{0.25}{4}\quad I = 0.02$ $v = \frac{1}{0.01} \times (\frac{0.25}{4})^{\frac{2}{3}} \times 0.02^{\frac{1}{2}} = 2.3m/sec$ $Q = 0.05 \times 2.3 = 0.12m^3/sec$

(4) Structural standard of water-gauge, etc.

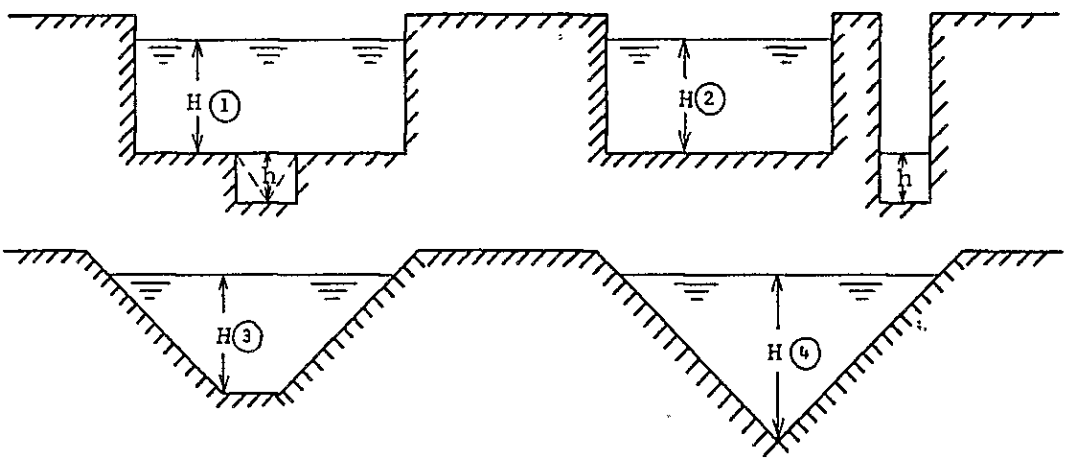
Location	Peak flood m^3/sec	Stage variation cm	Gauging facilities	Water-gauge	Incidental equipment
BACIA A	11.8	0 ∿ 171	Gauging dam Right-angled V-notch Side length 1.0m Square weir, Height 1.0m	Suiken 62 type stage recorder Type I-021 float Measuring range 0-150cm Paper speed 18mm/hr Powered by spring	
BACIA B	11.6	0 ∿ 150	Open channel with soil reserving dam Bottom width 0.5m Height 2.0m Side slope 10%	Recording period 1 month Float diameter 250mm Dimensions 553(w)×310(h)×255(d)(mm) Weight 23kg	
BACIA D	19.0	0 ∿ 150	Open channel with soil reserving and regulating dam Bottom width 1.0m Height 2.0m Side slope 10%	Pulley diameter 313mm	Measuring tank is made of concrete, being 20cm thick. Float, 25cm diameter and 10cm heigh
BACIA D Lysimeter Common for a, b and c	0.01	0 ∿ 17.3	60° V-notch Side length 20cm	K type stage recorder Type 1-0200 series Float Measuring range 0-50cm stage Paper speed 48mm/day Powered by spring Recording period 7 days	
BACIA D Slope flow experiment Common for a, b and c	0.1	0 43.3	60° V-notch Side length 50cm	Float diameter 180mm Dimensions 502(w)×250(h)×294(d)(mm) Weight 12.7kg	Measuring tank made of steel plate, 0.5(w)×1.0(l)×1.6(h), about 3mm thick Water supply device like an automatic waterer for poultry should be used, to keep a constant stage during no rain. (about 0.3 lit/day).

[Reference]

on the structure of the open channel of Area D:

(1) Since solid foundation ground cannot be obtained with a torrent gradient of about 1%, it is difficult to construct a high dam. And since a sufficient head cannot be obtained, an open channel system was selected, but a gauging dam system (sqaure weir with V-notch).

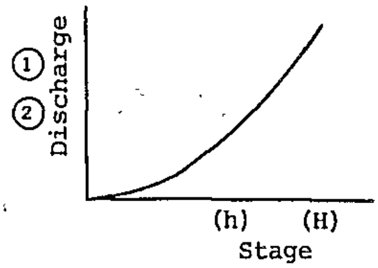
(2) For open channel system, there are double section method, separation method and triangular section method as shown below, as methods for measuring both low flow and flood discharge promptly and accurately.

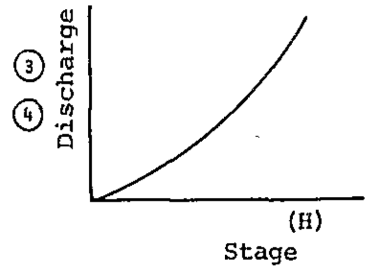


(3) Merits and demerits of respective channel types

Types ① and ② show double section method. When the head is at a low stage of h or less, measurement can be made relatively accurately, but when the head is slightly lower or higher than h, the relation between level and discharge cannot be secured accurately.

The rating curve is as follows.





Types ③ and ④ show single section method. In both low water and flood discharge, the change of level and the change of discharge are gradual.

(4) Reasons for adoption of type ③

For drainage area D, it was planned to adopt type ② at first. However, the discharges is normally in a range of 0.5 to 1.0m^3/sec in the dry season, and the discharge is expected to always change between 1.0 and 5.0m^3/sec in the rainy season with a peak discharge of 19m^3/sec. If double section method is adopted in this case, a heavy fluctuation of discharge curve appears around 1m^3/sec.

In time of flood, the flow velocity changes according to stage difference. Therefore, in case of type ①, the measurement of mean velocity is difficult. In case of type ②, the change of velocity causes head difference, and at the intake of the main channel and the sub-channel, irregular eddy currents are caused, threatening to affect the measurement accuracy.

In addition, in case of type ②, two stage recorders must be provided, involving the problem of cost.

For these reasons, it was decided to adopt type ③, easy in construction and measurement, and preferable in accuracy.

This type seems to be widely adopted in Switzerland and other country.

(5) Dam stability

Computer was used to calculate stability, applying the specifications given by the "Specifications of the Profile of the Gravity-type Concrete Dam Soil Retaining Concrete Works" (published by the Forest Civil Engineering Consultants). (See attached data).

3-4 Design Estimation

Design Plans and Drawings are shown in the "III. Implementation Design Plans".

Costs were estimated on the assumption that the Forestry Institute will be directly in charge of construction with unit requirement and unit costs determined according to the condition of the site. As regards labor costs, only the site allowance for personnel engaged in construction works were appropriated and unit material costs were based on the price list, Construcao São Paulo, 4 de Agosto, 1980.

The rates of exchange were: 53 cr/$, 224 yen/$ and ¥4.23/cr.

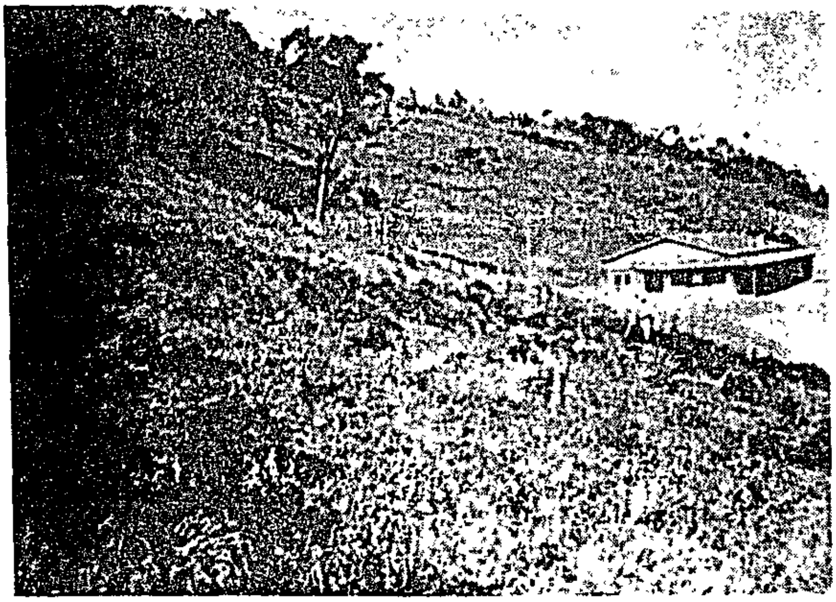
The total costs were estimated to be ¥57 million, of which a total of ¥20 million is allocated to the model facilities in Area D to be implemented in fiscal 1980.


Location at the gauging dam in Area A


Location of the gauging dam in Area B

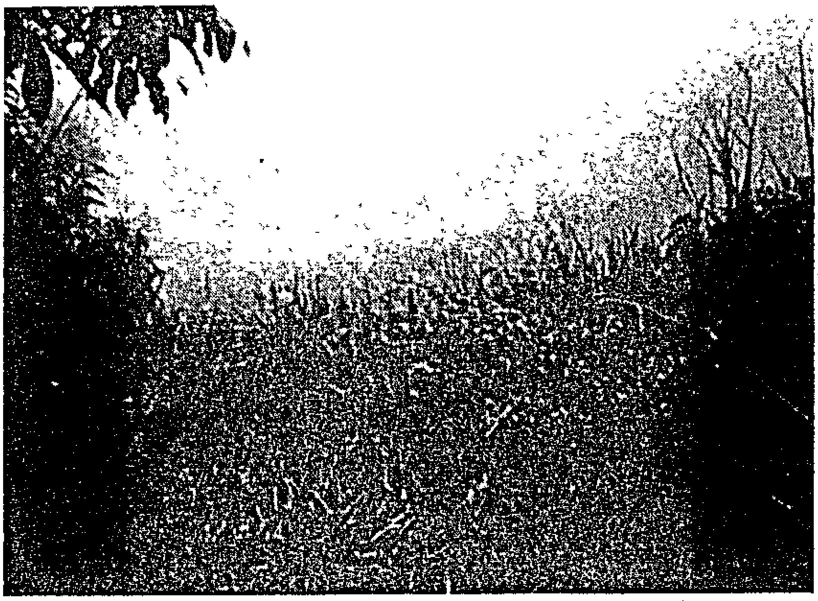
Location of the gauging dam in Area B (riverbed)

Condition of the riverbed in Area C



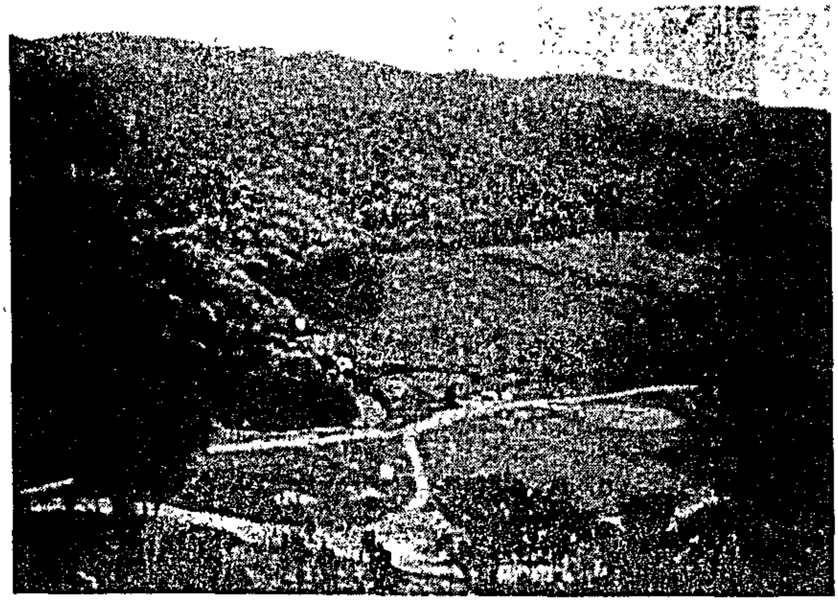
Proposed site for slope runoff test

Location of the gauging dam in Area D

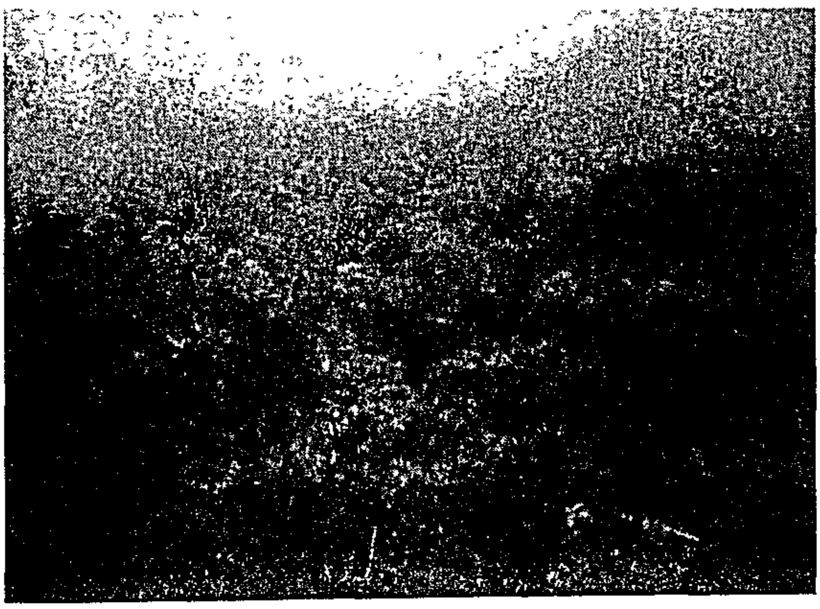


Moor in the upper reaches of the D basin

Middle reaches of the D basin



Condition of the xposed section in Area D



Stand type in the upper reaches of the D basin
(second growth)

4. Study on Simple Soil Conservation Works

4.1 Objectives

It is said that the São Paulo area will have the densest and most comfortable dwelling region in the world by the beginning of the 21st century.

The area is blessed with many favorable conditions such as comfortable climate throughout the four seasons, vast hilly highlands, many natural good ports, spacious arable land extending around, aboundant mineral resources, and excellent human resources.

However, several mountains rise in parallel to the coastline near the sea, and because of this, rainfall comes mainly close to the seashore. In addtion, due to the rainfall pattern peculiar to a subtropical area, rainfall also happens hourly and seasonally.

The mean precipitation of the entire area is about 1,600mm per year, but the duration of bright sunshine is long (average 150 hours per month), making the annual mean transpiration 1,200mm or more. Thus, the problem of conservation of "water and soil" is brought to the attention as the most important problem in watershed management.

The simple soil conservation is an important watershed management plan, the target of this research project, and definite plans and construction methods can be formulated only based on the results of research made in the respective areas in the future.

Therefore, at the present stage, studies are made on the basic orientation of soil conservation measures such as erosion control, prevention of water pollution, recovery of devastated land and prevention of such devastation, all according to the local administrative demand for water and soil conservation.

4.2 Causes of Devastation and Countermeasures

(1) Causes of devastation

Devastated mountainous land can be classified into infertile land (land shifting to devastated land), bare land, slided land, and creeping land.

Infertile land is formed by the deterioration of physico-chemical properties (water-holding capacity, pH, etc.) with the soil humus lost by forest fire, excessive felling, over-grazing, prescribed burning, over-clearing, etc. If it is left as it is, soil erosion starts, and the land will become bare land, etc.

Bare land refers to land which the top soil is running off, and B or C horizon is exposed. It often occurs in the areas of saprolite and Tertiary siltstones. If it is left as it is, heavy erosion is caused by stormy rain, such as surface erosion, gully erosion and rill erosion. Especially, in sandy soils, soils run off heavily.

Land slide occurs on a steep slope with relatively deep soil layer, mainly by stormy rain causing piping phenomena of interflow, pore pressure of seepage water, head erosion of wild stream, erosion of torrent, etc.

Land creeping is mainly caused by geological factors, being induced by artesian groundwater, erosion of spur, excavation at the toe of slope, etc.

Apart from land creeping, the form of devastation greatly depends upon soil texture.

Clayey soils are strong against the erosion by surface flow. If they hold moderate moisture, the cohesion is large, and even an almost vertically cut face can be held temporarily.

However, if they become dry, they are solidified, not allowing the easy invasion of vegetation, and at the time of storm, gullies and rills are formed, to promote soil runoff.

On the contrary, sandy soils are excellent in permeability. Therefore, when soil-covering vegetation is lost, depriving the soil of the binding force of the root system, the soils are heavily eroded by overland flow, forming deep gullies.

Since sandy soils are excellent in aeration and permeability, being suitable for growing plants in view of moisture economy, the vegetation can be revived relatively easily if the concentration of overland flow is prevented of if simple turfed channels, etc. are constructed, preventing gully erosion.

The relation between soil cohesion and soil erosion may be developed to a geological problem. For example, in the case of granites, an area of granodiorites containing lots of colored minerals and producing more clay minerals, is generally stronger to surface erosion than an area of biotite granites, and therefore, tends to be steep in the mountainside.

This is, for example, the case with a place in the middle latitude area of Japan where weak podsolic soils are affected by frost heaving. It is unknown whether this applies directly to the São Paulo area where rather latsolic soils are being formed.

In almost all the area of Paraiba Heightland and Basic de Taubate, virgin forests (Mata) were cut out to cultivate coffee at the beginning of the last century, and a coffee kingdom which could be boasted in the world was constructed on the thick humus layer and fertile land with excellent physicochemical properties preserved under dense forests.

However, this prosperity did not last even to the end of the century, when the coffee plantations moved to the hilly land in the north, in search of the violet fertile land, terra rossa (calcareous), the land left behind being mostly grass land, used for extensive grazing, and partially remained as agricultural land or planted forest of eucalyptusspp. etc.

The reason for the failure of coffee cultivation in less than one century is said to have been the decline of land productivity.

The reasons behind and the mechanism of the decline of land productivity are considered below.

This problem is highly concerned with the watershed magagement conservation of water and soil now being studied, and may determine the orientation of the study.

The decline of land productivity means that the land became unsuitable for coffee cultivation. What land is suitable for coffee cultivation (meteorological conditions excluded)? The answer is simple.

It is the forest land called "Mata" now remaining in the provincial forests of the Paraib a Paraiba Heighland and the secondary forests not more than decades of years after cutting.

This is, they are the samples named A to D of the soil profiles surveyed this time.

Of the above, A to C are in secondary forest, and D1 to 3 are in pasture.

The soils are intermediate type between acid latsol and reddish yellow podsol. A horizon is weakly acid and B horizon is neutral.

A horizon is blackish brown and rich in humus, being 20 to 30cm thick in forest and about 10cm thick in pasture.

The soils are sandy, though slightly clayey, and when moderately moist, they are soft, with root systems reaching about 1m.

What land is not suitable for coffee cultivation?

Near the experimental base of Kunha, soils of bare land were examined. A horizon is about 3cm, and B horizon is yellowish white and soild, showing pH5.5, being judged as acid latsol.

The soils must be the very soils which became unsuitable for coffee cultivation.

The soils of the Paraiba Heighland have a nature of being quickly solidfied, and to turn acid, when exposed to sunshine and air.

This is due to the chemical and physical properties of the soils. Only when covered with raw humus layer, with the surface shielded from the direct rays of the sun by crowns, etc, soils favorable for plant growth and water and soil conservation are created.

Judging from the fact that coffee cultivation moved to the land of highly calcareous terra rossa (hilly land on the north, with far smaller rainfall than in the Paraiba Heighland), the land productivity is supposed to be decisively affected by soil acidity rather than fertility components.

When the land was reclaimed for coffee plantations, the forests had to be cut, together with prescribed burning. Therefore, the humus layer on the surface was probably lost at that time. Since coffee was still cultivated for about one century, the deterioration of the soil must have progressed gradually, eventually reaching the decisive moment, necessitating withdrawal.

Since the remaining land of coffee plantations became grass land, already about one century has passed.

It is appropriate to consider that the deterioration of physicochemical properties of soils is faster in grass land than in coffee plantations.

This indication already appears in some regions. Deserted grass land called Canpos, and shrubland of low quality called Cerrado, may correspond to such regions.

If grass land becomes useless, infertile land and bare land remain, and soil texture is deteriorated more and more, to from a devastated complex. It is apparent that this causes grave problems not only in land use but also in water and soil conservation.

Places threatened to be devastated such as steep slope and infertile land must be made into forests as soon as possible, using the power of nature for starting soil improvement by humus. Peat moss, bark manure, or any other fertilizer or soil conditioner should be used, to artificially improve the physicochemical properties of soils. Either of these methods should be selected.

(2) Prevention measures against devastation

The prevention against devastation includes restoration from the state of being devastated (infertile land and the land in the process of devastation) as well as preventive measures taken before devastation occurs.

With regard to disasters, prevention is most important and is the best way in light of both effectiveness and cost.

Firstly, for prevention against devastation, causes of devastation should be studied to clarify the mechanism, and then actual local conditions should be examined, to make a list of places to be improved, planning and executing the most effective measures for the respective conditions.

Causes of Devastation and Countermeasures (Examples)

Item		High possibility of devastation	Medium possibility of devastation	Low possibility of devastation
Underlying rocks		Mylonite granties, Diabases, Andesites, Sandstones, Silt-stones (Taubate layer)	Mica schists, Gneisses, Quartz schists, Granites	Alluvium (sediment)
Topographic features	Longitudinal grade	30° or more	20° - 30°	20° or less
	Cross sectional form	Catchment type	Balanced type	Convex type
Soil texture	Depth to foundation ground surface	1m or less	1m - 2m	2m or more
	Soil texture	Acid latsol	Reddish yellow podsol	Others
	Grading	Sandy soils		Cleyey soils
	Acidity	pH5.5 or less		6 or more
Countermesures	Natural forest, secondary forest	Prohibition of cutting, extension of cutting age, improvement of forest type	Restriction of cutting, extension of cutting age, change of tree species	
	Afforestation	Long cutting period, change of tree species to those desirable for conservation, planting of soil improving trees, fertilization, tending	Selective cutting, change of tree species, tending, fertilization, control of cutting and logging methods	
	Brushland, Cerrado, etc.	Tending of ground cover, fertilization, tending, replanting		
	Pasture, Campos	Change to forest land, afforestation, fertilization, tending	Alteration of pasture and forest, combined forest and grazing (with soil improving trees), terrace (bench-out) works, fertilization, improvement of grass secies	Fertilization, improvement of pasture

To study the mechanism of devastation, in addition to basic studies, it is practical to examine and analyze the longitudinal sectional form (grade) and cross sectional form (trap efficiency) of mountainside, geologic structure, soils (physicochemical properties especially, pH, permeability, grading distribution, soil thickness, humus content, soil microorganisms, etc.), vegetation (forest type, grass species), land use conditions, etc., and to classify and arrange them neatly, considering practical countermeasures.

Survey items and contents, and concrete countermeasures are, for example, as shown in the following stable.

Therefore, for studying, a list of matters relating to survey contents and countermeasures should be made, to derive proper and appropriate measures according to the local situations.

Devastation prevention measures are often promoted by way of legal restrictions (protected forest) or administrative guidance (subsidy system), etc.

Therefore, it is important to secure the understanding of the rightfull persons of land, and to communicate with local inhabitants.

(3) Recovering measures for devastated land

Devastation should be prevented beforehand. However, if devastation is caused by abnormal natural phenomena, or by topographical, geological or other causes, with no natural recovery expected, afforestation for recovery should be made as early as possible, to prevent soil layer runoff and soil texture deterioration.

To recover devastated land such as bare land, slided land and creeping land by afforestation, usually a minimum structure of civil engineering is often required.

The land after sliding, loses it's weathered top soil to expose B or C horizon. In case of steep area, surface water is concentrated to flow down, to form gullies, and the erosion is repeated.

Even if greening works are made, the result is only the prevention of sediment transport of the very surface layer by herbs of gramineare. Therefore, the dynamic stability of soil layer must be secured by sheathing, etc. and the erosion by surface flow must be prevented by channels or by such foundation works as bench-out and terrace.

In case of especially hard cleyey soils, weathered rocks, etc., bench-out or boring may be required for laying the fundation whorks for afforestation, or covering work may be required for shielding against the direct sunbeam, or preventing the sheet erosion of rainfall.

In general, we have peneplains topographically, with valleys not too dissected, and most cleyey soils are resistant against the erosion of surface flow, the gradient of torrents being gentle, providing little possibility of longitudinal and side erosion. Thus, mostly, the foundation work can be simple.

Type of devastation	Land slide and seepage water type collapse	Interflow type collapse (piping)	Gully erosion	Sheet erosion	Grazing pasture
Geological structure	Contact faces between diabases (dike rocks) and crystalline schists, etc.	Gneisses, Mica schists, Quartz schists, Granites, Diabases, Andesites	Taubate layer (sandstones), Gneisses, Mica schists, Diabases	Taubate layer (siltstones)	
Soil texture	Montmorillonite and illite clay	Sandy soil	Sandy soil, Cleyey soil, fill-up surface	Cleyer soil, cut surface	Cleyey soil
Gradient		20° or more	20° or more	30° or more	20° or more
Cross sectional form	Catchment form	Catchment form	Catchment form and balanced slope	Balanced and convex slopes	Catchment form
Recovery measures	Underdrainage, Boring drainage, Sheathing	Turfed channel work, vegetation sack work, wooden fence work, sandbag work, sodding work, simple terracing work, planting, wicker work	Turfed channel work, wicker work, bench-out, covering work, sandbag work, sodding work, simple terraching work, planting	Seeds spray work covering work, bench-out (terrace), planting	Wicker work, planting, fertilization

The types of devastation expected in the Paraiba and recovery measures for them are summarized below, in classification between foundation works and greening works.

(4) Soil conservation and forests

Apart from special area containing lime, it seems impossible to use a mountainside with a gradient of 20 degrees or more as farm and pasture land for a long time.

The reason is that together with humus runoff, soil deterioration and soil productivity decrease cause heavy soil erosion with time.

This phenomenon is especially remarkable in low latitude area.

The rice terraces most famous in the world are found in the Philippines. These are paddy fields on steep slopes (30 degrees or more) reclaimed 1000 years ago. In this case, the slopes themselves are not used, but used as horizontal steps.

The farm lands maintained for a long time in the steep area and the slope fields are used as terrace lands in many countries.

The climax type of the ecosystem in slopes of 2 degrees or more is mostly forests. The reason is that though dense forests consume water and nutrition for growth, they, on the other hand, produce lots of organic materiels such as dead branches and leaves which are made into fertilizers under the shade of crowns, physicochemically creating soils favorable for growth.

Therefore, in a long-range view, well managed forests produce lumber and demonstrate a large effect of conservation such as recharge of water source and prevention of sediment runoff, being most preferable as a type of Land use of slopes.

Forest soils of slopes once broken are very difficult to be restored.

The improvement of physicochemical properties of soils takes many years, being essentially different from that of agricultural management based on tillage and fertilization.

Forest management in mountainous steep slopes is, therefore, required to be made systematically in long-range prospects.

4.3 Design of Simple Soil Conservation Works

Of the mountainside foundation works executed in Japan, the design and specifications of simple works are shown in the attached sheet, together with those of mountainside greeing works.

1. Design of the Hillside Foundation Work

1.1 Gabion Wall

Design of the gabion wall should be made in accordance with the following items:

1) The gabion wall should be used when the ground is unstable and likely to be broken due to differential settlement or slipping.

2) The height of the wall is less than 2.0m in principle, and the gradient is 30% to 40% in principle.

3) Fixed stake should be of green log, and its standard size is 0.06m in top end diameter. The length of the stake is 1.8m to 3.0m depending upon the height of the structure.

4) Where poor ground soil condition occurs, fascine or gravel should be embedded to prevent sinking of the gabion wall.

5) Standard quantity of each material used should be determined by reference to the table shown below.

Standard Quantities of Materials Used for Gabion (Wire Basket) Wall (per 10m length)

Structure: Wire basket; 0.13m mesh size; galvanized iron wire #10; 10m long and 2.0m high				
Material	Shape & Size	Q'ty	Unit	Remarks
Wire baskets	4.0×0.5×1.2m	10.0		To be determined based on the structure of section and so forth.
Fixed stakes	Top end dia. = 0.16m; 3.0m long, pine green wood	10.0		One stake to be used every 2.0 m length. Center stake Prop stake
Galvanized iron wire	BWG #10	25.0	kg	12kg to be used per $10m^2$

Material	Shape & Size	Q'ty	Unit	Remarks
Filling stone	Dia.: 0.15 to 0.3m	25.0	m^3	$2.5m^3$ to be used per each wire basket.
Fascine or gravel				To be used as required for stabilizing foundation.

(1) Due to its pliability gabion wall is used for retaining earth where the ground is soft. It is particularly advantageous if much debris and gravel are found within the working area since these easily can be utilized for the work. One of the features of this structure compared to others is that it will not be extremely damaged if the foundation sinks or moves. However, its height must be as low as possible, maximum 2.0m.

(2) Two types of gabion walls, wire basket type and wire cylinder type, are generally used, and the type must be selected by taking account of terrain, soil, amount of sediments and so forth.

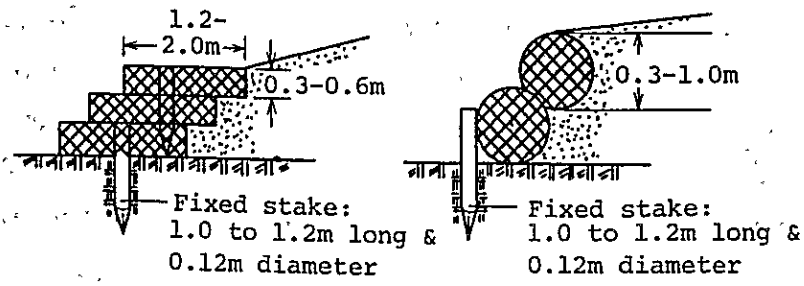
(3) Since the gabion quickly corrodes and breaks where a high acidity is present, gabion wall should not be used in design for such area if permanent effect is needed.

(4) The structure and work procedure are outlined below.

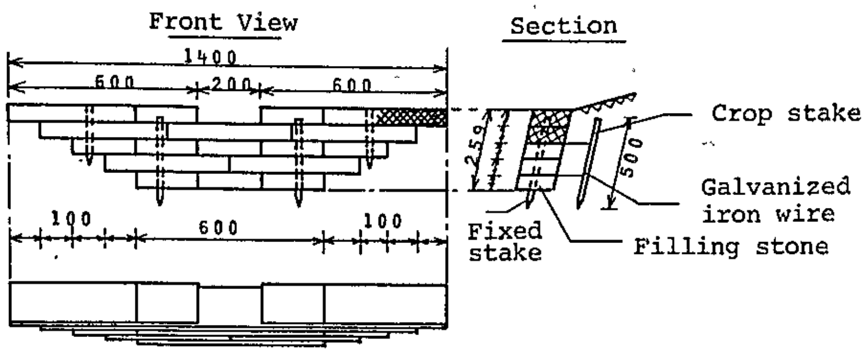
a. Completely fill up the wire basket or cylinder with filling stones, leaving no air gap. The size of filling stones should be sufficiently large so that they will not come out through mesh, and larger stones should be placed along the periphery of the wire basket or cylinder as far as possible.

b. After filling of stones, tightly fasten the opening with galvanized iron wire which has the same size and quality as those used for the basket of cylinder.

c. Drive the fixed stakes at 2.0m intervals and fix the wire basket or cylinder to the ground surface. Also connect them together with galvanized iron wire.



Example of Structure of Wire Cylinder Wall



Example of Structure of Wire Basket Wall

1.2 Log Piling Wall

Log piling wall should be designed in accordance with the following items:

1) Log piling wall should be used where the required strength of wall is relatively small and where the log material is easily available and the acquisition and delivery of other materials is difficult.

2) Height of wall is less than 1.0m in principle, and the gradient is from 30% to 50%.

3) Quality and specification of the material should meet the following requirements;

Fixed stake: Length: 0.7 to 1.0m Diameter: 0.09 to 0.10m

Crop log: Length: 0.7 to 1.0m Diameter: 0.1m minimum

Lateral log: Length: 2.0m minimum Diameter: 0.1m minimum

Species of tree: Species not easily rotten.

Stumps of miscellaneous bushes and trees, cuttings (approx. 0.3m long and 0.006 to 0.02m in diameter): High sprout ability needed.

(1) Log piling wall is suitable when adjustment of the gradient of slope is required in an area where a large strength is not needed as in the case of the foot part of small scale slided land. Since the logs are generally going to rot within several years, the height of wall should be as low as possible to prevent the other structures from being damaged even if the logs will be destroyed.

(2) Earth filled between logs should be fully stamped, stumps of miscellaneous bushes and trees and cuttings should be planted on the face of the slope to help on a quick recovery of vegetation. Also, some precautions are necessary since filled earth may run off if storm water flows down intensively.

Standard Quantities of Materials Used for Log Piling Wall (per $1.0m^2$)

Structure: Height: 1.0m maximum; Gradient: 40% (1:0.4)				
Material	Shape & Size	Q'ty	Unit	Remarks
Lateral logs	2.0m long, 0.1m dia.	2.5		
Crop logs	0.6m long, 0.1m dia.	7.5		
Fixed stake	0.9m long, 0.1m dia.	1.0		At 1.0m intervals
Stumps of miscellaneous bushes and trees	0.3 dia., 1.0m binding by straw rope	1.0	bundle	

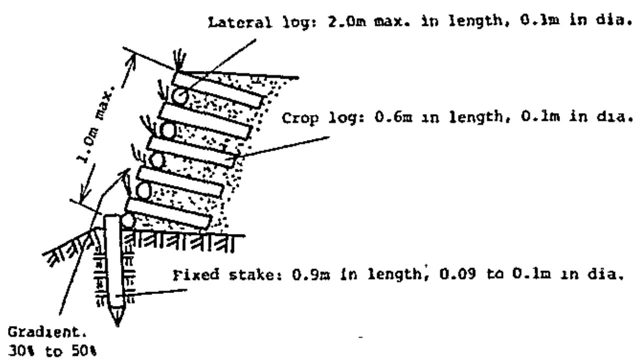
The structure and work procedure are outlined below.

a. After base excavation and grading, drive the fixed stakes vertically at 1.0m intervals, place the lateral logs in contact with these fixed stakes, place crop logs at 1.0m intervals in maximum over the lateral logs, and firmly tie the crop logs to the lateral logs with galvanized iron wire or bolts.

b. Fill up the gaps between lateral logs and crop logs with earth and stamp it.

c. Repeat the above procedure and stack the logs until predetermined gradient and height are obtained.

d. Embed the stumps and plant the twigs to the gap spaces created by the crop logs.



Example of Structure of Log Piling Wall

1.3 Concrete Board Wall

Concrete board wall should be designed in accordance with the following items:

1) This wall should be applied to an area where the rear earth pressure is small.

2) Wall height is 1.6m maximum in principle, and the gradient of wall is 30% (1:0.3) in principle.

3) Concrete boards and pipes used should conform to the JIS Standards. When soil concrete is used as filling material, soil concrete should be designed separately.

4) If the soil condition of the foundation ground is poor, reinforcing measures should be taken by using cobble stones and filling-up gravel.

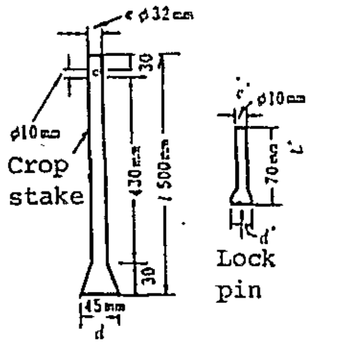
(1) Concrete board walls are widely used since the board is relatively light and convenient for transport and the wall can be easily built. However, since the wall cannot structurally withstand a high earth pressure, it is adopted to a small wall to be constructed for the purpose of correcting the grade and forming the basis of seeding.

(2) Wall height should be less than 1.6m (4 layers) in principle, and some distance should be maintained between two adjacent layers of boards to create a 30% to 50% grade for line connecting the surfaces of boards.

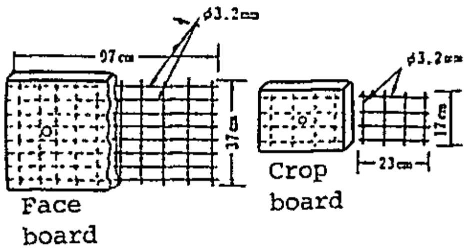
Standard Quantities of Materials Used for Concrete Board Wall (per 1.0m^2)

Structure: 1.6m in maximum				
Material	Shape & Size	Q'ty	Unit	Remarks
Concrete boards	0.4×1.0×0.03m	2.5		
Crop boards	0.2×0.25×0.03m	5.0		
Crop stakes	0.5m long, 0.03m dia.	5.0		
Lock pins	0.07m long, 0.01m dia.	5.0		
Backing gravel	0.15 to 0.5m dia.	0.3	m^3	
Gravel or soil concrete		0.37	m^3	For filling.
Cobble stones, etc.			m^3	To be used as required when foundation soil is poor.

(3) Working method: Install concrete boards and other required parts, fill up the back spaces with gravel or soil concrete until predetermined thickness is obtained, fully stamp the gravel or soil concrete, and tension the face boards and crop boards. Repeat the above procedure and stack the wall while maintaining a some distance between adjoining board layers until they are stacked up to the predetermined height.

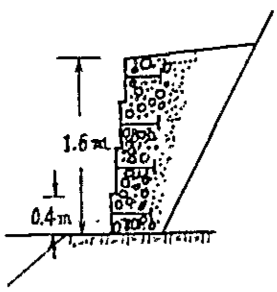


Standard sizes of crop stake & lock pin

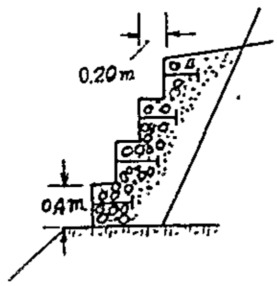


Standard size of metal wire

Standard Size & Specification of Concrete Board



Wall to be stacked steeply with soil concrete for core filling and gravel for back filling.



Wall to be stacked with a gentle slope in a distance of 0.2m from face to face with gravel for both core and back filling.

Example of Structure of Concrete Board Wall

1.4 Square Frame Wall

Square frame wall should be designed in accordance with the following items: 1) This wall should be used where the ground is poor in soil condition and is likely to cause irregular sinking or get irregular earth pressure, and also where groundwater needs to be drained. 2) Wall height is 3.0m maximum in principle, and the gradient of wall is 50% (1:0.5) in principle. 3) Square frame should be of the type conformable to the JIS standards. Its standard size is 0.15×0.15×0.5 to 2.0m. 4) If soil condition of the ground is extremely poor, the ground should be reinforced.

Standard Quantities of Materials Used for Square Frame Wall (per frame)

Structure: 2.0m long, 2.5m deep at top, 3.5m deep at bottom, 1:0.5 slope, 4.0m long.

Material	Shape & Size	Q'ty	Unit	Remarks
Square frame	Reinforced concrete	1.0		4.80 m per frame
Bolts	ϕ16mm	60.0		
Triangular washers	For ϕ16mm	60.0		
Binding wire	#8, galvanized	7.8	kg	
Filling stones	0.15 to 0.50m dia.	17.6	m^3	To be filled up to crown of upper collar brace. $(\frac{1.86+2.79}{2}\times1.87\times4.07)-(0.15\times0.15\times4.07)$

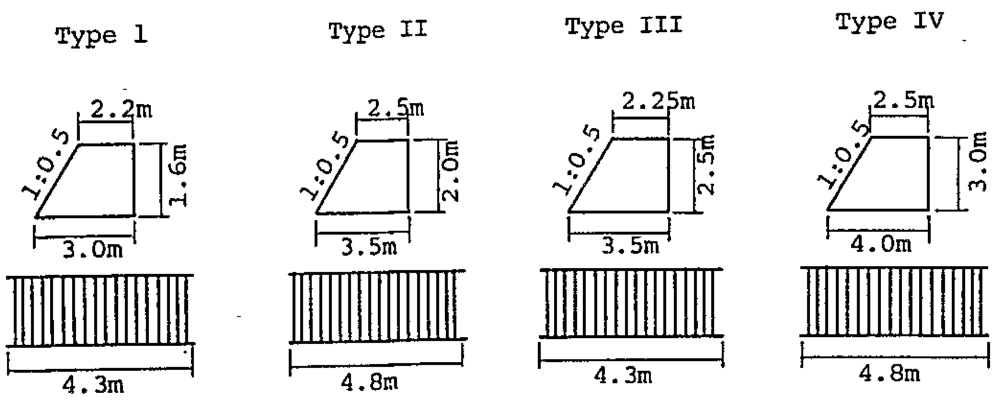
(1) One of features of the square frame wall is that this wall is movable since it comprises frames connected with reinforcing bars and boulders filled in the frames so that it does not break easily even if the ground moves irregularly or irregular

sinking occurs. In addition, since the installation of the square frames is easy, this wall is economical if boulders, debris or gravel for filling can be easily obtained at the site.

(2) Several kinds of materials can be used for square frames such as reinforced concrete column, reinforced concrete pipe and wood, and structural types of walls vary considerably. Generally, one side slope frame and square frame assembled with square reinforced concrete to trapezoid or square shape or principal rafter frame assembled to triangular shape is used widely. Since this structure withstands against earth pressure by means of weight of stones and gravel filled in the frames, a sufficient sectional area will be required when the earth pressure is large.

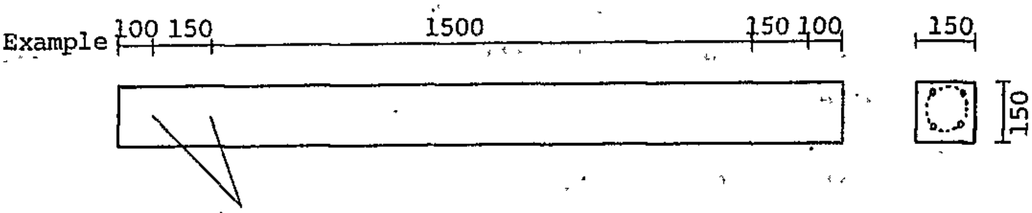
(3) As long as the square frame wall is stable against earth pressure, the face of the slope can be made steep to prevent the face from being damaged by falling rock. However, since the crown of frame frequently breaks due to falling rocks, it is required to protect the crown by placing wire basket on top of the crown where there is a potential falling of rocks.

The following structures are available for the square frame walls:

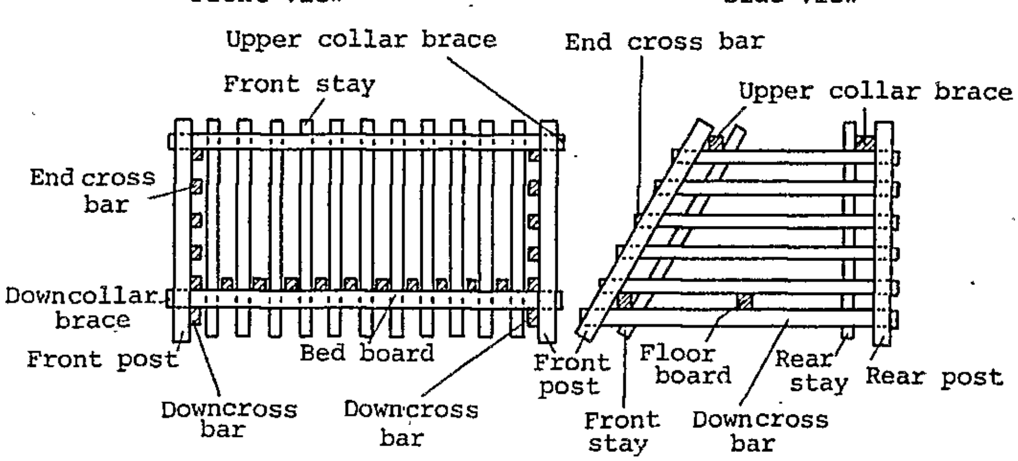


Kinds of Reinforced Concrete Square Frame
(one side slope frame)

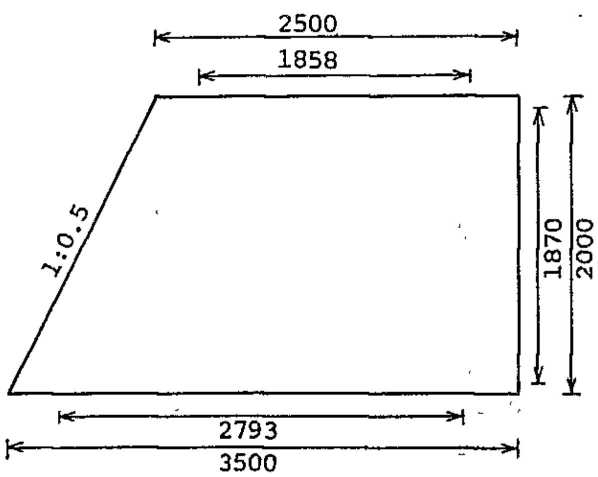
Square frame: 0.15m high × 0.15m wide × 2.0 to 0.5m long



Specification of Square Frame



Example of Structure of Square Frame Wall



Example of Structure of Square Frame Wall

1.5 Steel Flexible Frame Wall and Steel Frame Wall

Design of the steel flexible frame wall and steel frame wall should be performed in accordance with the following items:

1) These walls should be used when ground soil condition is poor, and probable occurrence of irregular sinking or of receiving irregular earth pressure is anticipated.

2) Wall height is 3.0m in maximum in principle, and the gradient of the face is from vertical to 30% (1:0.3) in principle.

3) Steel frame should conform to the requirements of JIS Standards.

(1) Flexible wall can withstand the earth pressure by means of its own weight. It is also unique that the frame strcture of this wall has flexibility and consequently can respond to the movement of the ground more or less. That is, this wall satisfies the requirements needed as a gravity type structure and employs the frame as a cell-type container so that the stability of structure as a whole may be kept even if the members are bent, or slightly deformed by impact or other forces as long as the stones filled in do not come out.

Flexible wall can be used even on the dangerous ground which is so soft and weak that other gravity-type structures cannot be accepted. Another advantage of this wall is that it is not restricted by seasons since its handling and assembling is easy and concrete is not used.

(2) Steel flexible frame wall must be designed and arranged in such a manner that the flexibility will be provided in a direction perpendicular to the direction of external force being applied, since this affects the stability calculations of resistant moment of the cells against the shearing force.

(3) Limit height of the wall should be 2.0m by taking account of the safety. Where a height greater than 2.0m is required,

it should be obtained by placing several layers of frame units.

(4) Debris as well as cobble stones may be used as filling. If the size of filling stones is too small, it is preferable to use expanded metal or the like to prevent the filling stones from coming out through the gaps in the frames.

(5) Generally L type is used for the wall.

(6) As same as other types of walls, the foundation ground must be able to respond to the maximum compressive forces due to the weight of flexible frames themselves and other external pressures. However, base excavation may be slightly shallower by taking account of the characteristics of the flexible frames.

(7) Steel frame wall is similar to the steel flexible frame wall. This steel frame wall may have the filling stones in the steel frames slanted backward to form a wall set back at its top.

(8) Conditions of applications and method of construction should conform to those of the steel flexible frame wall.

Standard Quantities of Materials Used for Steel Flexible Frame Wall (per one set)

Structure: Height: 1.0, 2.0 and 3.1 m; No gradient (level)				
Materials	Shape & Size	Q'ty	Unit	Remarks
Steel frame, L type	Height × Basic width			
H - 100	1.0 × 1.5 m	450.4	kg	Single unit
H - 200	2.0 × 1.5 m	677.2	kg	Single unit
I - 300	3.1 × 1.5 m	1,116.1	kg	Vertical, 2-layer stack
Filling stones	Dia.: 0.05 to 0.15m	2.70	m^3	For H-100
		5.40	m^3	For H-200
		8.37	m^3	For I-300

Materials	Shape & Size	Q'ty	Unit	Remarks
Expanded metal		8.38	kg	For H-100
		16.76	kg	For H-200
		25.98	kg	For I-300

(Note): Expanded metal is laid in single layer with weight of 4.19 kg per square meter.

Standard Quantities of Materials Used for Steel Frame Wall (per one set)

Structure: Height: 1.5 and 2.0m; Gradient: 1:0.3 (30%)				
Materials	Shape & Size	Q'ty	Unit	Remarks
Steel frame	Height Length Width			
L type	1.5 × 2.0 × 0.8m	259	kg	
	2.0 × 2.0 × 1.0m	319	kg	
Filling stones	Dia.: 0.05 to 0.15m	2.16	m^3	L type 1.5m high
		2.88	m^3	L type 2.0m high

1.6 Design of Channel

1.6.1 Opening section of channel

The opening section of channel should have the sizes sufficiently large to handle the maximum discharge safely in the catchment area.

Estimation of discharge and determination of opening section must be made by calculations. A safety factor of about 5.0 should be used when designing channel on hillside slope. It is required to consider not only the catchment area in the construction area but also the topographic conditions in nearby area and so forth when designing.

Channel section used usually has the trapezoid or arc shape. Generally, trapezoid channel is used where the amount of water is large, while the arc channel is used where the amount of water is small.

1.6.2 Location, gradient, sub-wall & socket for water of the channel

1) The location of the channel should be carefully selected so that the most effective catchment and drainage can be achieved, for example, a stripe of depression on a hillside. 2) The gradient should be designed so that a naturally depressed stripe, if possible, can be obtained throughout the surface of the slope. However, within a certain span, the gradient must be constant. When combining two channels, the angle between them must be appropriate to provide a smooth combination of water at the confluence. 3) If the length of channel exceeds 20 meters, sub-wall must be provided for support. 4) If, as a result of a wall or sub-wall, a head occurs between upper and lower channels, a socket should be provided at the lower channel.

(1) The channel must be constructed at the location which gives the most rational catchment and drainage by taking account of the shape of slope upon completion of the hillside works. Where the shape of slope in the cross section is rather flat and wide across a large area, a parallel arrangement is necessary. In a depressed terrain, trunk channel should run through the most depressed section and branch channels should be connected to the trunk channel.

(2) The channel's gradient should be determined so that the depressed section occurs as natural as possible from the top to the foot of the area.

However, if the gradient of the channel's middle portion or of the adjoining portion between the channel and the wall suddenly changes, sediment may be deposited on the gentle sloped portion and the function of channel may be lost, thus a constant gradient must be maintained within the same span. Therefore, wall or sub-wall should be provided to create a head at the point where the gradient or direction of channel begin to change. This head is effective for reducing the power of running water.

When combining the channels, they should be connected to assure the smooth flowing of water into the channel. In this case and also for the curved section of the channel, the outer edge section should be raised higher by the following formula to prevent overflow due to centrifugal force:

$$h = \frac{BV^2}{gr}$$

where,
- h: Up-height in m
- V: Current speed in m/sec.
- B: Upper width of channel in m
- r: Radius of curve in m
- g: Gravitational acceleration

(3) If the length of the channel exceeds 20m, sub-wall or the like should be provided to prevent the breaking of the channel due to settlement of ground or overflow.

(4) If a head is created by the wall or sub-wall, a socket should be provided in the lower section of the channel to receive running water wholly. The length (ℓ) of socket for water should be determined by the following formula:

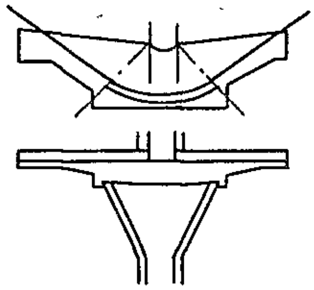
$$\ell = V\sqrt{\frac{2(h+h')}{9.8}} - nh \quad \text{(Unit: m)}$$

or, $\ell = 1.5(h+h') \sim 2.0(h+h')$

where, h: Height of wall

h': Depth of channel

n: Down-stream slope of sub-wall



An Example of Socket of Channel

1.6.3 Standard applications for channel and underdrain

Application Reference Table for Channel & Underdrain

Degree of devastation	Water-collecting condition	Base condition	Channel: Kinds of works	Underdrain: Kinds of works	Remarks
Plate-shaped or strap-shaped shallow planar and similar land-slide due to slip and fall or surface la yer.	Large amount	Hard or inter-mediate	Channels made of concrete, wet pitching, semicircular pipe, U-shape pipe, concrete block or corrugated pipe.	Underdrain made of gravel, gabion or collecting pipe.	1. If the gradient of the channel or underdrain is very steep (about 25° or larger), heavy and large structure should be avoided as far as possible. If construction of such a structure is in-avoidable, it is absolutely required to construct a sub-wall capable to support such channel of underdrain. 2. In an area such as landslip type slided land where the ground tends to slide, work using flexible material such as gabion should be selected.
		Soft	Channels made of sodding, wicker, gabion, or sandbag.	Underdrain made of flexible materials such as gabion, NETORON, or HECHIMARON.	
	Small amount	Hard or inter-mediate	Channels made of dry pitching, semicircular pipe, U-shape pipe, or corrugated pipe. (No work is required where the slope is gentle or where erosion does not occur.)	Underdrain made of gravel or fascine. (No work is required where the slope is gentle or where erosion does not occur.)	
		Soft	Channels made of sodding, wicker or sandbag.	Underdrain made of flexible materials such as fascine, NETORON, or HECHIMARON.	
Linear or branch-shaped depres-sions or similar landslide due to ground surface erosion.	Large amount		Same as above.	Same as above.	
	Small amount				
Shell-shaped or horseshoe-shaped deep depressions or similar landslide due to interflow or groundwater.	Large amount		Same as above.	Same as above.	
	Small amount				

(Note): 1. Water-collecting condition should be classified to either "large" or "small" by taking totally account of water-collecting area, shape of slope, presence of normal water, discharge during rainfall, amount of snowfall, etc.

2. Base condition should be classified into "hard", "medium" of "soft" by taking totally account of conditions concerning the erosion resistance of the ground such as geology, soil condition and deposit thickness of the area or which the channel or the underdrain will be designed.

1.6.4 Design of various kinds of channels

1.6.4.1 Concrete channel

Concrete channel should be designed in accordance with the following items:

1) Concrete channel should be mainly used for the trunk channel with a large discharge or where there is a large amount of normal water flow. 2) The shape of section should be trapezoid in principle. 3) Backfill should be made for the sidewall part in principle. 4) Cobble stones should be placed on the foundation part in principle. 5) Backing gravel is 0.2m thick in principle.

Standard Quantities of Materials Used for Concrete Channel

Structure: Trapezoid, 1.6m upper width, 1.0m lower width, 1.0 m depth Crown thickness of sidewall: 0.20m Waterside slope: 1:0.3 Back slope: Reverse 1:0.1				
Material	Shape & Size	Q'ty	Unit	Remarks
Concrete		0.57	m^3	
Backing gravel	Dia.:0.15 to 0.50m	0.47	m^3	
Paving cobble stones		0.11	m^3	
Frame		3.7	m^2	

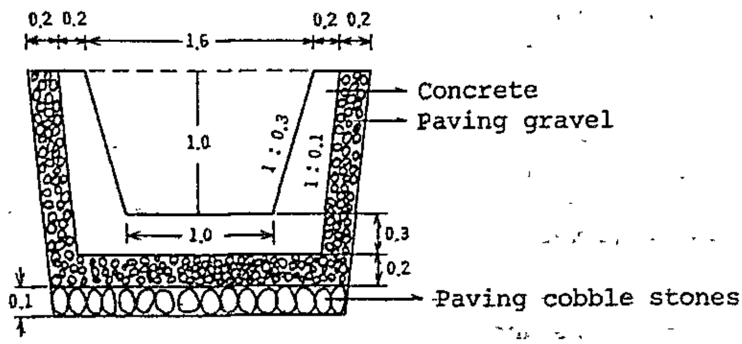
(1) The advantages of concrete channel are in its highest strength and its section that can be determined freely depending upon the discharge and terrain.

(2) Ordinary concrete channels will have 0.3m bottom thickness, 0.2m crown thickness of sidewall, 1:0.3 to 1:0.5 waterside slope, and vertical or reverse 1:0.1 back slope.

(3) Concrete channel has smaller roughness coefficient than that of pitched channel and tends to create higher current speed from which rapid flow or jumping tends to occur easily. Therefore, it becomes necessary to build sub-walls at several places to reduce the current speed.

(4) Backing gravel is required to prevent the channel from being damaged due to differential settlement or the like. For this reason, 0.2m thick backing gravel should be placed at the bottom and stamped. This backing gravel is generally not required if the sidewall is vertical, but backing gravel with 0.3m maximum thickness should be adopted if a considerably high earth pressure to the sidewall is expected.

(5) After placing concrete, backfilling should be made up to the top of the sidewall of the channel.



Example of Structure of Concrete Channel

1.6.4.2 Wet pitching channel

Wet pitching channel should be designed in accordance with the following items:

1) This channel should be applied when water runs constantly, a trunk channel has a large amount of discharge, or fixing of natural watercourse is reqiured.
2) The shape of section of this channel should be either trapezoid or arc.

3) Stone material should be broken stones or quarry stones having staying length greater than 0.25m. Quality specification stated in the paragraph 1.2.2 must be met.

4) Filling concrete should be filled up to the staying of stone consolidation. The amount of filling concrete must be calculated by multiplying the area of stone consolidation by 1/2 of staying length for broken stones and by 1/3 of staying length for quarry stones.

5) Backing gravel and concrete must conform to the paragraph 1.6.4.1.

Standard Quantities of Materials Used for Wet Pitching Channel (per 1.0 m^2)

Structure: Trapezoid, 1.6m upper width, 1.0m lower width, 1.0m depth, 1:0.3 slope.				
Material	Shape & Size	Q'ty	Unit	Remarks
Stone consolidation (broken stone)	0.3m staying	1.0	m^2	18 stones per $1m^2$ as standard
Backing concrete		0.13	m^3	
Backing gravel	0.05 to 0.15m diameter	0.27	m^3	
Stumps of miscanthus	1.0m binding by straw rope	0.6	Bundle	

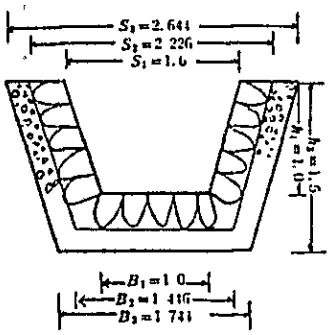
(1) Wet pitching channel should be used where the work area is large, water from spring or drain water from underdrain constantly exists, a simple channel is likely to be broken due to steep slope and flow-down of sediment or gravel, or fixing of natural watercourse is required. This channel is economical where stone material is easily available.

(2) Following precautions are necessary during work since stone material is used:

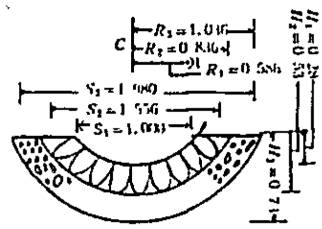
(a) Each stone should be laid in such a manner that its longer side becomes parallel to the direction of water running.

(b) Backing gravel and backing concrete should be placed very neatly so as to prevent the stones from being pulled out.

(c) Backfilling will be required after construction of channel.



Example of Structure of Trapezoid Section of Wet Pitching Channel



Example of Structure of Arc Section of Wet Pitching Channel

1.6.4.3 Dry pitching channel

Dry pitching channel should be designed in accordance with the following items:

1) Dry pitching channel should be used where the gradient is relatively steep without water constantly running or where the ground is hard and only small amount of water is collected.

2) Arc shape should in principle be used for this type of channel.

3) Filling gravel should be placed up to the staying thickness of the stone consolidation.

Standard Quantities of Materials Used for Dry Pitching Channel (per. 1.0m²) Structure: Arc Shape, 1.2m Arc Length, 0.28m Depth				
Material	Shape & Size	Q'ty	Unit	Remarks
Stone consolidation (broken stone)	0.25m staying	1.0	m^2	17 per $1m^2$ should be used as standard.
Backing gravel	0.05 to 0.15m diameter	0.5	m^3	
Stumps of miscanthus	1.0m binding by straw rope	0.6	bundle	

(1) Dry pitching channel should be used for branch channels having no water constantly running, since its subgrade is broken by seepage water and also the channel may be broken. This type of channel is suited to a place where stone materials is easily available.

(2) The quantity of filling gravel should be the same as that of filling concrete.

(3) Since the bed of dry pitching channel is easily eroded by the running of seepage water, stamping of foundation and sufficient filling of backing gravel are particularly required.

1.6.4.4 U-shape concrete and concrete block channels

U-shape concrete channel and concrete block channel should be designed in accordance with the following items:

1) These types of channels should be used when mechanized or labor-saving construction method is required at the places where water constantly runs or where a large discharge occurs during rainfall.

2) The structure shown in the figure below should be used as standard of the U-shape concrete channel. Connection of those concrete pieces should be made by the joint surface mortar.

3) The standard thickness of foundation concrete of the concrete block channel should be 0.15m.

4) U-shape concrete and concrete blocks should meet the requirements of JIS Standards and have required strength.

5) Specification and quality of concrete and backing gravel, and the procedure for treatment and backfilling of foundation portion should be the same as those of the concrete channel.

Standard Quantities of Materials Used for U-shape Concrete Channel (per 3m)

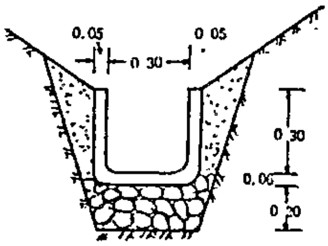
Structure: U-shape concrete channel, 0.4 to 0.45m channel width, 0.45m depth				
Material	Shape & Size	Q'ty	Unit	Remarks
U-shape concrete		10.0	pieces	
Backing gravel	0.05 to 0.15m diameter	0.34	m^3	
Joint surface mortar		0.01	m^3	

Standard Quantities of Materials Used for Concrete Block Channel (per 3m)

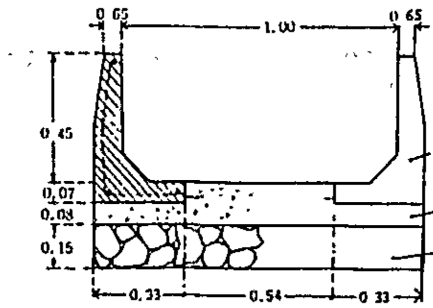
Structure: 1.0m wide, 0.45m depth, L-type Angle Concrete Blocks				
Material	Shape & Size	Q'ty	Unit	Remarks
Concrete blocks		20.0	pieces	
Foundation concrete		0.40	m^3	
Backing gravel	0.05 to 0.15m diameter	0.54	m^3	
Joint surface mortar		0.01	m^3	

(1) Concrete block channel should be used for trunk channel having a large amount of collected water, while small-scale U-shape concrete channel should be used for branch channel having relatively small amount of collected water.

(2) U-shape concrete channel has a structure made of U-shape concrete blocks connected together. Extra precautions are necessary when making the joints of blocks since they are likely to be broken due to settlement of ground.



Example of Structure of
U-shape Concrete Channel



Example of Structure of
Concrete Block Channel

(3) There are many different types of concrete block channels; some types have sidewall separated from bottom portion to adjust the width of channel while other types have board-like concrete blocks connected together. If weight increases and the danger of slipping is foreseen by using these blocks, sub-wall should be provided.

1.6.4.5 Sodding channel

Sodding channel should be designed in accordance with the following items:

1) Sodding channel should be used where the gradient is gentle, water does not run constantly, discharge is small, there is no sediment transport, and growing of sods is possible.

2) The shape of channel section in principle should have the arc form, 1.2m in length of chord and 0.3m in depth.

3) Standard sod should normally be 0.33m long, 0.20m wide, and 0.06m thick. Vegetation block or vegetation sack may be used in lieu of sods.

4) Peg should normally be 0.20m long and 0.008 to 0.025m in diameter, and peg should have high sprout ability. If such pegs are not available, bamboo pegs may be used.

Standard Quantities of Materials Used for Sodding Channel (per $10m^2$)

Structure: 1.0m arc length and 0.3m depth				
Material	Shape & Size	Q'ty	Unit	Remarks
Sods	Length: 0.33m Thickness: 0.03m Width: 0.2m	187.5	pieces	Sodding: 147.0 required End sod (cut to 2): 81.0 required
Pegs	Length: 0.2m	147.0	pieces	Green trees to be used

(1) This type of channel work is economical but, on the other hand, sods must be available and soil condition at the site must be suited for the growing of sods.

(2) Other restrictions are that there should be no sediment transport and the amount of running water should be small. Therefore, this type of channel is suited for channel in small land area and, for branch channel.

(3) More precautions are necessary than those for other types of channel works since the vegetation of sods are involved. The following precautions should be taken:

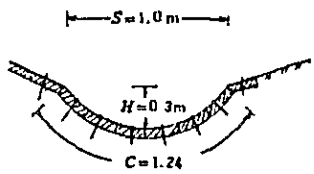
(a) Subgrade should be fully stamped.

(b) Sods should be laid very close to each other on the subgrade, stamped and then secured with pegs. About 2/3 of length of each peg should be inserted.

(c) Sods on the shoulder of channel should be slanted toward channel.

(d) No cross joints are allowed for the sods.

(e) If vegetation block or vegetation sack is used in lieu of sods, the tip of each peg should be pointed to reduce the break of sack or block to a minimum. Standard specification of this channel is shown below.



Example of Section of Sodding Channel

1.6.4.6 Wicker channel

Wicker channel should be designed in accordance with the following items:

1) This wicker channel should be used where the gradient is gentle and discharge is small.

2) If the gradient is slightly steep or the total length of channel exceeds 10m, sub-wall made of wicker should be privided.

3) A straight log with 1.5m stake length and 0.08m top end diameter should be used. Whicker must be green wood having as much flexibility and high sprout ability as possible. Its branches must be removed and the wicker should be 3.0m long in minimum and 0.006 to 0.009m in base diameter.

4) Stake interval should be 0.7 to 1.0m, the maximum height of wicker should be 0.5m and scions should be inserted to the wicker.

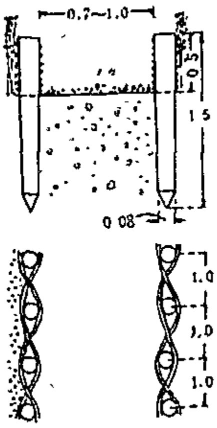
5) For preventing the erosion of subgrade, fascines or cobble stones must be laid. Fascine should be longer than 0.7m and be a small branch having about 0.02m in base diameter.

Standard Quantities of Materials Used for Wicker Channel (per 1.0m)

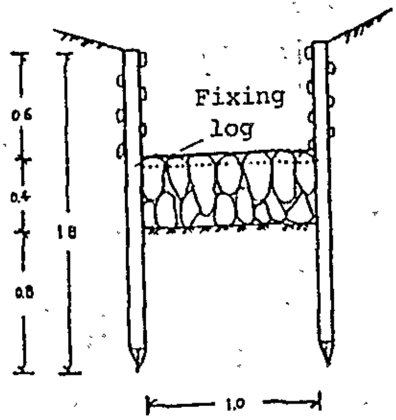
Structure: 1.0m channel width, 0.6m wicker height, 0.4m stone consolidation height				
Material	Shape & Size	Q'ty	Unit	Remarks
Cobble stones	0.15m dia. minimum	0.40	m^3	For channel bed.
Logs	1.8m long, 0.06m top end dia.	3.00		0.67m stake interval.
Logs	1.0m long, 0.06m top end dia.	0.75		For fixing logs. One required for 2 stakes.
Band twigs	3.0m long minimum, 0.03m base diameter, 25 twigs per bundle	1.20	Bundle	For fence.
Scions	0.3m long.	10.0		For cuttings in fence.
Nails	0.09m long.	0.03	kg	For securing cuttings, 0.03kg is needed per 1m.
Fascines	0.7m long minimum, 0.02m base diameter, 1.0m binding by straw rope.	6.0	Bundle	For laying on channel bed (where cobble stones are not used).

(1) Since strength and endurance of this work are slightly lower than those of other works, this type of channel work should be applied to almost flat area or at the place where the discharge is small. One of advantages of this work is that most of materials can be obtained at the site.

(2) Since the wicker easily rots, it is required to insert branches of tree having high sprout ability after filling back of the fence to compensate this rotting.



Example of Structure of Wicker Channel (1)



Example of Structure of Wicker Channel (2)

1.6.4.7 Gabion Channel

Gabion channel shall be designed in accordance with the following items:

1) This gabion channel should be used when flexible channel is required at a place where poor soil condition or similar condition occurs.

2) Civil work sheet should be laid on the subgrade in principle to prevent water seepage.

3) Logs, each being 1.0 to 1.5m long and 0.12m in diameter, should be used for the fixed stakes. One log should be used for every two meters of channel.

Standard Quantities of Materials Used for Gabion Channel (per 10m)

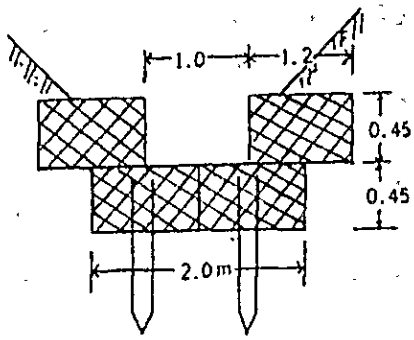
Structure: Wire basket, 0.13m in mesh, #10 galvanized iron wire, 10m long				
Material	Shape & Size	Q'ty	Unit	Remarks
Wire baskets	4.0x0.45x1.2m	10.0		
Filling stones	0.15 to 0.3m dia.	21.6	m^3	
Fixed stakes	1.50m long, 0.12m dia.	10.0		Within 2.0m interval
Gravel layer		4.0	m^3	
Galvanized iron wire	BWG #10	25.0	kg	

(1) In the areas where the rigid structures are likely to be broken because of poor soil condition or irregular movement of ground such as landslip, flexible gabion channel is suited. This is particulary economical when filling cobble stones or debris are available in nearby area.

(2) Since the gabion channel has high permeability, seepage water will flow along the subgrade and erosion is likely to occur. Therefore, nylon, vinylon or other similar sheets should be laid for preventing erosion or adjacent underdrain should be provided.

(3) About 0.5m thick wire basket should be used in such a manner that its cross section will have a rectangular shape. Occasionally, wire cylinder with about 0.6m in diameter is laid in the arc form.

(4) Method of work for connections between wire cylinders or baskets, filling of stones, tying of openings, and fixing of wire basket or cylinder should be almost the same as that of gabion wall.



Example of Structure of Iron Wire Gabion Channel

1.6.4.8 Sandba channel

Sandba channel should be designed in accordance with the following items:

1) This type of channel should be used to the areas where water normally does not run and sediment transport does not occur.

2) Sandbag is generally made of polyethylene and some amount of seeds and fertilizer are added in it. Its size is 0.6m in length and 0.4m in width.

3) Cross section of the channel should be either trapezoid or arc shape.

4) Standard fixed stake is 0.5m long and 0.04m diameter, and 3 stakes should be used for the channel per meter.

Standard Quantities of Materials Used for Standba Channel (per 10m)

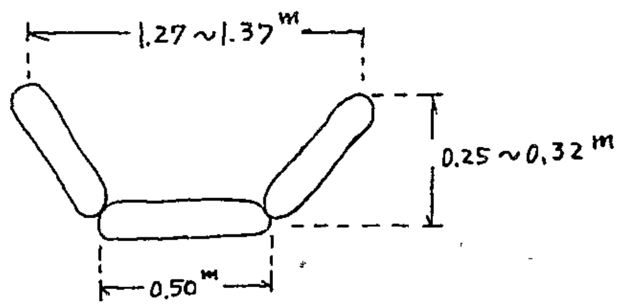
Structure: Trapezoid shape, 1.30m in upper width, 0.50m in lower width, 0.25 to 0.32m in depth.				
Materials	Shape & Size	Q'ty	Unit	Remarks
Sandbags	Polyethylene, 0.60×0.40m	100		With seeds and fertilizer. Finishing size: 0,50×0.30×0.10m

Materials	Shape & Size	Q'ty	Unit	Remarks
Fixed stakes	0.50m long, 0.04m diameter	30		
Filling earth	Good quality soil	1.5	m^2	

(1) Since sandbags can be easily carried to the site and filled up with earth available at the site, the work is simple and saves labor.

(2) Recovery of vegetation is expected since seeds and fertilizer are contained in the bags.

(3) Sandbag surface having seeds should be placed on top when laid in the channel, and the standard finishing size of sandbag should be 0.5m long, 0.3m wide and 0.1m thick. After filling up the sandbags with earth, they should be laid on the subgrade, fully compacted against subgrade and fixed with the stakes at predetermined intervals.



Example of Structure of Sandbag Channel

1.6.4.9 Corrugated pipe channel

Corrugated pipe channel should be designed in accordance with the following items:

1) This type of channel should be used in areas where somewhat a large amount of water is constantly running or a large amount of discharge occurs during rainfall.

2) The shape of cross section is semi-circular in principle.

3) Corrugated pipes and auxiliary parts used should conform to the requirements of JIS Standards.

4) One fixed stake, 0.5m long and 0.09m in top end diameter, should be used for the channel, every 3.0m in length.

Standard Quantities of Materials Used for Corrugated Pipe Channel (per 0.6m)

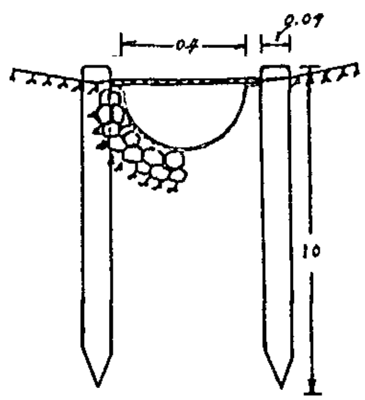
Structure: 0.40m in length of chord, 0.20m in depth, semi-circular pipe				
Material	Shape & Size	Q'ty	Unit	Remarks
Corrugated pipe channel	Type A, galvanized 600×600×2mm	1 (0.6)	(m)	
Or corrugated semi-circular pipes	0.4m in chord length, 0.6m in length, 1.6mm in thickness, with bolts, nuts and packings	1 (0.6)	(m)	
Fixed stakes	Top end dia.: about 0.09 Length: 1.0m	0.003	m^3	Five required at one place
Galvanized iron wire	#10, annealed	0.05	kg	

(1) The advantage of this work is to use light materials that can be transported easily. Therefore laying is very simple and its work does not require much labor. On the other hand, this channel tends to be worn away where sand and gravel transport occurs, and corrosion begins relatively in early stage. This channel is also unable to resist against acidic water. Since laying and removal of this channel are simple, it can be used as a temporary drain channel.

(2) Corrugated pipes are connected and assembled with bolts. When installing the corrugated pipes, extra precautions

should be required for them never to be given any eccentric impact land.

(3) Method of bed excavation and treatment of foundation should conform to that of the concrete channel described before.



Example of Structure of the Corrugated Pipe Channel

1.7 Design of Underdrain

1.7.1 Designing underdrain

In the design of the underdrain, the following items should be fully taken into account:

1) The fittest kind and construction of this work must be selected corresponding to the amount of groundwater, and the shape of cross section of the slided land.

2) Appropriate arrangement of underdrains which can efficiently collect and drain the spring water and seepage water must be determined.

3) Water collected by the underdrain should have the wall as adjoining point and be drained to the channel at this point.

4) Some precautions should be taken for preventing particularly the clogging and water leakage to adjacent land in the design of the underdrain work.

(1) If the slided land was caused by the spring water, the measures to drain off the groundwater should be taken. Underdrain is suitable to this purpose.

(2) If there is a spring, the underdrain work must start from that point. If grading earth is deposited thickly and its draining is required, underdrain must be installed at a place for example a depressed portion on the land, by which water can be collected and drained in the most efficient way. In this case, the range collectable and drainable for water by one underdrain should be determined, and consequently proper branches or parallel arrangement of underdrains should be provided if necessary.

(3) Bed excavation of underdrain generally tends to become shallow, but it is required to excavate the ground up to the groundwater level and to install the underdrain so far. Also, if spans become long, a wall work should be provided as an adjointing point and draining water should be introduced to the channel through the openings or the like provided on the wall.

(4) If an underdrain has a potential cause of clogging, it should be prevented by using filters such as sand, gravel, fascine, straw mat, secondary mat products (coconut plam fibers, polyester, etc.) and so forth. In case of installing underdrain in an area which has high permeability such as sedimentary layer, vinyl sheets for civil work should be laid on the bottom of the underdrain.

1.7.2 Design of various kinds of underdrains

1.7.2.1 Gravel underdrain

Gravel underdrain should be designed in accordance with the following items:

1) This type of underdrain should be used where there is a large amount of groundwater such as spring water.
2) Waterproof sheets should be laid on the subgrade to prevent the water seepage in principle.
3) The size of gravel is 5 to 15cm in diameter, and fascine should be longer than 2.0m and 0.001m base diameter.

Standard Quantities of Materials Used for Gravel Underdrain (per 10m)

Structure: 0.4m lower width, 0.8m upper width, 1:0.2 slope				
Material	Shape & Size	Q'ty	Unit	Remarks
Gravel	0.05 to 0.15m dia.	2.50	m^3	
Fascines	2.0m long minimum, 1.0m binding by straw rope.	5.0	bundle	For covering fascines.
Civil work sheets (waterproof sheets)	0.9m long, vinyl sheets, etc.	6.0	m^2	To be used if underdrain is in sedimentary layer.

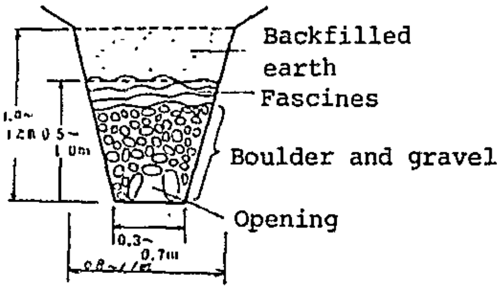
Construction and work procedure should be outlined below.

(a) If bed excavation is required on the scale of 0.5 to 1.0m height and 0.3 to 0.7m bed width, waterproof civil work sheets should be laid on the bottom surface.

(b) Underdrain openings should be made on the bottom and gravel should be placed over and around them. The largest size of gravel should be used at the bottom and gradually smaller ones as it approaches to the top.

(c) Fascine covering should be made on top of gravel and backfilling should be made after fascine covering.

(d) Earth for backfilling should have a good water permeability.



Example of Structure of Gravel Underdrain

1.7.2.2 Fascine underdrain

Fascine underdrain should be designed in accordance with the following items:

1) This underdrain should be used to the area where groundwater such as spring water or seepage water exists in small quantity.

2) Fascine is 2.0m in the minimum length and about 0.03 to 0.04m in the base diameter and fascines bundled to 0.5m diameter is used. #10 binding iron wire is used and about 0.5kg of iron wire should be used for each bundle.

3) Gravel and covering fascine materials, the method of bed excavation, and foundation treatment should conform to those prescribed in Gravel Underdrain.

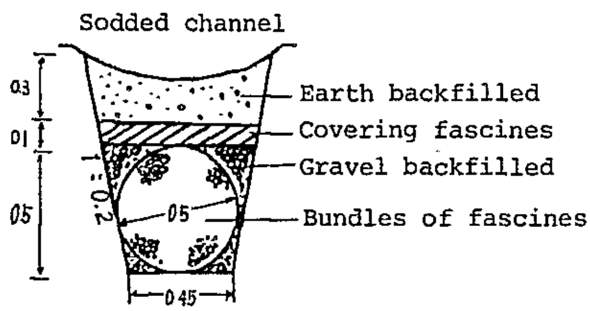
4) Underdrain using secondary products such as NETORON or HECHIMARON should also conform to the provisions stated in Gravel Underdrain.

Standard Quantities of Materials Used for Fascine Underdrain (per 10m)

Structure: 0.5m lower width, 0.9m upper width, 0.9m depth, 1:0.2 slope				
Material	Shape & Size	Q'ty	Unit	Remarks
Fascines	2.0m length minimum, 0.01 to 0.03m dia., bound to 0.5m dia.	5.0	bundle	
Gravel	0.05 to 0.15m	0.4	m^3	
Covering fascines	2.0m length minimum, 0.01m dia., 1.0m binding by straw rope	5.0	bundle	
Galvanized iron wire	#10	1.65	kg	

Ordinary construction of fascine underdrain and work procedure:

Excavate bed of the scale of 0.5m depth and 0.45m bottom width. Place fascines and fill gravel. Then, place covering fascines and backfill earth.



Example of Structure of Fascine Underdrain

1.7.2.3 Gabion underdrain

Gabion underdrain should be designed in accordance with the following items:

1) This type of underdrain should be used for the places where the ground is unstable due to poor soil condition or where

a large amount of groundwater such as spring water exists on a steep land.

2) The construction of this type of underdrain should conform to the provisions of Fascine Underdrain.

3) Wire cylinder is used as gabion, and filling stones have the diameter of 5 to 15cm, and standard fixed stake is 1.0 to 1.5m long and 0.12m in diameter.

4) Covering fascines should conform to the provisions of Gravel Underdrain. If required, waterproof civil work sheets should be laid on the bottom.

Standard Quantities of Materials Used for Gabion Underdrain (per 10m)

Structure: 0.6m dia. and 2.0m depth				
Material	Shape & Size	Q'ty	Unit	Remarks
Galvanized wire cylinder	4.0m long, 0.6m dia. 0.13m mesh	2.50		
Cobble stones	0.15 to 0.25m dia.	2.55	m^3	$1.02m^3$ per one cylinder
Fixed stakes	0.06m top end dia., 1.5m long.	5.0		0.5 stake needed per 1m
Bark of Japanese cedar	0.9m long, vinyl or others	6.0	m^2	$0.6m^2$ per 1m
Covering fascine	2.0m long, 0.01m dia., 1.0m binding with straw rope.	5.0		
Gravel	0.05 to 0.15m dia.	0.5	m^3	

(1) Gabion underdrain is flexible and capable to respond to the change or movement of the ground.

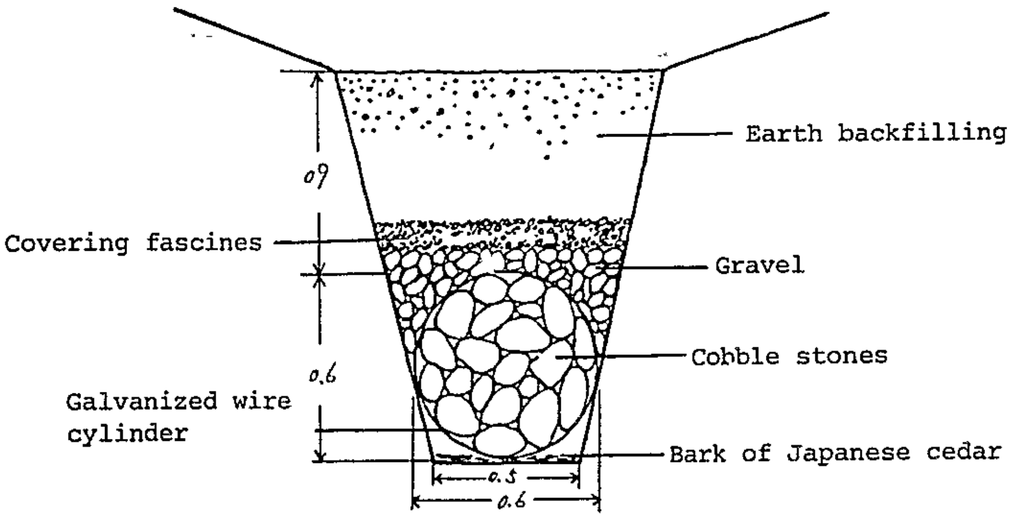
(2) Construction and work procedure are outlined below.

a. Bed excavation and foundation treatment should conform to the provisions of Gravel Underdrain.

b. Fill cobble stones and install wire cylinder, and then connect the wire cylinders together. If waterproof civil work sheets must be laid, it should be done before installing the wire cylinders.

c. Wire cylinders filled up with cobble stones and installed should be secured to the foundation by means of fixed stakes.

d. Fill the gravel around the wire cylinders fixed, place covering fascines over the cylinders and backfill the earth over the covering fascines.



Example of Structure of Gabion Underdrain

1.7.2.4 Water-collecting pipe underdrain

Water-collecting pipe underdrain should be designed in accordance with the following items:

1) This type of underdrain should be used where there is a large amount of groundwater such as spring.

2) Water-collecting pipes must be concrete pipes, hume pipes or vinyl pipes having water-collecting apertures on upper half of the section. The qualities of these pipes should conform to the JIS Standards.

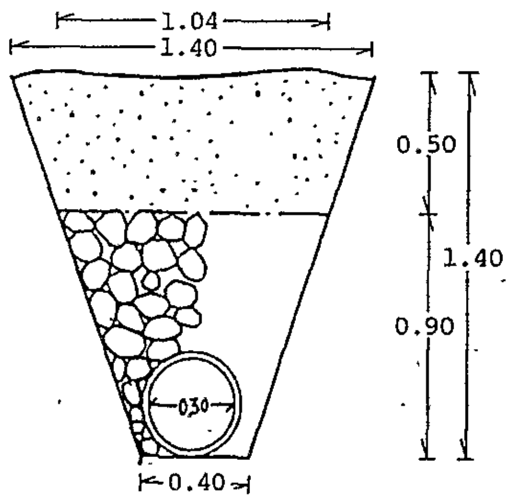
3) The size of gravels is 0.05 to 0.15m in diameter, and standard covering fascine is 2.0m long and 0.01m in diameter.

Standard Quantities of Materials Used for Concrete Water-Collecting Pipe Underdrain (per 1.0m)

Structure: 1.4m deep, 0.4m wide, 0.3m dia. water-collecting pipes, 0.9m thick gravel filling				
Material	Shape & Size	Q'ty	Unit	Remarks
Concrete water-collecting pipes	0.3m inner dia., 1.0m long, with sockets	1.0	m	
Gravel	0.05 to 0.15m dia.	0.55	m^3	For screen.
Fascines	2.0m long, 0.01m dia.	5.0	bundle	For covering fascines.

Construction of water-collecting pipe underdrain:

After bed excavation, lay the water-collecting pipes, fill the screen materials, place covering fascines over them, and backfill the trench with earth.



Example of Water-Collecting Pipe Underdrain

2. Executions of Hillside Seeding

2.1 Standard Materials, Quantities and Working Methods of the Hillside Seeding

(1) Fence work

(a) Wicker work

Materials and methods of wicker work should conform to the follwing items:

1. Unless specifically prescribed in the working drawings or the special specifications, the materials should conform to the following:

   a. The standard size of wickers is 2.0m in minimum length, 4 to 8cm in base diameter, and 0.6 to 0.9cm in top end diameter, and each wicker should be free of small branches. Twenty-two wickers should be contained in each bundle.

   b. The standard size of piling logs is 1.5m in length and 8cm minimum in top end diameter. Each piling log should be straight.

2. The following precautions should be taken during wicker work:

   a. When making steps on a slope of hill or mountain to perform wicker work, the width of those steps is 30 to 50cm as a standard unless specified other otherwise.

   b. Piling logs should be driven at intervals of 75 to 100cm to the depth of two-thirds of the length in principle. At least one-half of the length must be driven even though it is rather difficult to do.

c. Piling logs should be driven vertically on the steps. If it is done on a slope, they should be driven along the direction of a bisector which is made between the perpendicular to the slope and the vertical.

d. The height of wicker work is 50cm as a standard.

e. Wickers should be braided together as close as possible, and earth will be put back. Miscanthus or weeds should be planted on the surface, which is finally tamped by foot. Also, cuttings will be planted in the gaps between the wickers.

f. In this braiding work, the top two wickers must be completely braided not to be lost easily, or they must be fixed with iron wire or the like if necessary.

Standard Quantities of Materials Used for Wicker Work (per 10m)

Material	Shape & Size	Q'ty	Unit	Remarks
Piling log	1.5m long, 8cm minimum in top end dia.	15		0.75m spacing between logs.
Fascines	2.0m long minimum, 3 to 4cm in base dia., and 22 wickers per bundle.	5	bundle	0.5m high.
Scions (cuttings)	20cm long, with high sprout ability such as willows, 100 scions per bundle.	0.5	bundle	
Miscanthus stubble	30cm in stem length, 1m binding with straw rope.	1.0	bundle	Miscanthus or weeds stubble
Galvanized iron wire	Galvanized, #12 to #18.	0.3	kg	For fixing top fascines if needed.

(1) Wicker work should be used when the earth layer on hillside slope is relatively thick or when it is required to control the flow of earth from grading work.

(2) Since wickers used for this work will rot within 2 to 3 years, they must be functionally strengthened by planting cuttings.

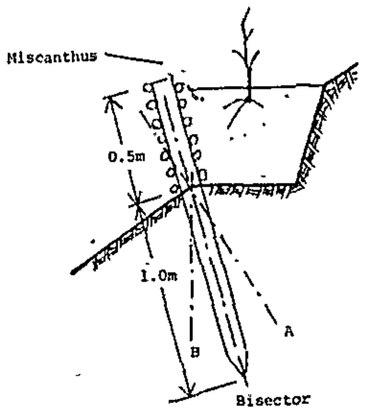
(3) Wickers should have a sprout ability as high as possible.

(4) If the intervals between piling logs is too long, wicker may become too weak. But the braiding activity may become very difficult if the intervals is too close. Thus, this spacing should be properly determined depending upon the terrain and soil conditions at the site.

(5) The length of piling logs is determined by the soil conditions and the depth of earth layer, and the driving depth of a piling log should be greater than two-thirds of its length in principle. Each log should be driven along the bisector between the vertical and the perpendicular to the hillside slope, as illustrated in the figure shown below.

(6) The height of wicker should be determined depending upon the slope of wicker, vertical spacing between upper and lower wickers and the soil conditions but generally it should be 0.5m.

(7) If wickers are not available, split bamboo may be used instead.



Wicker Work

(b) Wooden fence

Materials and work of wooden fence should conform to the following items:

1. Unless specifically prescribed in the working drawings or special specifications, the materials should conform to the following:

   a. The standard fence board should be 1 to 2cm thick, and miscellaneous log should have about 3 to 8cm top end diameter.

   b. The standard size of piling log must conform to the requirements described in the provisions for wicker work.

2. The following precautions must be taken when constructing the wooden fence:

   a. Terracing (cutting steps into slope) and driving of logs should conform to the requirements of the wicker work.

   b. The standard finishing height of fence is 45cm.

c. Fence boards or logs should be arranged as close as possible, and terraces will be filled with earth, planted with miscanthus or weeds stubbles, and the earth should be tamped by foot as finishing. Cuttings will be planted in gaps between boards and logs.

d. Top ends of fence boards or logs should be fixed to the piling logs with nails or iron wire to prevent them from being pulled out.

Standard Quantities of Materials Used for Wooden Fences (per 10m)

Material	Shape & Size	Q'ty	Unit	Remarks
Piling logs	1.5m long, 8cm in top end dia.	15		0.75m spacing between logs.
Fence boards	2.1m long, 15cm wide, 1.5cm thick	15		0.45m high when finished.
Fence logs	3 to 8cm in top end dia.	30		For logs.
Miscanthus stubble	30cm stem length, 1m binding by straw rope.	1	bundle	Miscanthus or weeds stubbles.
Cuttings	20cm long, with high sprout ability, 100 cuttings per bundle	0.5	bundle	
Nails	4.5cm long, hooked nails	100	g	For connecting boards at the top.
Iron wire	#12 to #18, annealed	300	g	For connecting logs at the top.

(1) Wooden fence uses logs and boards in lieu of fascines for wicker work, and the purpose and work method of the wooden fence are the same as those of the hillside wicker.

(c) Other fence works

When constructing steel board fence, the following points should be taken into account:

a. Methods of terracing, driving of piling logs, and back-filling of earth should conform to the requirements of wicker work. However, special type of fence work shall conform to the special specifications.

b. Fixing method for fence board and piling log should conform to the special specifications.

c. If required, miscanthus, weeds stubbles or scions will be planted.

The construction of "other fence works" is almost equal to that of the wicker work, in which secondary products such as steel plate, iron board or vinylchloride board will be used in lieu of the fascines. Also, it is possible to attach seeds to nets or fences for the purpose of greening.

(2) Terracing work with sods

(a) Three pieces terracing with sods (including 4 or 5 pieces terracing)

Work of 3, 4 or 5 pieces terracing with sods should conform to the following:

a. In the terracing work with sods, horizontal terraces, each 40 to 60cm wide, must be cut at 1.0 to 1.5m on centers in vertical distance. Then, basic sods will be laid flat while leaving about 10 to 20cm for the berm, slope sods will be planted at the center of the basic sods, straws should be placed behind the slope sods and earth will be backfilled over the straws, and miscanthus stubbles will be planted below the basic sods. If the portion of berm has poor soil conditions, straws should be laid flat. Slope sods should be slanted to a grade of about 1:0.3, about one-half of earth required must be backfilled, then the earth should be tamped with lawn hammer and feet, the remaining half of the required earth should be backfilled, and crown sods finally placed.

b. The crown sods must be hammered until they become almost flat. Earth placed on the crown must not be too thick.

c. Standard height of finished slope is 30cm for 3 pieces terracing and 54cm for 5 pieces terracing with sods.

d. When vegitation block is used in lieu of sods, such a block should be worked in accordance with the requirements for the sods.

Standard Quantities of Materials Used for Terracing Work with Sods (per 10m)

Material	Shape & Size	Q'ty	Unit	Remarks
Sods	When using turf; 33cm in length, 20cm in width, and 6cm in thickness	90	pieces	For 3 pieces terracing.
		120	pieces	For 4 pieces terracing.
		150	pieces	For 5 pieces terracing.
Vegetation blocks	When using vegetation blocks in lieu of turfs; 25cm in length, 20cm in width, and 3cm in thickness.	120	pieces	For 3 pieces terracing.
		160	pieces	For 4 pieces terracing.
		200	pieces	For 5 pieces terracing
Pegs	Green stems, wire, or bamboo.	180 ~400		Two per sod vegetation block.