stressed also and moved gradually by sliding movements. No water seepage was observed during the operation of soil removal works because groundwater levels were relatively deep.

4) Effect of the work

The soil removal works were conducted for securing the safety of the whole landslide area by reducing the earth pressure from the upper slope of the landslide area. According to the stability analysis along the survey lines, W and X, which are aligned to cross the soil removal area in the western and the central parts of the landslide area, improvement of safety factors of about 3 % and about 8 % were expected for the line-W and the line-X.

Judging from the topographic conditions such as inclination of slopes and topographic shapes, the only possible soil removal area was considered to be at the site where the soil removal works were conducted. The soil removal work was expected to stabilize the main part of the landslide area with cooperative effects by the drainage well construction and drilling of groundwater collection boreholes, which were conducted as an experimental investigation.

No clear evaluation of the soil removal works for the landslide stability is possible so far because there has been no heavy rainfall or continuous rainfall since completion of the soil removal works. A certain amount of rainfall has been recorded since December 1989, but there has been no very heavy rainfall or continuous rainfall in the area. Even after this rainfall no significant displacements has been confirmed by the monitoring equipment. Therefore, it seems to be able to conclude that the landslide movements may have been stabilized by the soil removal works at least for relatively heavy rainfall so far.

(2) Stability analysis for soil removal works

Stability analysis in relation to the soil removal work was performed along the Line-W, which crosses the old abandoned reservoir, and Line-X, which aligns in the eastern part of Line-W. The stability analysis was made for confirming the improvement of the safety factor by soil removal works, following the same procedure for the drainage well construction. The results of stability analysis indicate that the safety factors for the area will be increased by about 3 % to 7 % for Line-W and Line-X by the soil removal work. The results obtained are summarized as follows:

IMPROVEMENT OF SAFETY FACTOR BY SOIL REMOVAL

LINE	BEFORE SOIL REMOVAL	AFTER SOIL REMOVAL
W	F.S = 1.0	F.S = 1.031
X	F.S = 1.0	F.S = 1.071

While the safety factor will be increased by several percentage points as a result of the soil removal works as shown in the above table, the expected improvement in the safety factor is not sufficient for the required value of 1.2 for the long term protective measures. An adequate safety factor has to be secured therefore a combination of measures, such as surface water drainage, groundwater drainage, soil removal, piling works, and other measures.

II.3.2 Emergency Counterweight for a Small Landslide

(1) Location of the small landslide

A possible minor landslide movement was observed by the records of extensometer E-3 for 1 mm to 3 mm per day at the end of October. The open cracks crossing E-3 were observed to move at the same time. The extensometer records are shown in Fig.I.2.6-20 (Supporting Report-I). The total displacement amount recorded by the extensometer readings was 120 mm between October 1989 and the end of January 1990. Although there was no displacement in the inclinometer readings on September 12, 1989, clear displacements were observed in the readings measured in the borehole, BV-X1, at depths of 5.0 m and 10.5 m on November 29, 1989. Moreover, the probe of the inclinometer could not be inserted deeper than 10 m on December 12, 1989.

According to the measurement results of the extensometer, E-3, the inclinometer in BV-X1, and the observation results of open cracks, a minor landslide was estimated in the size of 80 m in width and 60 m in length. The extent of this small possible landslide was estimated from the location of E-3 and the berm at El.46 m in the soil removal area.

There was a relatively large rainfall of about 100 mm between February 20 and 21, 1990. After this rainfall movement of one more possible minor landslide was observed by the extensometer reading of E-3. The probe of the borehole inclinometer could not be inserted more than 2.5 m in BV-X1 at the end of February. The slide surface of this minor landslide seems to be derived from the above mentioned minor landslide. For the stabilization of this landslide a counterweight embankment was required. The location of the small landslide and the emergency counterweight site are shown in Fig.II.3.2-1.

(2) Stability analysis

The location and dimensions of the required counterweights for mitigation of the concerned small landslide were determined by stability analysis. For the stability analysis the slide surfaces of the small landslide were assumed to be as shown in Fig.II.3.2-2 and

Fig.II.3.2-3

Based on the results of the stability analysis, counterweighting by soil embankment on the berm at El.46 m was planned as an emergency protective measure for this minor landslide, and the counterweight was provided at the end of January. The size of counterweight is 5 m in width and 40 m in length on the berm at El.46 m. The design of the counterweight is shown in Fig.II.3.2-2. The improvement of safety factor by the counterweight was expected for about 9 %. Movement of the possible minor landslide has been mitigated by this emergency protective measure.

The expected safety factors for the firstly to the thirdly assumed slide surfaces are 1.046, 1.119 and 1.134 after completion of three stages emergency counterweights.

(3) Execution of emergency counterweight

1) Purpose of the work

Soil removal works were carried out in Phase-I of the 2nd Stage study period. Overburden materials of about 50000 m^3 were removed from the upper central part of the landslide area. The soil removal works were made as one of the emergency protective measures for the landslide movement. The essential purpose of the works seems to have been achieved successfully because no remarkable landslide movement was observed in the landslide area as a whole in the last rainy season.

Movement of a small landslide, however, was observed after the soil removal works at the southeastern part of the soil removal work site since October 1989. Embankment of the first emergency counterweight for about 650 m^3 was made on the berm at El.46 m in the soil removal area at the end of January 1990. The required amount of the emergency counterweight was calculated by the stability analysis.

The landslide movement was checked by this counterweight for a short period. The expected safety factor is 1.094 for the firstly assumed slide surface after completion of the first counterweight. However, the movement was resumed after the relatively heavy rainfall in February. The sliding surface for the resumed landslide movements was assumed to be secondary to the slide surface of the first small landslide. The landslide displacement indicated by extensometer readings show intensive movements from the beginning of March 1990 after the rainfall brought by the cyclone "Edisaona".

Taking the accelerated landslide movement and the site condition for available counter measures into consideration, JICA study team recommended MOLG additional emergency counterweights to mitigate the movement at the middle of March 1990 (before the end of Phase-I in the Stage-2 study). MOLG organized the works for the emergency counterweight at the middle of May 1990, corresponding to the recommendation from JICA study team. The embankment of the second emergency counterweight was started at the middle of May 1990.

Judging from the assumed shallower slide surface and the topographic condition, the possibilities of damage is not likely to be very serious, even if the small landslide is occurred. However, there is a possibility that the landslide might be extended to the upper slopes if the landslide movement actually occurs. The recommendation for the emergency counterweight was made from these considerations.

2) Location and dimension of the work

The small landslide is located in the southeastern part of the soil removal area. The upper margin of this landslide is bounded by the open cracks running across extensometer E-3. There are no clear deformations or clear cracks which seem to be accompanied by the displacements caused by the small landslide along the drainage channels aligned at the upper parts of the open cracks. Therefore, movements of the small landslide seem not to extend to the upper part of the surface drainage channels so far.

The lower extremity of the small landslide is considered to be higher than the berm at El.46 m in the soil removal area because the movement of the small landslide was decelerated by the first embankment of emergency counterweights, and phenomena accompanied with landslide movements such as cracks or heaving of ground surface have not been observed below the berm at El.46 m.

A schematic drawing of the counterweights is shown in Fig.II.3.2-2 and the quantity of the counterweights and the stability analysis results are summarized in Table II.3.2-1 and Table II.3.2-2. The volumes are 655 m_3, 485 m_3 and 154 m_3 for the first, second and third counterweights.

Embankment of the first counterweight was made on the berm at El.46 m for 3 m in height. The second counterweight was started on the berm at El.49 m for 3 m in height, covering the first counterweight between El.46 m and El.49 m. The embankment of counterweight was made under compaction by a vibration loader at every 50 cm in thickness approximately. The lengths are about 40 m and 34 m for the first and second counterweights. After completion of the second counterweight, embankment of the third counterweight was made continuously on the berm at El.52 m for 3 m in height. The length of the third counterweight is about 21 m.

The small landslide was estimated to occupy an area of about 60 m in length and about 40 m in width at the start of movement immediately after the soil removal works. However, the size is considered to have been decreased by embankment of the first counterweight on the berm at El.46 m. The size of the decreased landslide is assumed to be about 50 m in length and about 40 m in width.

3) Progress of the work

The soil excavation site for supplying soil materials for the first counterweight was selected at about 500 m east of the soil removal area. The soil excavation site for supplying soil materials for the second and third counterweights was selected at about 300 m to the west of the soil removal area. The soil materials were collected from flat and gentle slope areas.

The soil excavation and embankment of the first counterweight was started at the end of January 1990, and the work took about one week.

The soil excavation and the embankment works for the second and third counterweights were started in the middle of May and were completed by the beginning of June. The works took about two weeks to complete except for installation of drainage channels and vegetation planting.

4) Effect of the work

According to the monitoring records of extensometer, E-3, displacement movement triggered by the soil removal works since the end of October 1989 ceased temporarily after completion of the first counterweight embankment. However, the displacement resumed after the heavy rainfalls in February and March 1990. Intensive displacements continued until the end of April 1990. Displacement by the landslide movements was reduced with the decrease in rainfall in May 1990.

Reduction of landslide movement after completion of the additional counterweight embankments was observed at the time. From observation results of the extensometer, E-3, the counterweight embankment appears to have been effective so far. However, movements in the rainy season have not been very clear because there is the possibility that the movement may be induced by heavy rainfall. For the stabilization of the small landslide, determent works such as piling will be required as a long term protective measure.

TABLES

TABLE II 2.1-1 DESIGN EARTH PRESSURE

DEPTH (m)	DESIGN EARTH PRESSURE q : (tf/m²)	DEPTH (m)	DESIGN EARTH PRESSURE q : (tf/m²)
0.00	0.00	10.00	9.00
0.50	0.45	10.50	9.45
1.00	0.90	11.00	9.90
1.50	1.35	11.50	10.35
2.00	1.80	12.00	10.80
2.50	2.25	12.50	11.25
3.00	2.70	13.00	11.70
3.50	3.15	13.50	12.15
4.00	3.60	14.00	12.60
4.50	4.05	14.50	13.05
5.00	4.50	15.00	03.50
5.50	4.95	15.50	13.95
6.00	5.40	16.00	14.40
6.50	5.85	16.50	14.85
7.00	6.30	17.00	15.30
7.50	6.75	17.50	15.75
8.00	7.20	18.00	16.20
8.50	7.65	18.50	16.65
9.00	8.10	19.00	17.10
9.50	8.55	19.50	17.55
10.00	9.00	20.00	18.00

TABLE II 2.1-2 ALLOWABLE EXTERNAL PRESSURE

THICKNESS (mm)	STIFFENER RING SIZE (mm)	STIFFENER RING INTERVAL (m)	ALLOWABLE PRESSURE FOR BUCKLING (tf/m^2)	ALLOWABLE PRESSURE FOR COMPRESSION (I) (tf/m^2)	ALLOWABLE PRESSURE FOR COMPRESSION (II) (tf/m^2)
1. Without perforation					
2.7	....	....	11.05	40.90	9.25
	H-125	2.0	44.24	56.48	24.25
	H-125	1.5	55.30	61.68	28.44
	H-125	1.0	77.43	72.07	36.38
	H-125	0.5	143.81	103.25	58.70
3.2	....	....	13.13	48.47	10.96
	H-125	2.0	46.32	64.05	26.31
	H-125	1.5	57.38	69.25	30.62
	H-125	1.0	79.51	79.64	38.76
	H-125	0.5	145.89	110.82	61.45
2. With perforation					
2.7	....	....	8.84	40.90	8.22
	H-125	2.0	42.03	56.48	23.94
	H-125	1.5	53.09	61.68	28.18
	H-125	1.0	75.22	72.07	36.18
	H-125	0.5	131.59	103.25	58.57
3.2	....	....	10.51	48.47	9.74
	H-125	2.0	43.70	64.05	25.90
	H-125	1.5	54.76	69.25	30.28
	H-125	1.0	76.89	79.64	38.50
	H-125	0.5	143.26	110.82	61.28

* (I) : in the case that only compressive strength is considered.
(II) : in the case that bending moment is considered.

TABLE II 2.1-3 REQUIRED QUANTITY OF MATERIALS FOR THE WELLS

MATERIAL	SPECIFICATION	UNIT WEIGHT (kg)	DRAINAGE WELL QUANTITY	DRAINAGE WELL WEIGHT (kg)	INTERMEDIATE WELL QUANTITY	INTERMEDIATE WELL WEIGHT (kg)
Steel plate	P10, t2.7mm	27.43	77plates	2109.8	217plates	5952.3
	Perforated	27.43	210plates	5754.0	…	…
Stiffener ring	H-125, l=2747.5mm	65.4	24pcs	1569.6	12pcs	784.8
Stiffener	H-175, l=6000mm	241.2	4pcs	964.8	…	…
	l=4500mm	180.9	4pcs	723.6	…	…
Connecting plate						
for ring	330×125×12mm	3.89	48plates	186.7	24plates	93.4
for stiffener	340×175×12mm	5.6	8plates	44.8	…	…
- do -	340×140× 6mm	2.24	8plates	17.9	…	…
Bolt	M16×35mm	0.146	3528pcs	515.1	2758pcs	402.7
	M16×45mm	0.160	420pcs	67.2	210pcs	33.6
	M20×50mm	0.283	528pcs	149.5	192pcs	54.3
	Nut for M20	…	192pcs	…	96pcs	…
	U-bolt M16	1.07	48pcs	51.4	…	…
Ladder	A-type H=1500mm	37.8	2pcs	75.4	…	…
	B-type H=2000mm	48.5	6pcs	291.0	…	…
	C-type H=1000mm	27.5	3pcs	82.5	…	…
	Step	41.4	3pcs	124.2	…	…
	Vertical H=4000mm	61.0	…	…	3pcs	183.0
	Vertical H=2000mm	32.0	…	…	1pc	32.0
	Handrail H=1000mm	17.6	1pc	17.6	…	…
	Metal fixtures	2.5	39pcs	97.5	…	…
Cover	Dia.=3600mm	610.0	1pc	610.0	1pc	610.0
		TOTAL WEIGHT (kg) =		13461.4		8146.1

TABLE II 2.1-4 MAIN MATERIALS REQUIRED FOR THE DRAINAGE WELL

MATERIAL	UNIT	MANUFACTURER IN MAURITIUS	AVAILABILITY IN MAURITIUS	BASIC PRICE FOR COST ESTIMATE (Rs.)	(Yen)
Portland cement	t	none	available	1097	0
Ready mixed concrete	m³	exist	available	1643	0
Sand	m³	exist	available	381	0
Gravel	m³	exist	available	270	0
H-shape steel, H200xH200	t	none	none	0	63000
Gas pipe, 100A, 4.5t	m	none	none	0	1098
PVC pipe, dia=40mm	m	exist	available	0	223
Plate for concrete form	m³	exist	available	16344	0
Dynamite	kg	exist	available	0	950
Detonator	nos	none	available	0	190
Taper rod, 22mm	nos	none	none	0	6550
Cross bit, 36mm	nos	none	none	0	6000
Metal crown, dia=66mm	nos	none	none	0	4000
Metal crown, dia=116mm	nos	none	none	0	8000
Core tube, dia=66mm	nos	none	none	0	20900
Metal crown, dia=116mm	nos	none	none	0	41500
Boring rod, dia=66mm	nos	none	none	0	11600
Boring rod, dia=116mm	nos	none	none	0	15800
Liner plate, etc.		none	none	0	0
Light oil	l	none	available	5.3	0
Gasoline	l	none	available	11.2	0
Oils and fats	l	none	available	17.7	0
Electric power	KWH	exist	available	3.3	0

* Basic price indicated with Yen does not include transportation cost.

TABLE Ⅱ 2.1-5 MAIN MACHINES REQUIRED FOR THE DRAINAGE WELL

MACHINE		AVAILABILITY IN MAURITIUS	BASIC UNIT COST FOR COST ESTIMATE (Rs.)	(Yen)
Bulldozer	3t class	available	400	0
Bulldozer	20t	available	653	0
Backhoe	0.35m³	available	450	0
Truck crane	11t	available	587	0
Dump truck	4t	available	400	0
Dump truck	12t	available	527	0
Truck trailer		available	320	0
Macadam roller	11t	available	400	0
Hand hammer		not avail.	0	1310/day
Pick hammer		not avail.	0	160/day
Boring machine		not avail.	0	82949/day
Boring pump		not avail.	0	5313/day
Air compressor	5m³/min	not avail.	0	6700/day
Air compressor	10.5m³/min	not avail.	0	13500/day
Submergible pump	80mm, 5.5KW	not avail.	0	1583/day
Blower	50m³/min, 0.75KW	not avail.	0	152/day
Disel generator	25KVA	not avail.	0	3540/day
Winch	7.5KW	not avail.	0	1600/day
Air hammer		not avail.	0	4440/day
Skip Tower		not avail.	0	1962/day
For the Reference :				
Tractor shovel	1.5m³ class	available		
Wheel roader	1.5m³	available		
Tire roller	11t	available		
Motorized grade	3.1m	available		

TABLE II 2.1-6 REQUIRED MANPOWER FOR THE DRAINAGE WELL CONSTRUCTION

KIND OF WORK		3/MINIMUM WAGE	BASIC UNIT PRICE FOR COST ESTIMATE		
			4/DAILY WAGE	5/EXTRA PAY	UNIT PRICE
Foreman		83.70	330	165	495
Operator		39.00	220	0	220
Assistant Operator		39.00	170	0	170
Driver		39.00	202	0	202
Mechanic		51.46	230	0	230
Electrician		44.59	230	0	230
Carpenter		50.08	184	92	276
Concrete Worker		……	159	80	239
Masonry Worker		52.96	182	0	182
Plumber		……	182	0	182
Rigger		……	197	99	296
Skilled Labour		44.59	232	116	348
Semi-skilled Labour		……	143	72	215
Common Labour		32.56	118	59	177
Average daily working hours		8 hours			8 hours
Extra pay for overtime	normal overtime	50 %			……
	night overtime	50 %			……
	holiday overtime	100-200 %			……

* 3/ According to "Labour Laws of Mauritius (2nd edition)", 1988.

4/ Though drainage well construction is not experienced enough in Mauritius, extra pay is calculated as 50 % up.

TABLE Ⅱ 2.1-7 QUANTITY OF GROUNDWATER COLLECTION BOREHOLES AND DRAINAGE BOREHOLES

WORK ITEM	BOREHOLE DIA. (mm)	DRILL LENGTH (m)	PROTECTION PIPE DIA. (mm)	KIND OF PROTECTION PIPE	REMARKS
Groundwater collection borehole	66.0	1000.0 (50M x 20holes)	48.0	PVC pipe (VP40)	with strainer
Drainage borehole	116.0	50.0	101.6	SGP90A	Drainage well to intermediate well
	116.0	70.0	101.6	SGP90A	Intermediate well to drainage channel

* 1) Diameter of protection pipes are indicated with outer diameter.
2) SGP pipe : gas pipe (carbon steel pipe)
3) Protection pipe has to be the same quality mentioned above or better.

TABLE II 2.2-1 QUANTITY OF MATERIALS FOR CONSTRUCTION OF DRAINAGE WELL

Item		Quantity
Liner Plate	Type	AN-type
	Diameter	3.5m
	Thickness	2.7mm
	Width	500mm
	Nos. of Seperate	7 pcs
	Coating	Galvanised
	Total Depth	15.5m (including 0.5m height above the ground)
Ring Stiffener	Nos. of Stage	6 stages
	Size	H-125 x 125 x 6.5 x 9
Vertical stiffener	Length	10.7m x 4 pcs
	Size	H-175 x 175 x 7.5 x 11
Ladder	Type	Spiral
	Nos. of Landing	3 stages
Bottom	Type	Concrete
	Thickness	0.3m
Steel Cover	Type	Expanded Metal
	Diameter	3.65m
Fense	Height	2m

TABLE II 2.2-2 QUANTITY OF MATERIALS FOR CONSTRUCTION OF INTERMEDIATE WELL

Item		Quantity
Liner Plate	Type	AN-type
	Diameter	3.5m
	Thickness	2.7mm
	Width	500mm
	Nos. of Seperate	7 pcs
	Coating	Galvanised
	Total Depth	15.5m (including 0.5m height above the ground)
Stiffner	Nos. of Stage	3 stages
	Size	H-125 x 125 x 6.5 x 9
Ladder	Type	Vertical Ladder Type Step
	Nos. of Landing	2 stages
Bottom	Type	Concrete
	Thickness	0.3m
Cap	Type	Expanded Metal
	Diameter	3.65m
Fense	Height	2m

TABLE II 2.2-3 QUANTITY AND SIZE OF DRAINAGE BOREHOLES

Item	Upper Section	Lower Section
Drilling Diameter	135 mm	
Drilling Length	45 m	75 m
Protection Pipe of Borehole		
Nominal Code	SGP 100A	
O. D.	114.3 mm	
Thickness	4.5 mm	
Coating	Anticorrosive	

Notes : Upper Section : Between Drainage well and Intermediate well
Lower Section : Between Intermediate well and Outlet

TABLE II 2.2-4 QUANTTIY OF MATERIALS FOR OUTLET WORKS OF DRAINAGE BOREHOLES

Item		Quantity
Drainage Channel	Length	18.0 m
	Depth from Ground	2.0 m
	Width at Bottom	0.5 m
	Inclination of wall	1 : 0.7
Mud Pit	Size at Bottom	1.0 m x 1.0 m
	Depth for Ground	2.8 m
Excavation	Volume	451 m³
Mascnry	Thickness	0.3 m
	Volume	181 m³

TABLE II 3.2-1 QUANTITY AND SIZE OF EMERGENCY COUNTERWEIGHT EMBANKMENT

Counterweight	Length (m)	Width (m)	Height (m)	Volume (m^3)	Elevation (m)	Time
First	40	5-6	3	655	46-49	Jan. 1990
Second	34	6-4	3	485	49-52	May. 1990
Third	21	2-3	3	154	52-55	Jun. 1990

* The first counterweight was for the landslide movements since Oct. 1989.

* The Second and third counterweights are for the landslide movements since Feb. 1990.

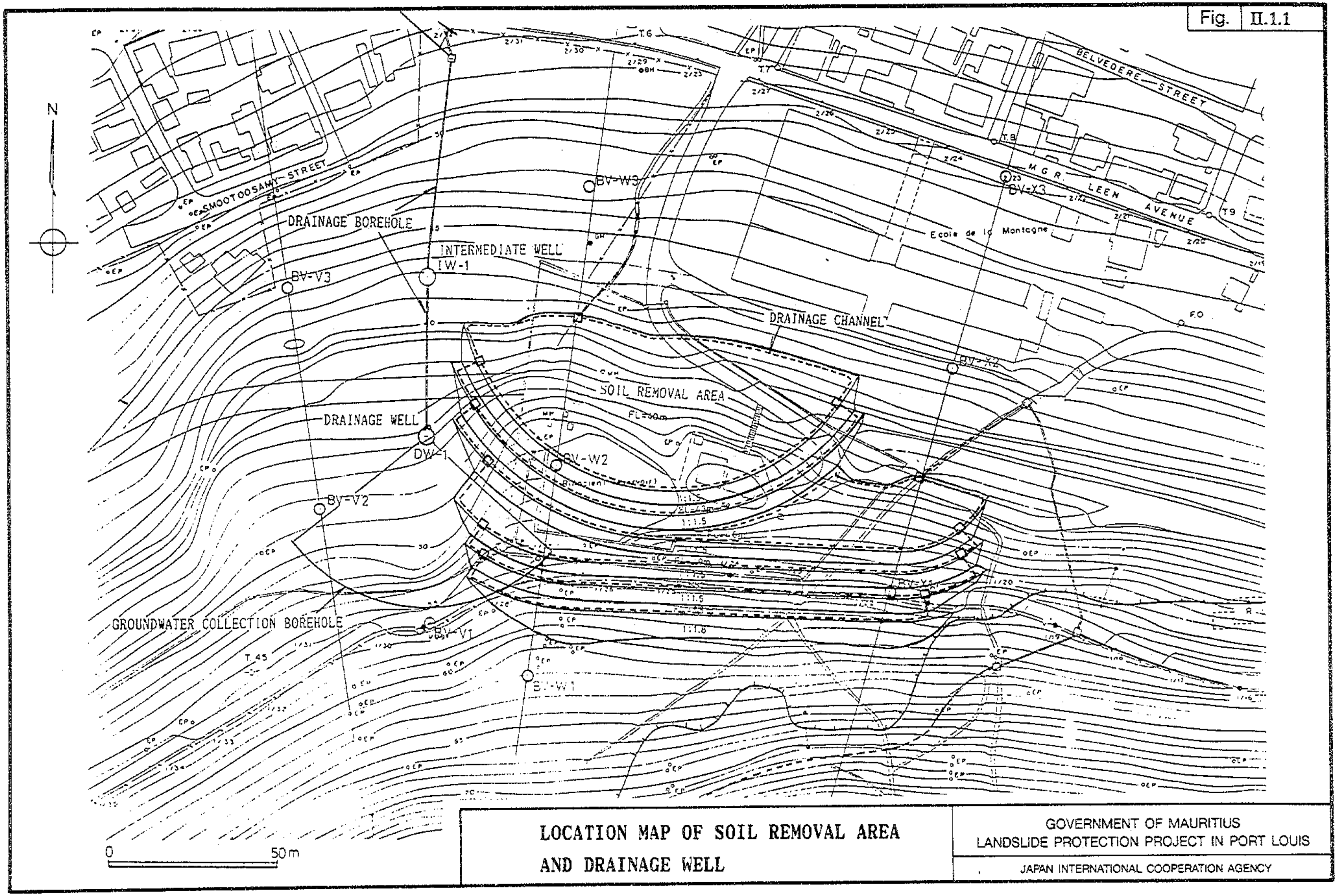
TABLE II 3.2-2 SUMMARY OF STABILITY ANALYSIS RESULTS ON THE SMALL LANDSLIDE BELOW EXTENSOMETER, E-3

STAGE	c (kg/sq. cm)	phi (deg.)	A	B	C
0	1.00	14.89	1.00	1.103	1.224
I	1.00	14.89	1.094	1.103	1.224
I	1.00	13.05	1.00	1.016	1.134
I + II + III	1.00	13.05	1.046	1.119	1.134

c : cohesion of soil
phi : internal friction angle of soil
A : safety factor along the firstly assumed sliding surface
B : safety factor along the secondary assumed sliding surface
C : safety factor along the thirdly assumed sliding surface
I : at the completion of the first counterweight
I + II + III : at the completion of the first to the third counterweights

FIGURES

Fig. II.1.1

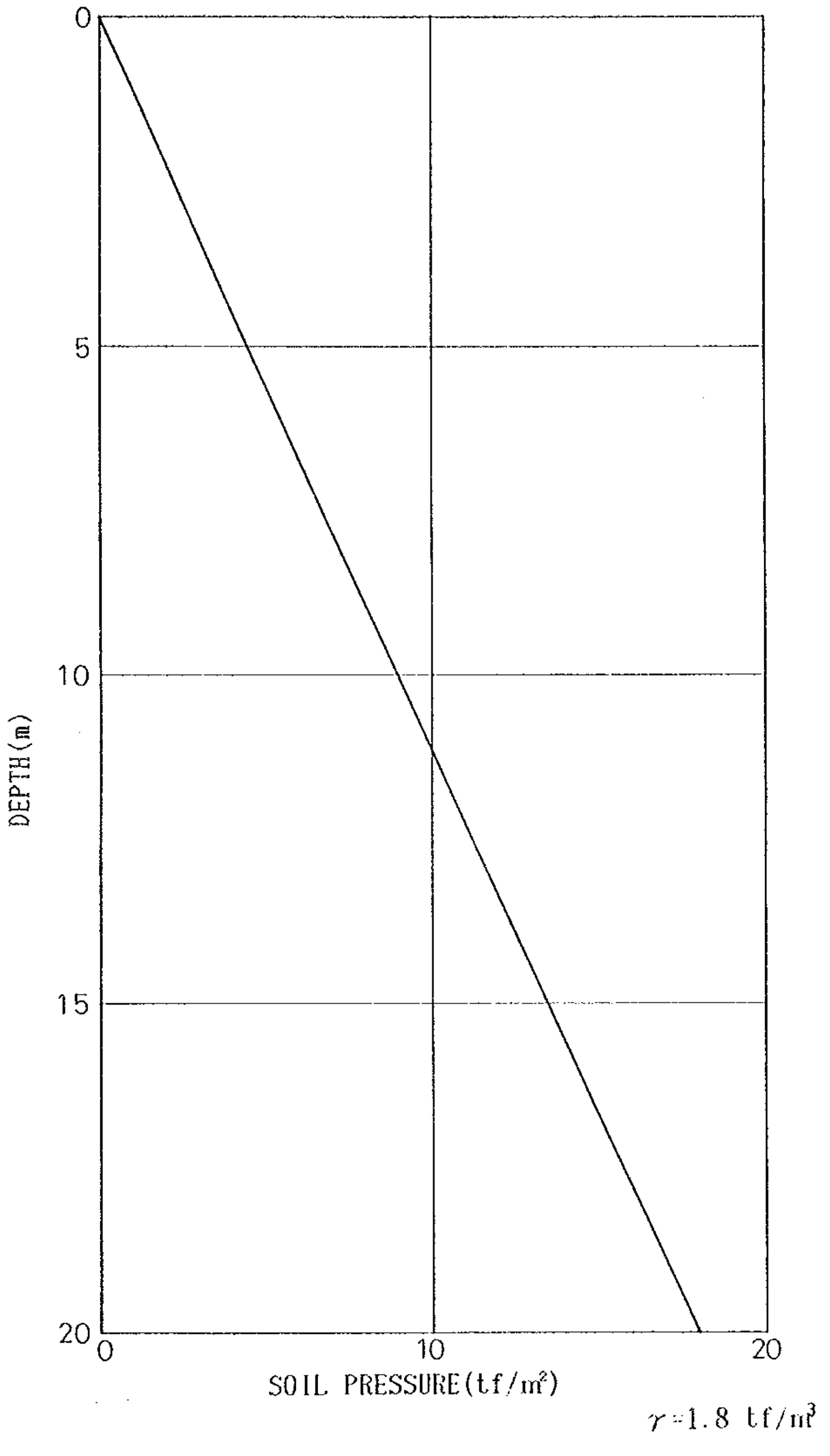


LOCATION MAP OF SOIL REMOVAL AREA AND DRAINAGE WELL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.1-1

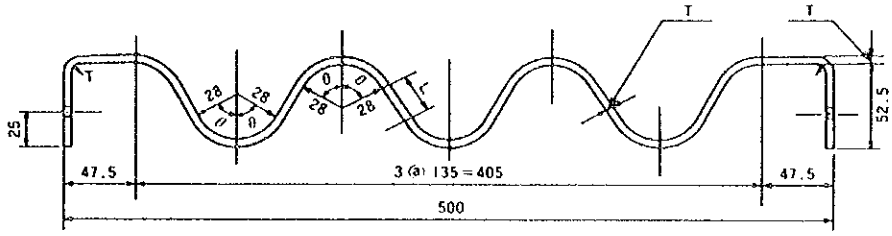


DISTRIBUTION OF UNIFORM STATIC EARTH PRESSURE

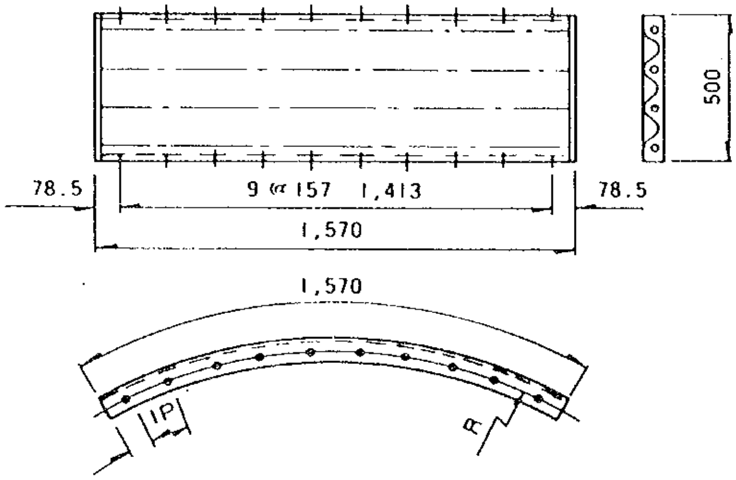
GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

AN-TYPE LINER PLATE (SS34)



P10 SECTION



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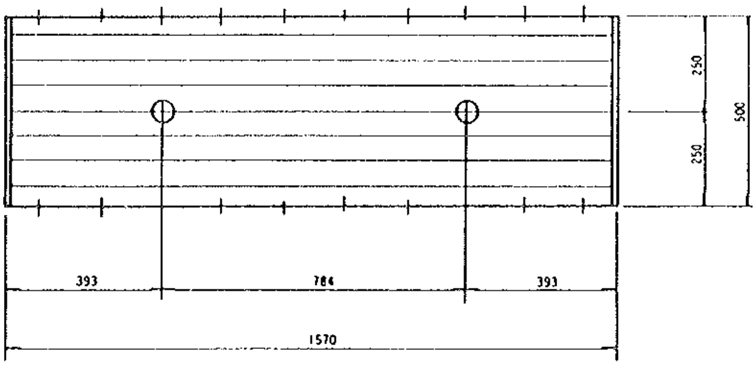
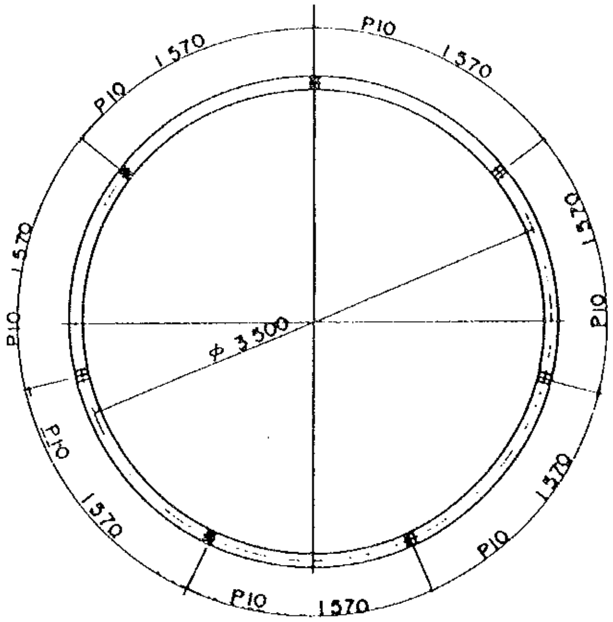
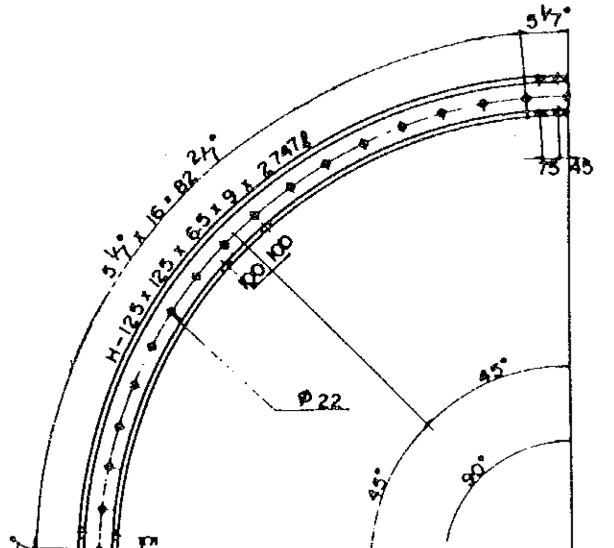


DETAIL OF LINER PLATE	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS JAPAN INTERNATIONAL COOPERATION AGENCY

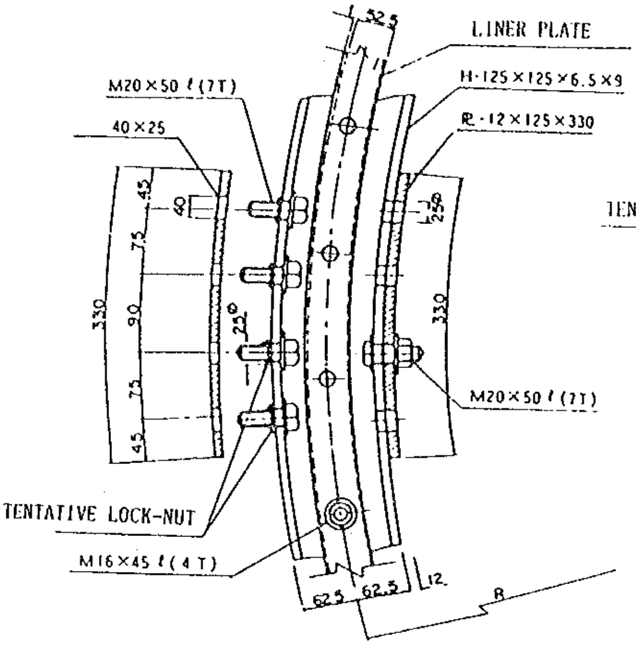


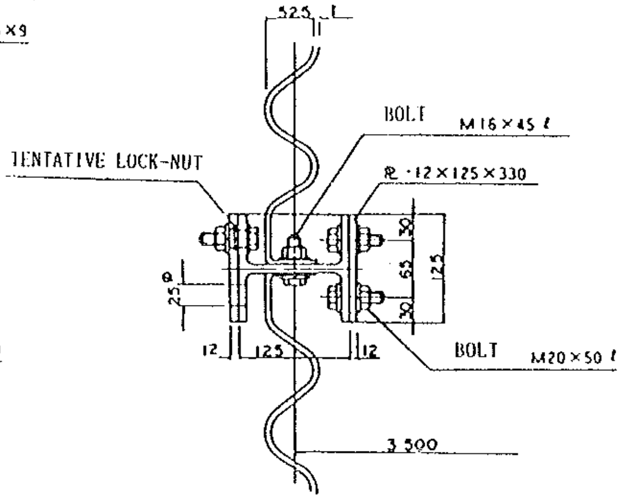
a) LINER PLATE

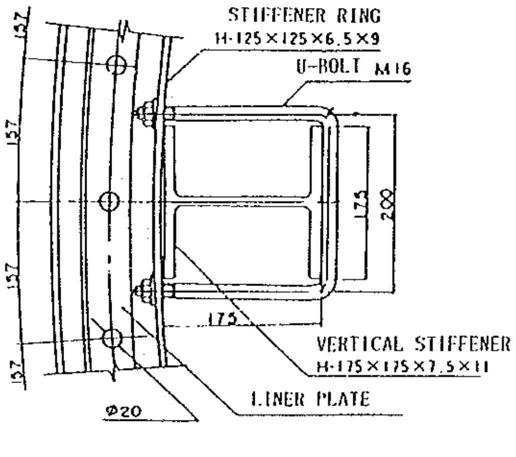


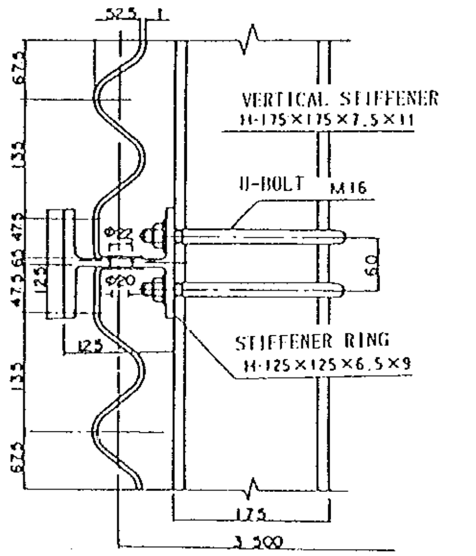
b) STIFFENER RING

LINER PLATE AND STIFFENER RING	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS JAPAN INTERNATIONAL COOPERATION AGENCY







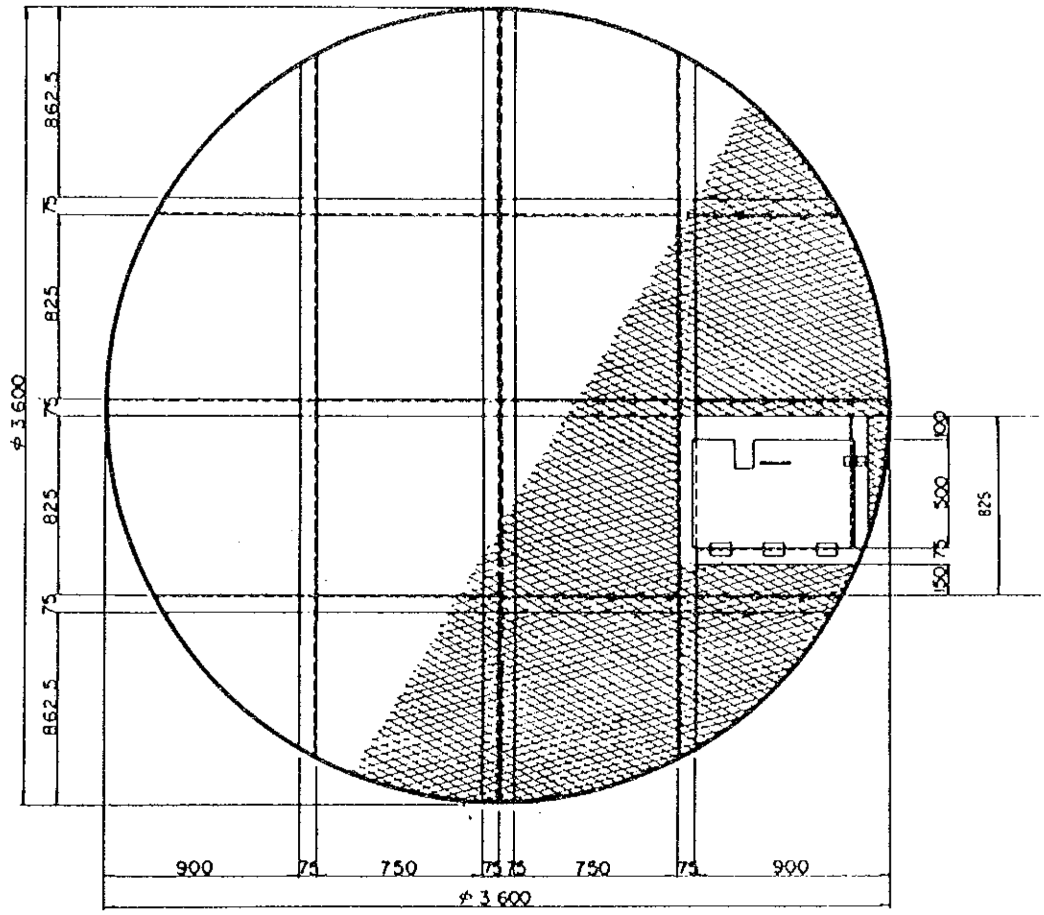


CONNECTION OF STIFFENER AND FIXING OF VERTICAL STIFFENER RING

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.1-5



STEEL COVER OF WELLS

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.1-6

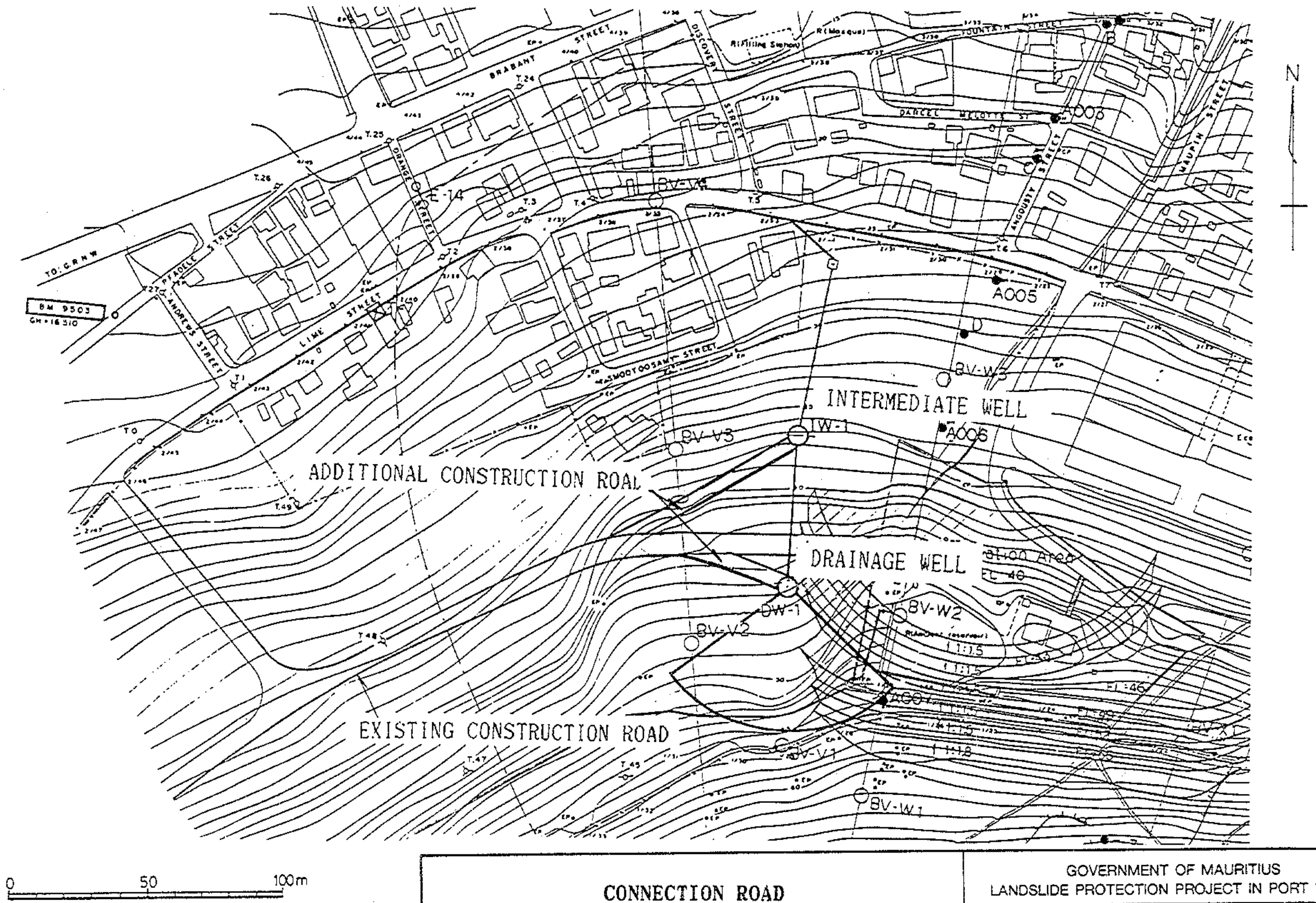
WORK ITEM	QUANTITY	UNIT	TOTAL MONTH												
			1	2	3	4	5	6	7	8	9.	10	11	12	13
1. Material order	1.0	l.s.													
2. Material supply	1.0	l.s.													
3. Temporary works	1.0	l.s.													
4. Drainage well	20.0	m													
5. Intermediate well	15.0	m													
6. Drainage borehole (Intermediate well to ground surface)	60.0	m													
7. Drainage borehole (drainage well to intermediate well)	60.0	m													
8. Groundwater collection borehole	1000.0	m													
9. Drainage channel	30.0	m													
10. Leakage protection works	1.0	l.s.													
11. Appurtenant works	1.0	l.s.													
12. Dismantle, cleaning works	1.0	l.s.													

TIME SCHEDULE FOR THE EXPERIMENTAL INVESTIGATION

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.1–7

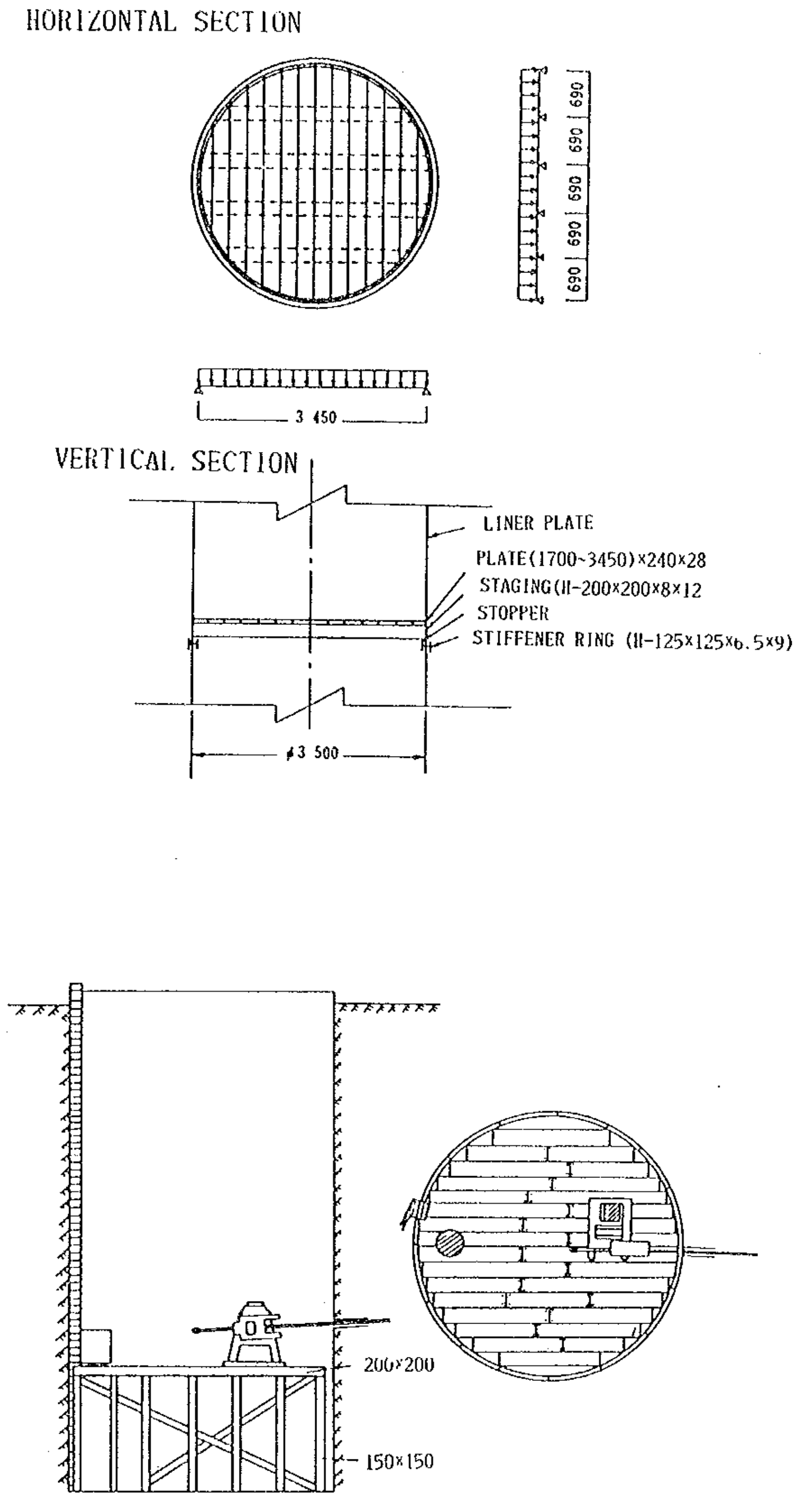


CONNECTION ROAD

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

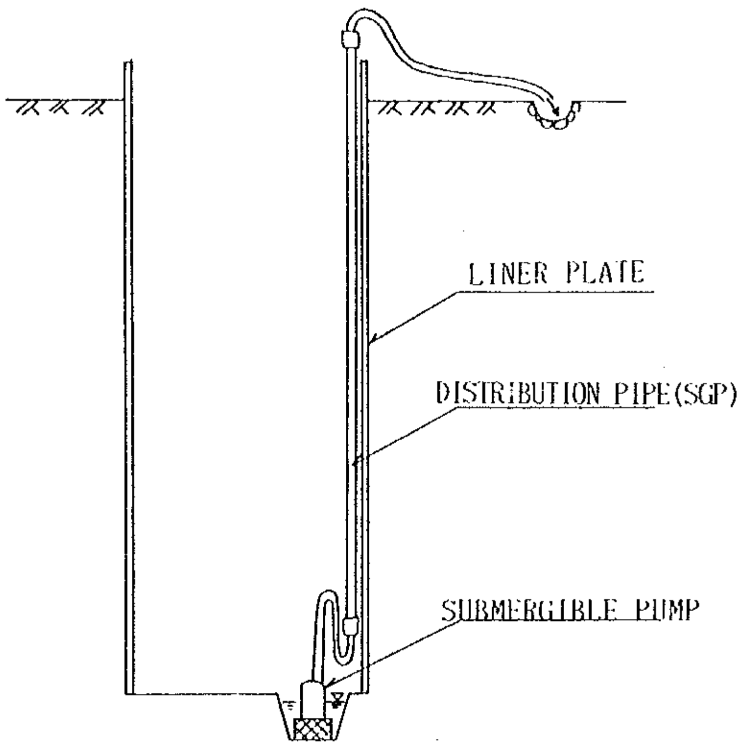
Fig. II.2.1-8



UNIT:mm

WORKING STAGE FOR GROUNDWATER COLLECTION AND DRAINAGE DRILLING	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
	JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.1-9

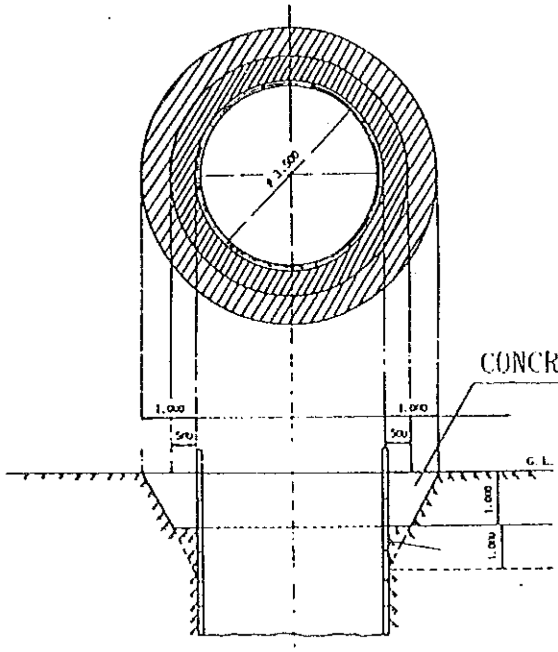


PUMPING OUT FROM DRAINAGE WELL

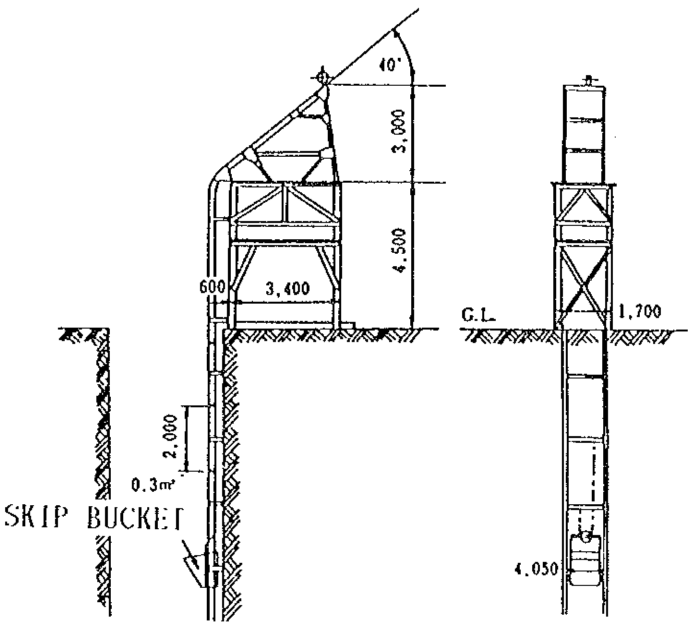
GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

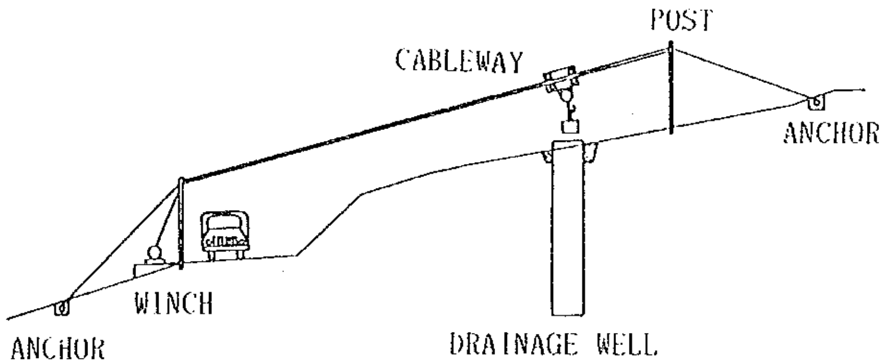
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.1–10



FIXING OF CONCRETE CAP	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS JAPAN INTERNATIONAL COOPERATION AGENCY



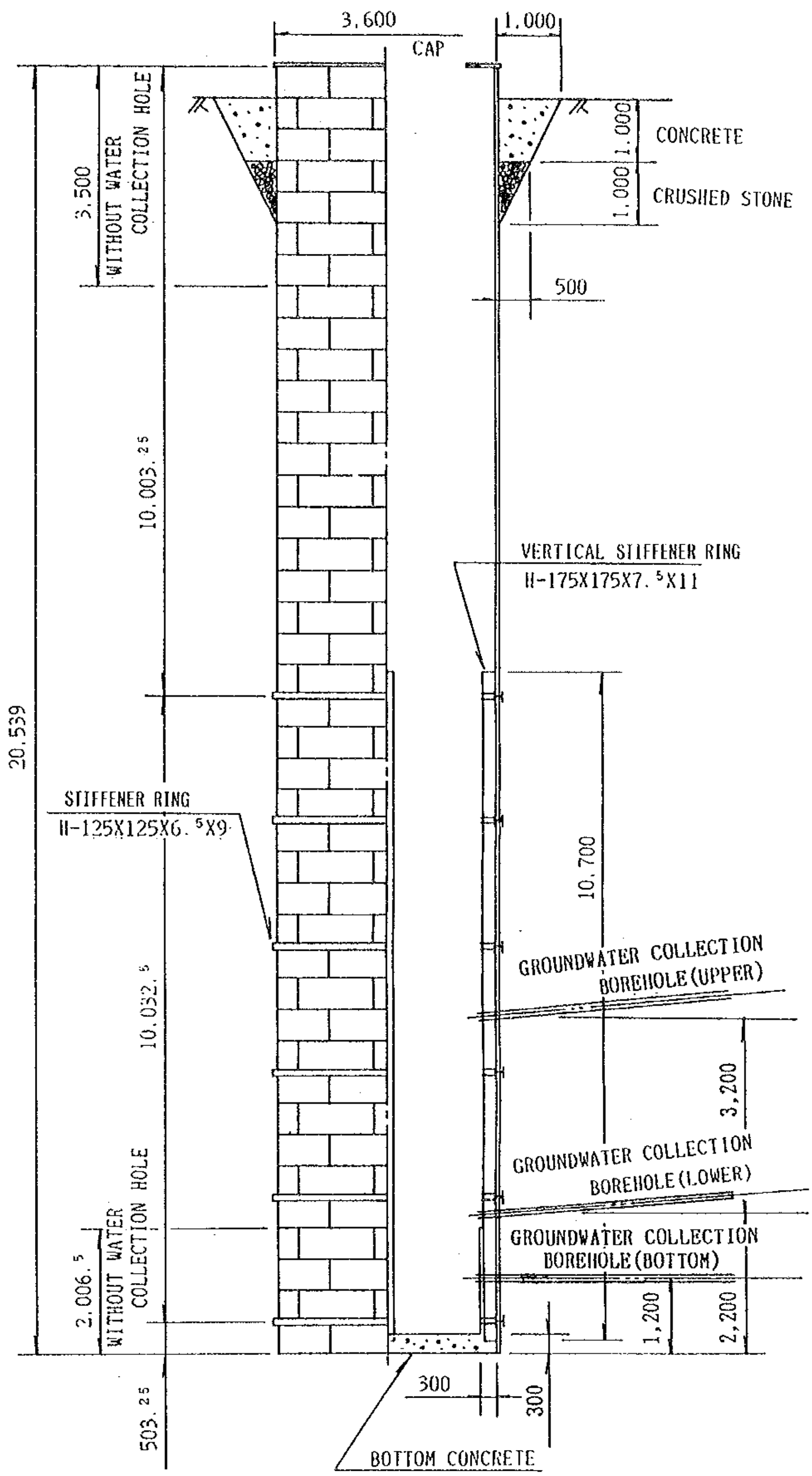


EXAMPLE OF MUCKING FROM DRAINAGE WELL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

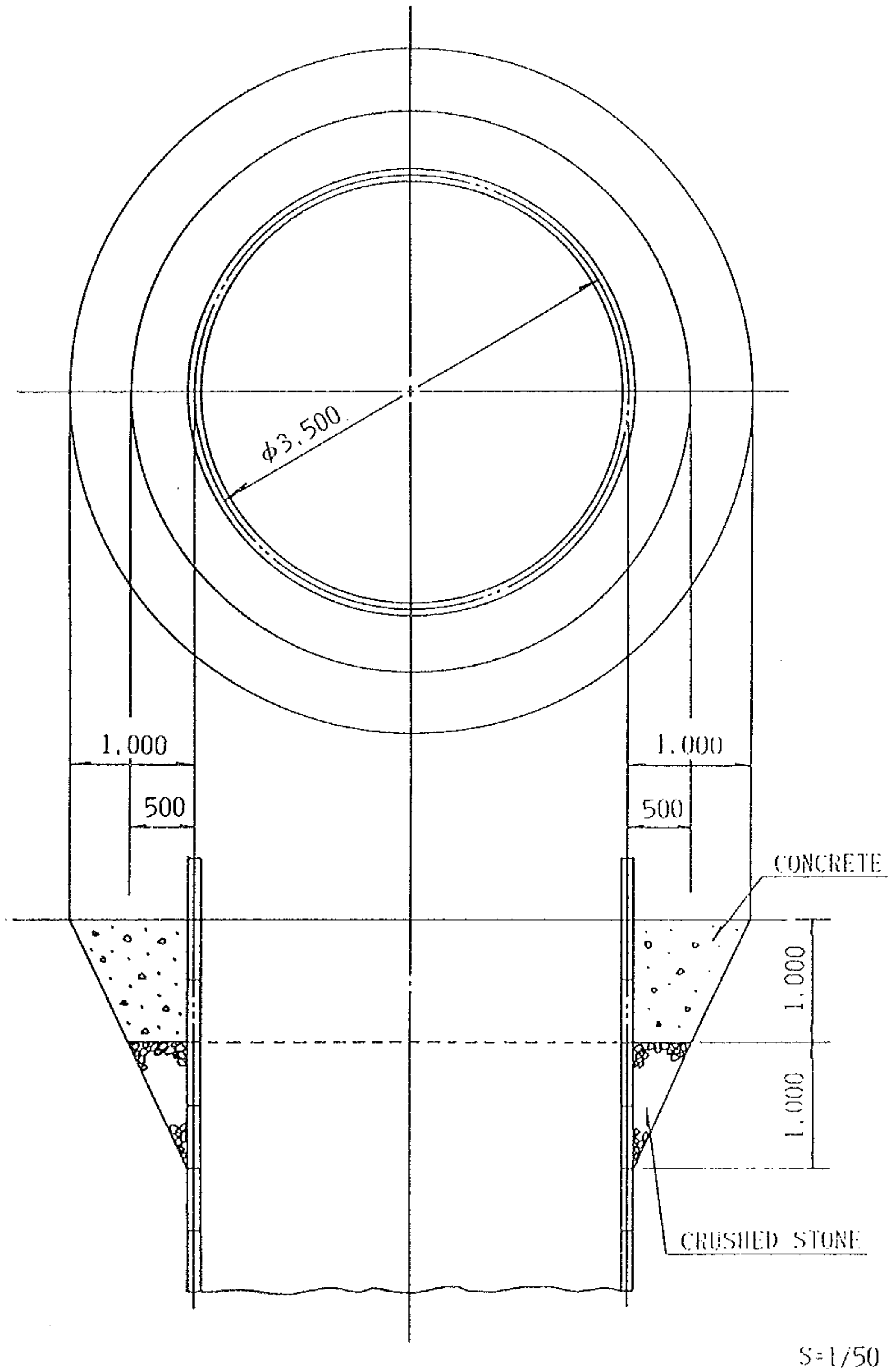
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-1



STRUCTURE OF DRAINAGE WELL	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
	JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2–2

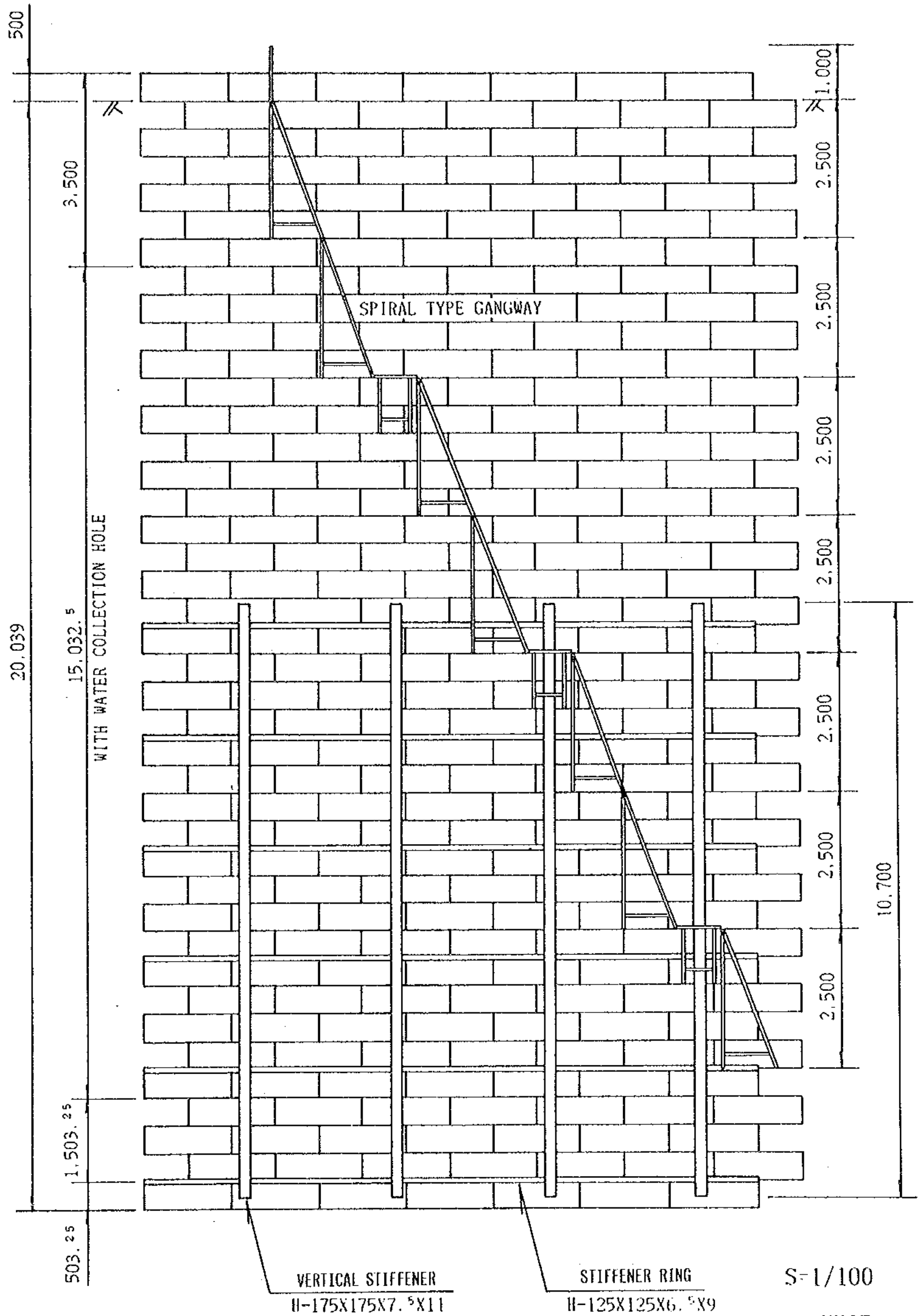


UPPER STRUCTURE OF DRAINAGE WELL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

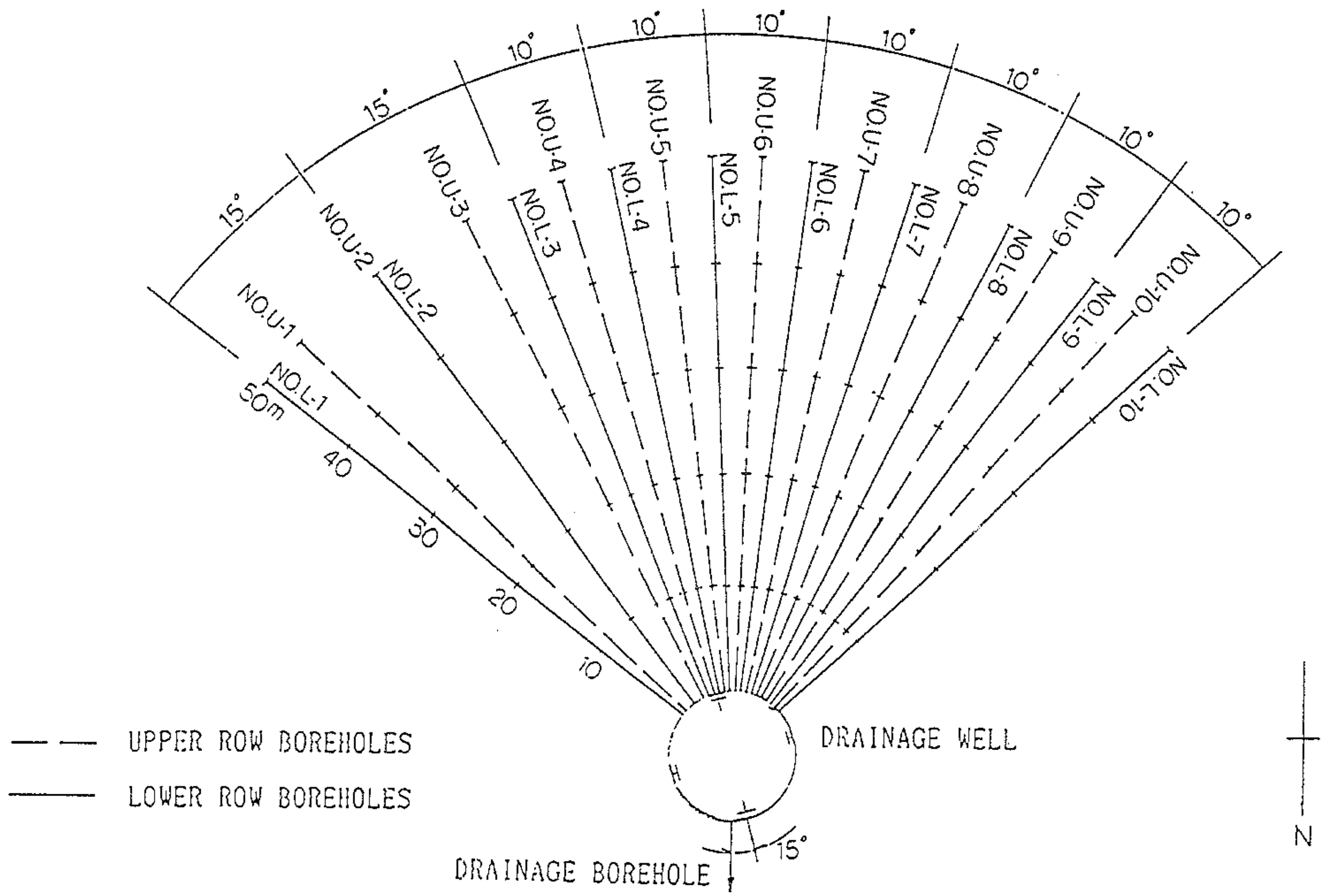
Fig. II.2.2-3



PROFILE OF DRAINAGE WELL

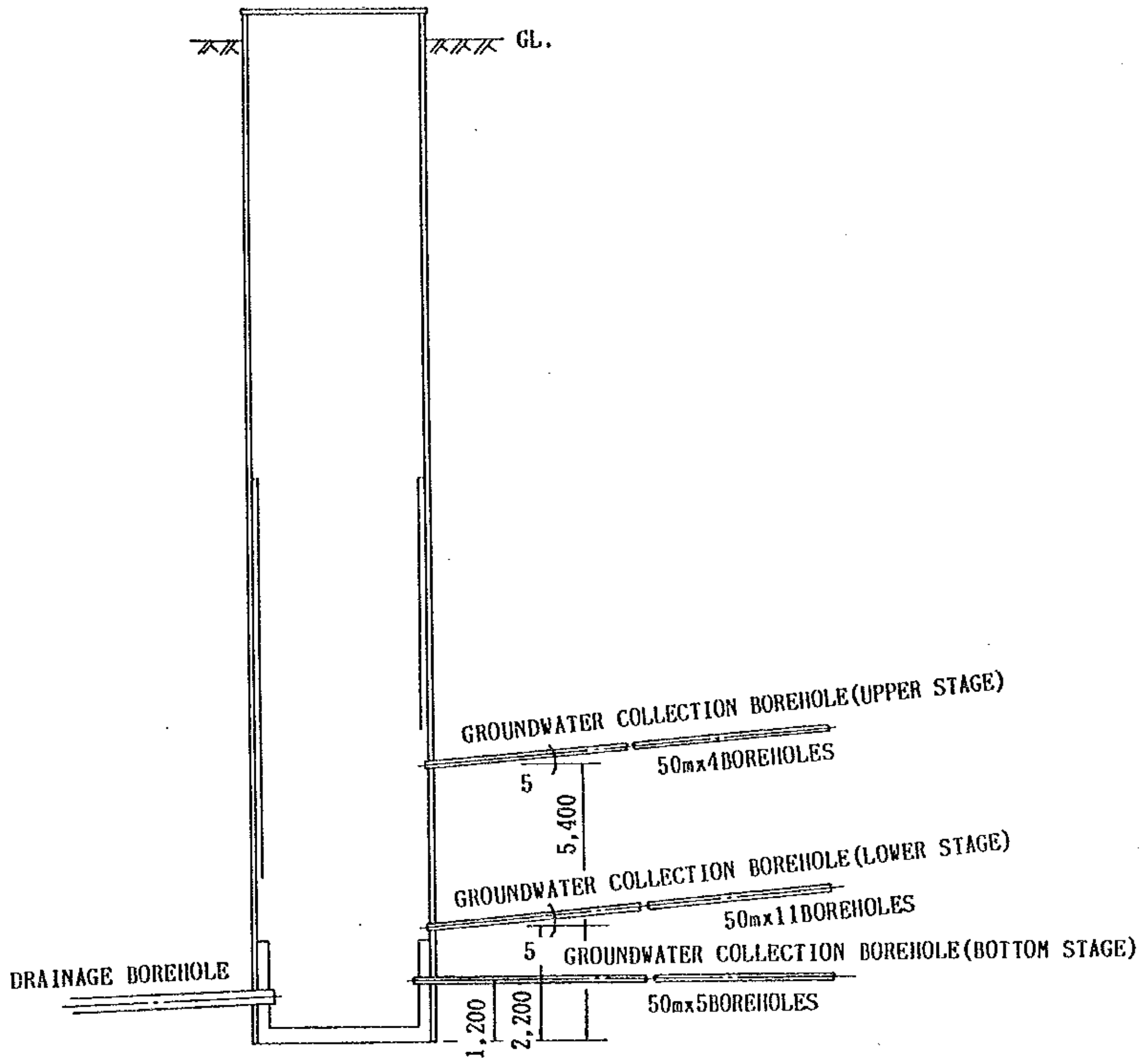
GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2–4



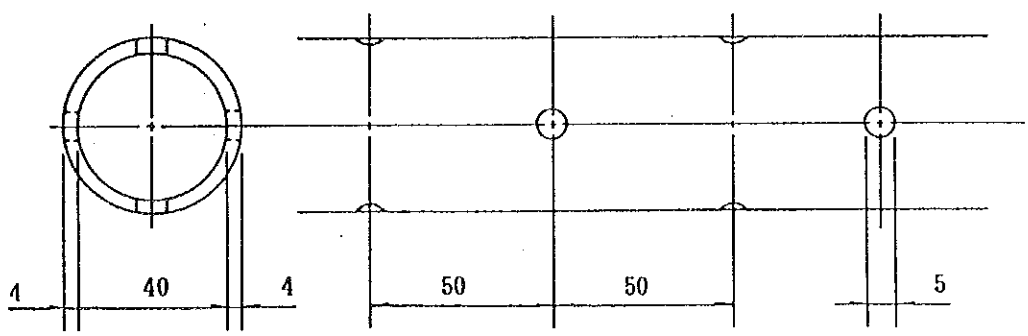
HORIZONTAL ARRANGEMENT OF GROUNDWATER COLLECTION BOREHOLES	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-5



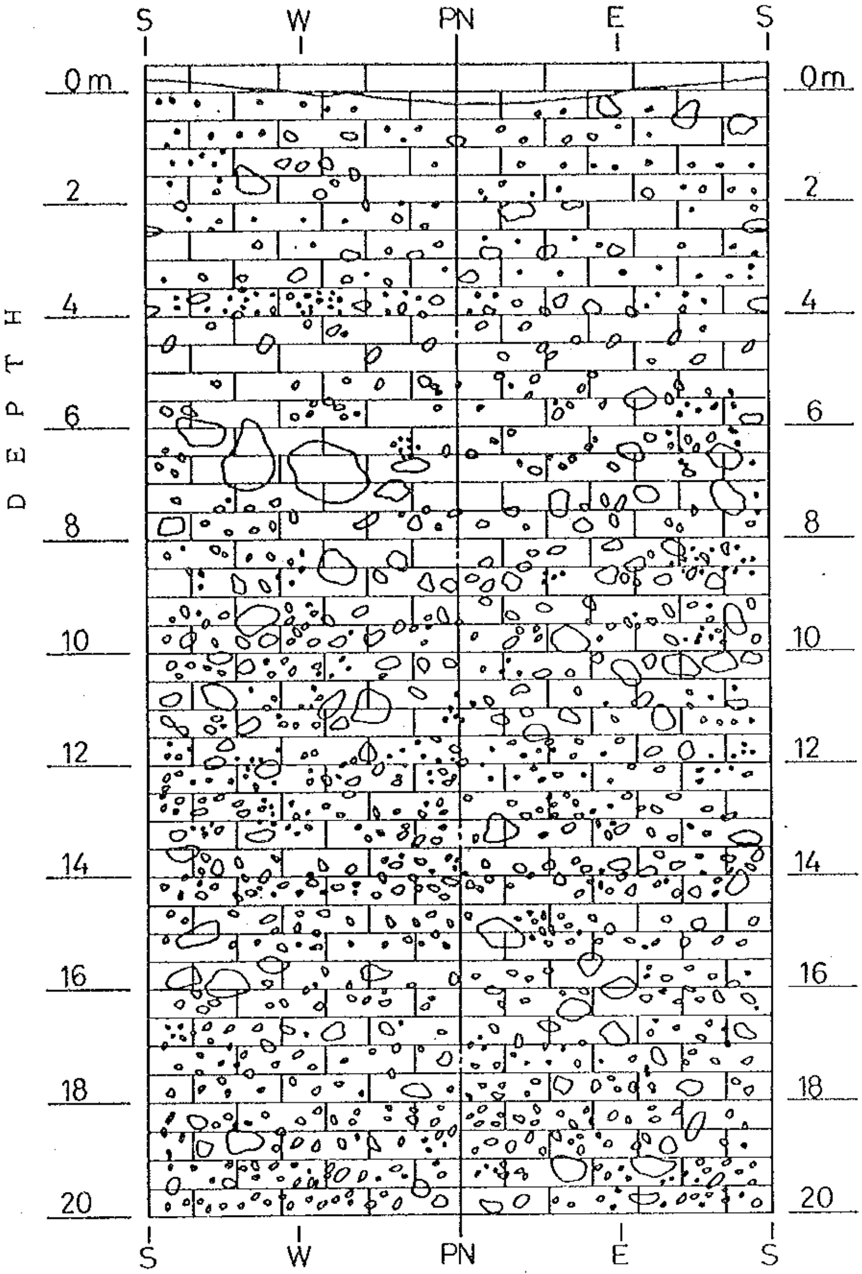
POLYVINYL CHLORIDE(PVC) PIPE

UNIT: mm



VERTICAL ARRANGEMENT OF GROUNDWATER COLLECTION BOREHOLES AND STRAINER PIPE	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-6



Note.

Materials (surrounding the drainage well) are composed of basalt gravel and cohesive clayey soil.

No groundwater level is observed.

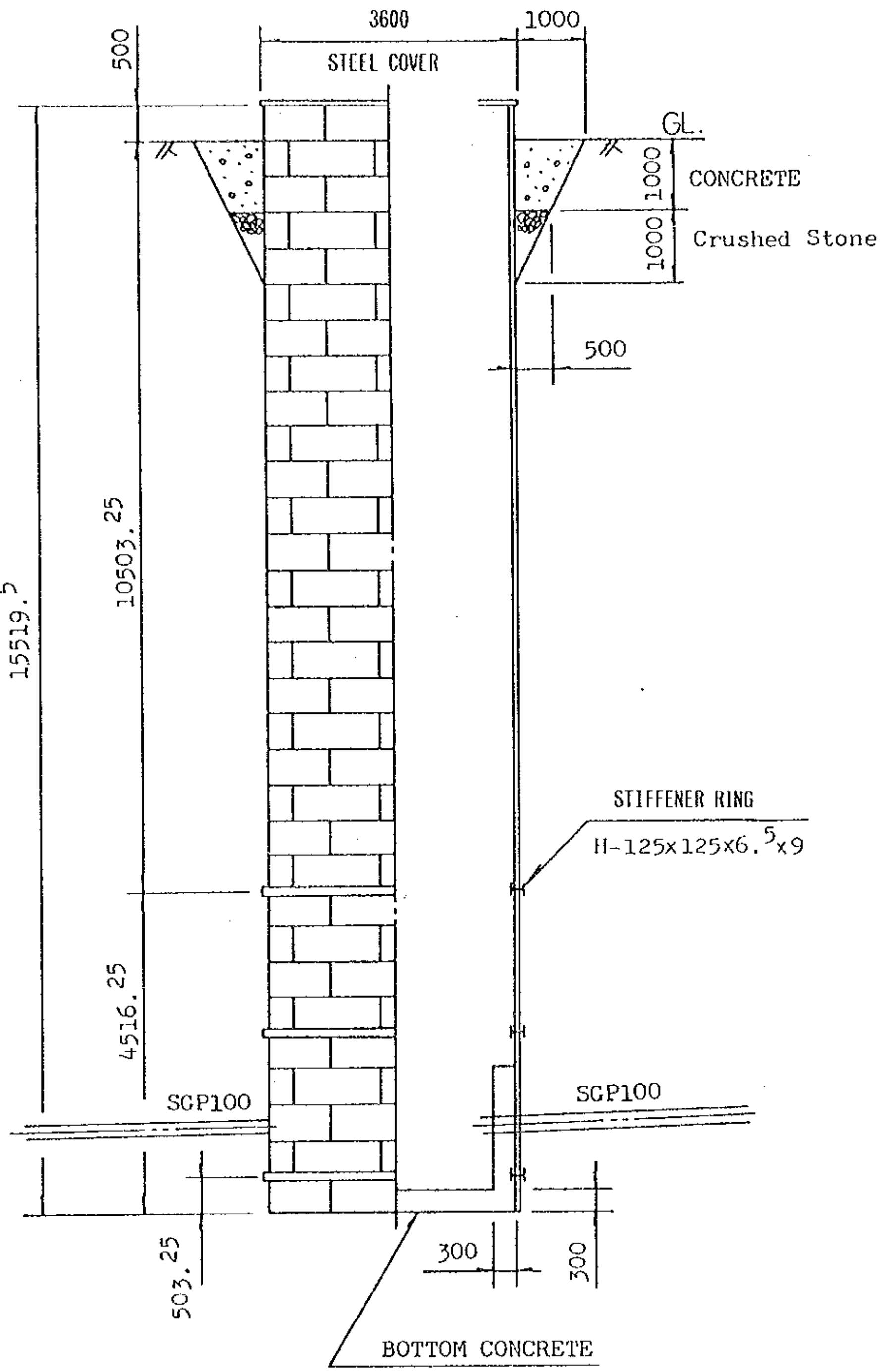
Clayey soil appears to be reddish brown.

Frequent slickensides are developed in clayey soil.

Clayey soil is slightly sandy below 13m.

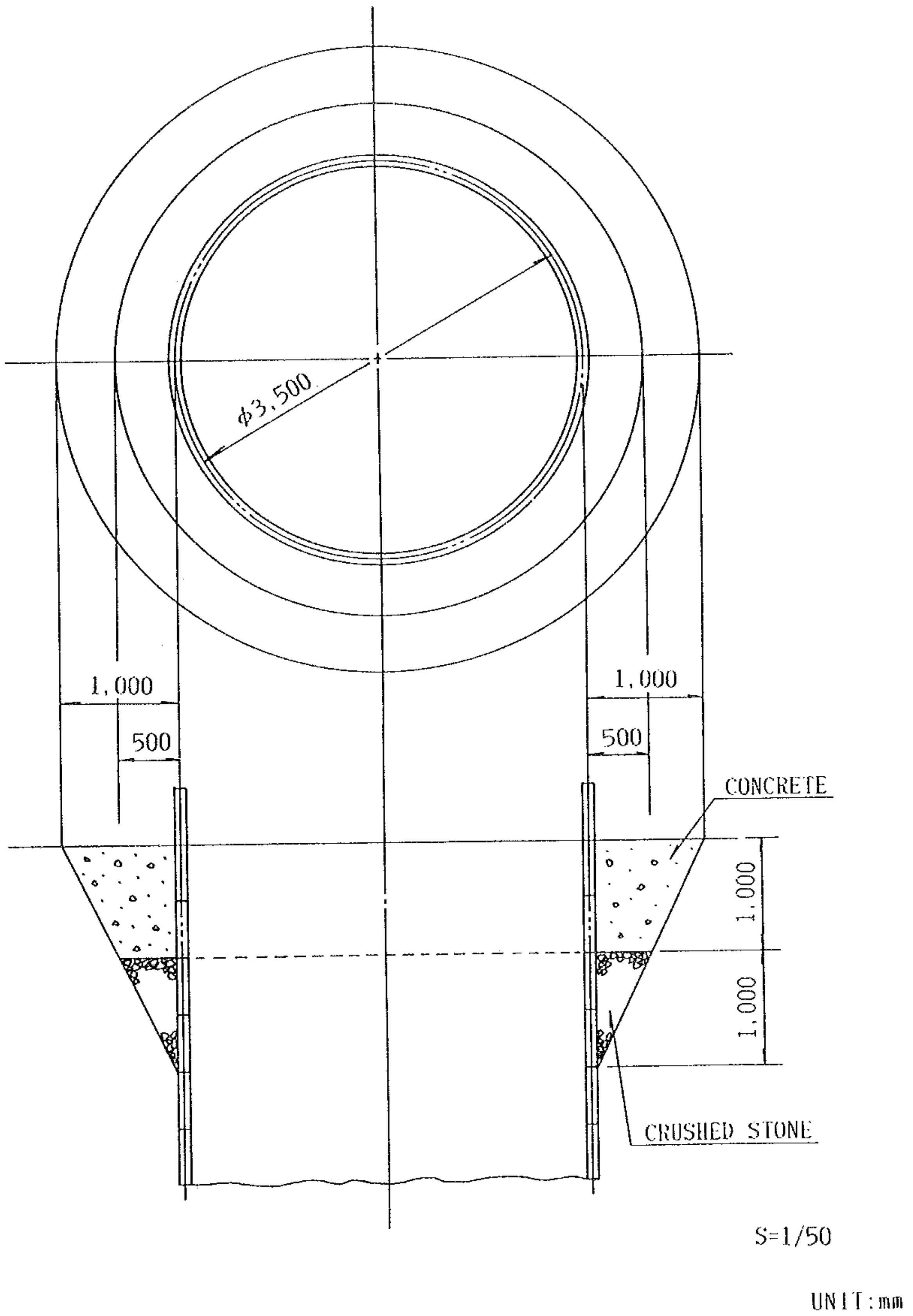
SUBSURFACE CONDITION SURROUNDING DRAINAGE WELL	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-7



STRUCTURE OF INTERMEDIATE WELL	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-8

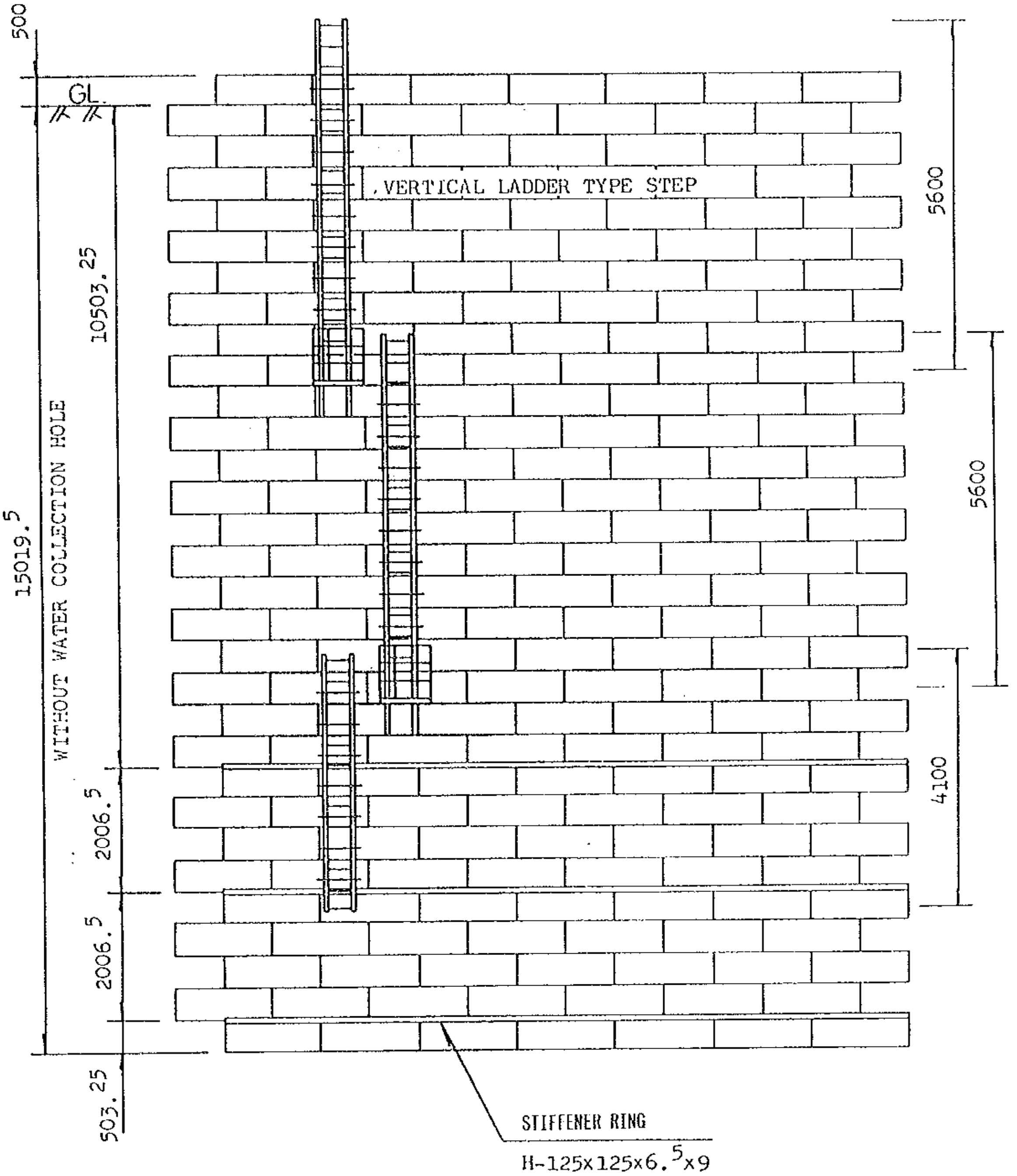


UPPER STRUCTURE OF INTERMEDIATE WELL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-9

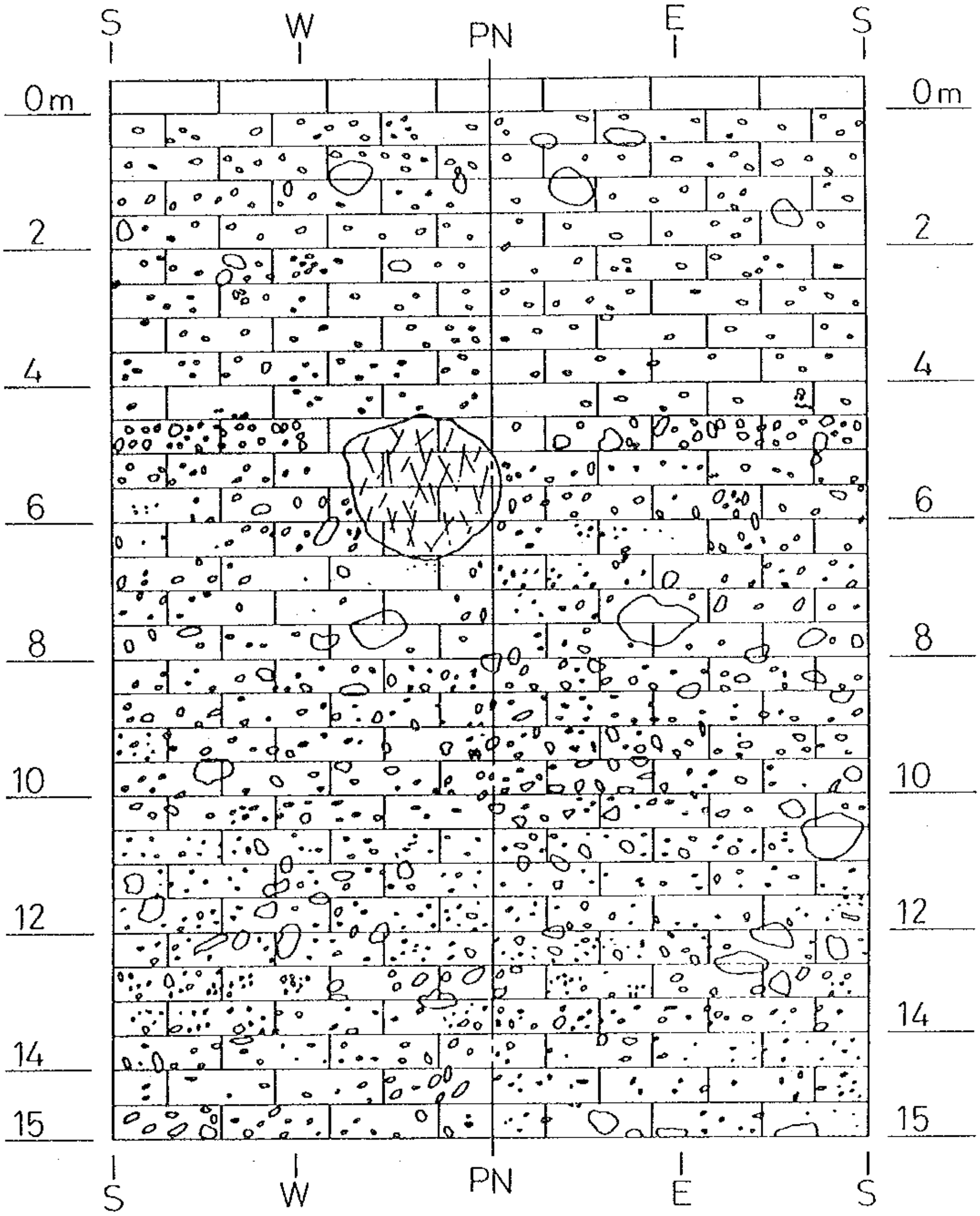


PROFILE OF INTERMEDITE WELL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-10



Note:

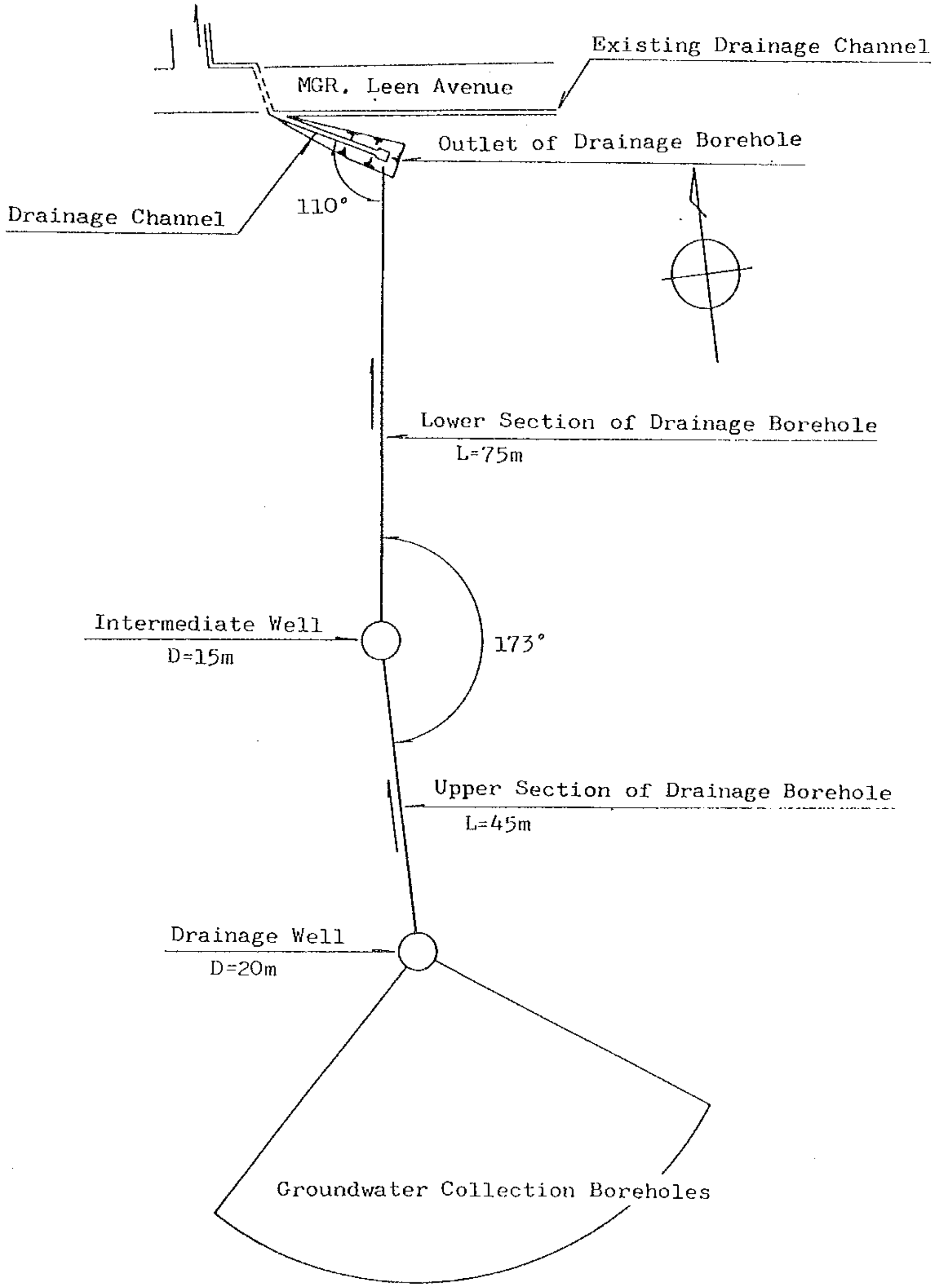
Materials(surrouding the intermediate well) are composed of basalt, gravel and cohesive clayey soil.
No groundwater level is observed.
Clayey soil appears to be reddish brown.
Frequent slickensides are developed in clayey soil.

SUBSURFACE GEOLOGICAL CONDITION SURROUNDING INTERMEDIATE WELL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

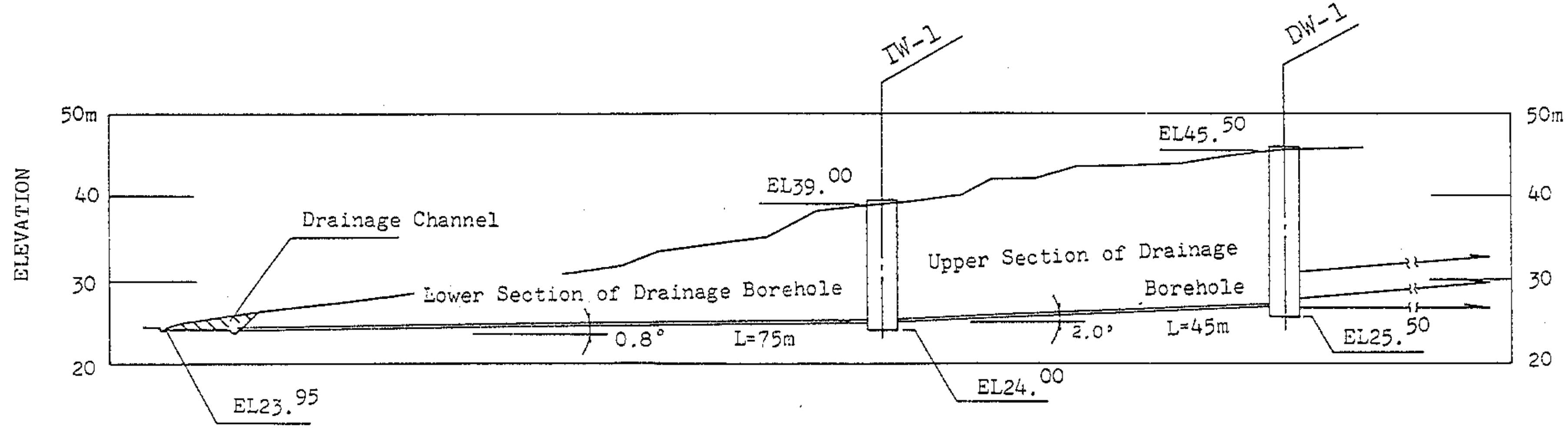
JAPAN INTERNATIONAL COOPERATION AGENCY

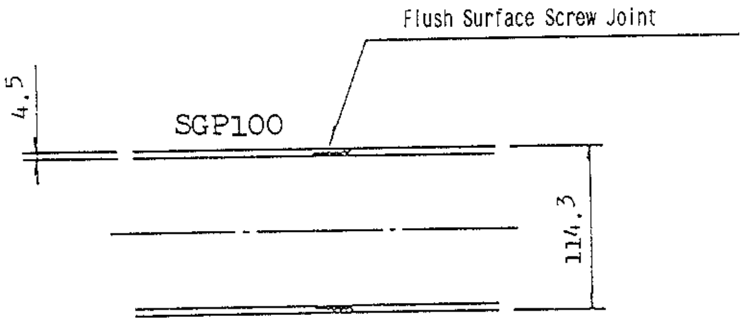
Fig. II.2.2-11



ALIGNMENT OF DRAINAGE BOREHOLES	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
	JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-12





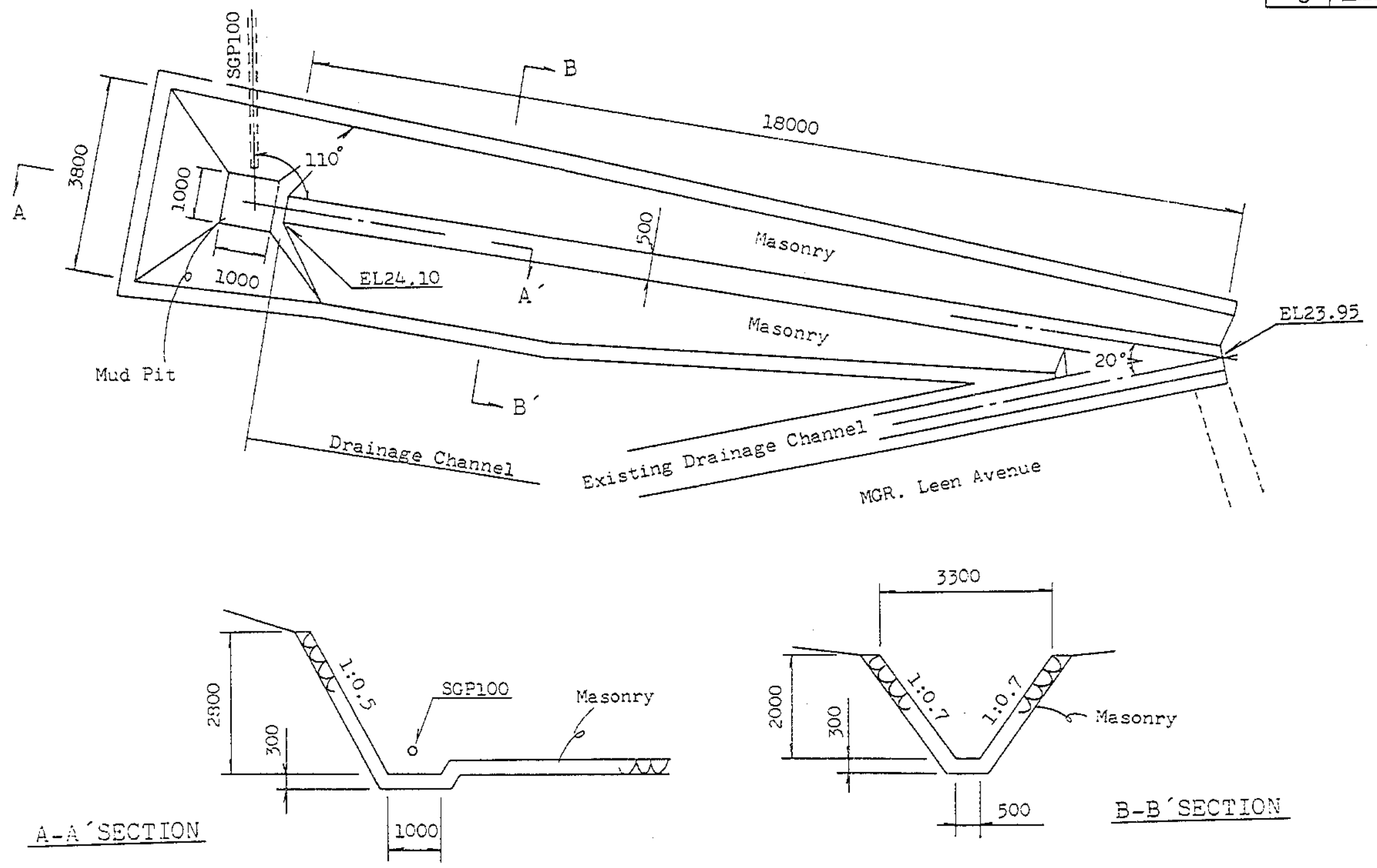
DRAINAGE BOREHOLE

PROFILE OF DRAINAGE BOREHOLES

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

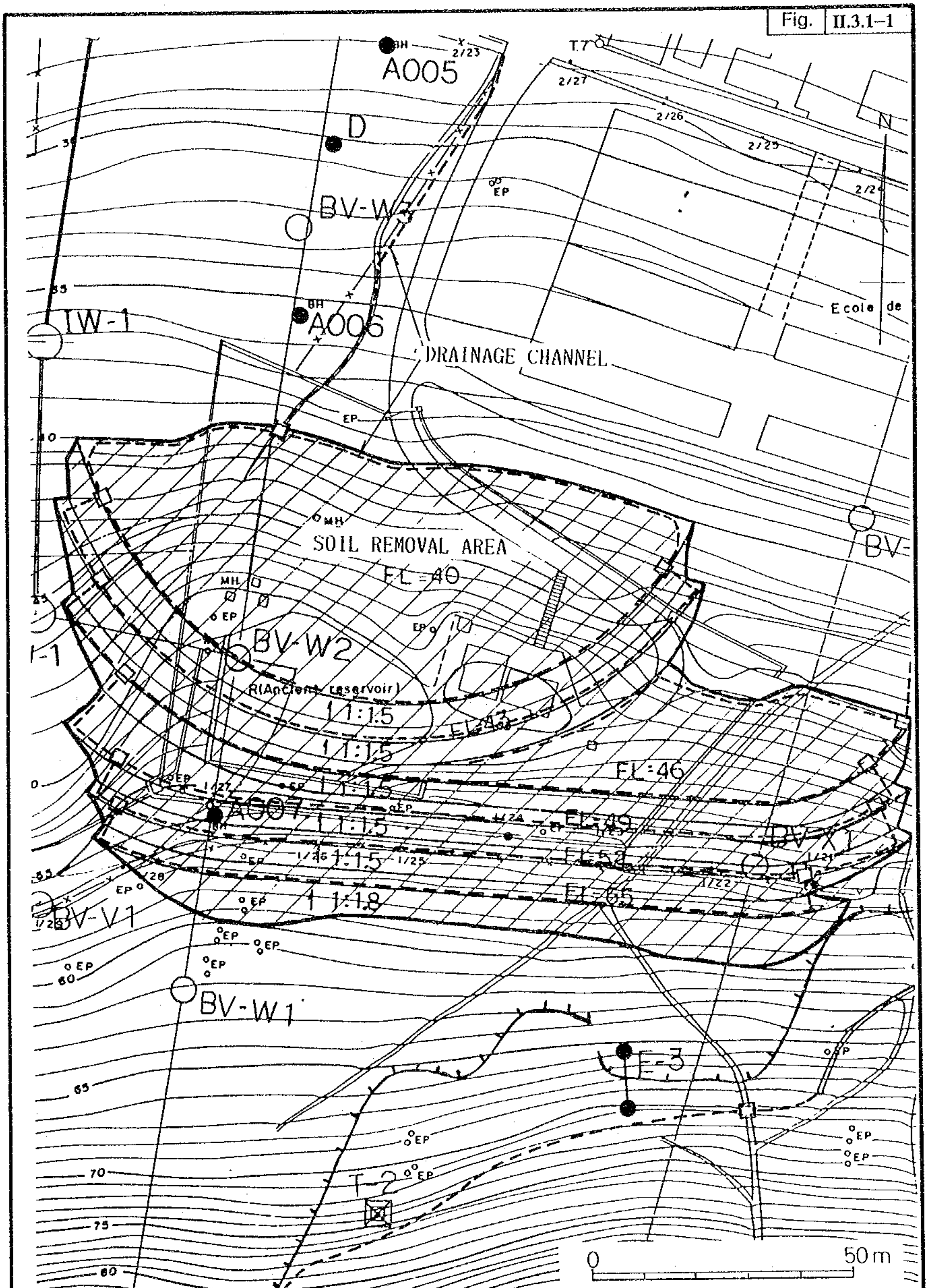
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.2.2-13



OUTLET WORKS OF DRAINAGE BOREHOLE	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.3.1-1

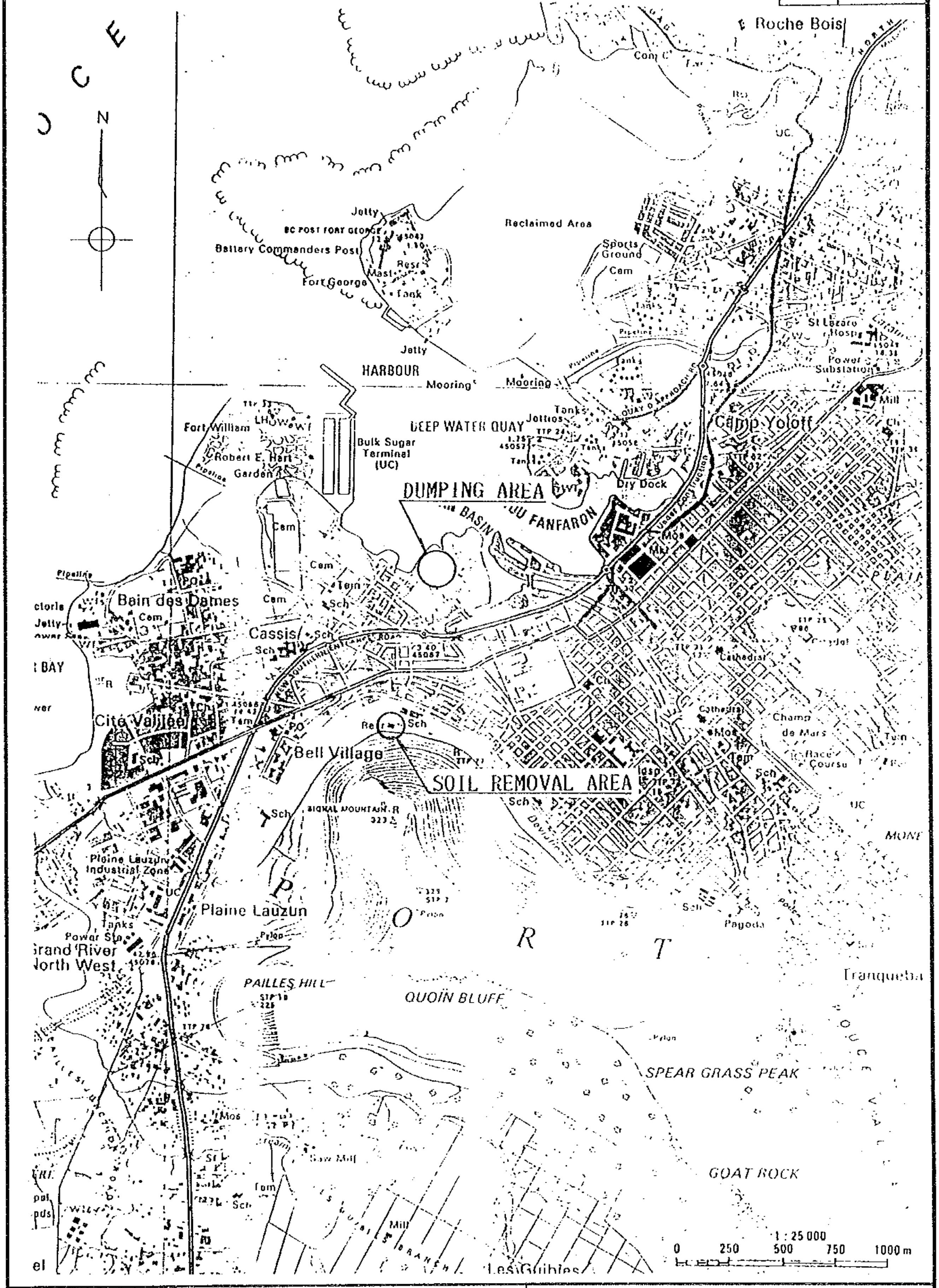


DESIGN FOR SOIL REMOVAL

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

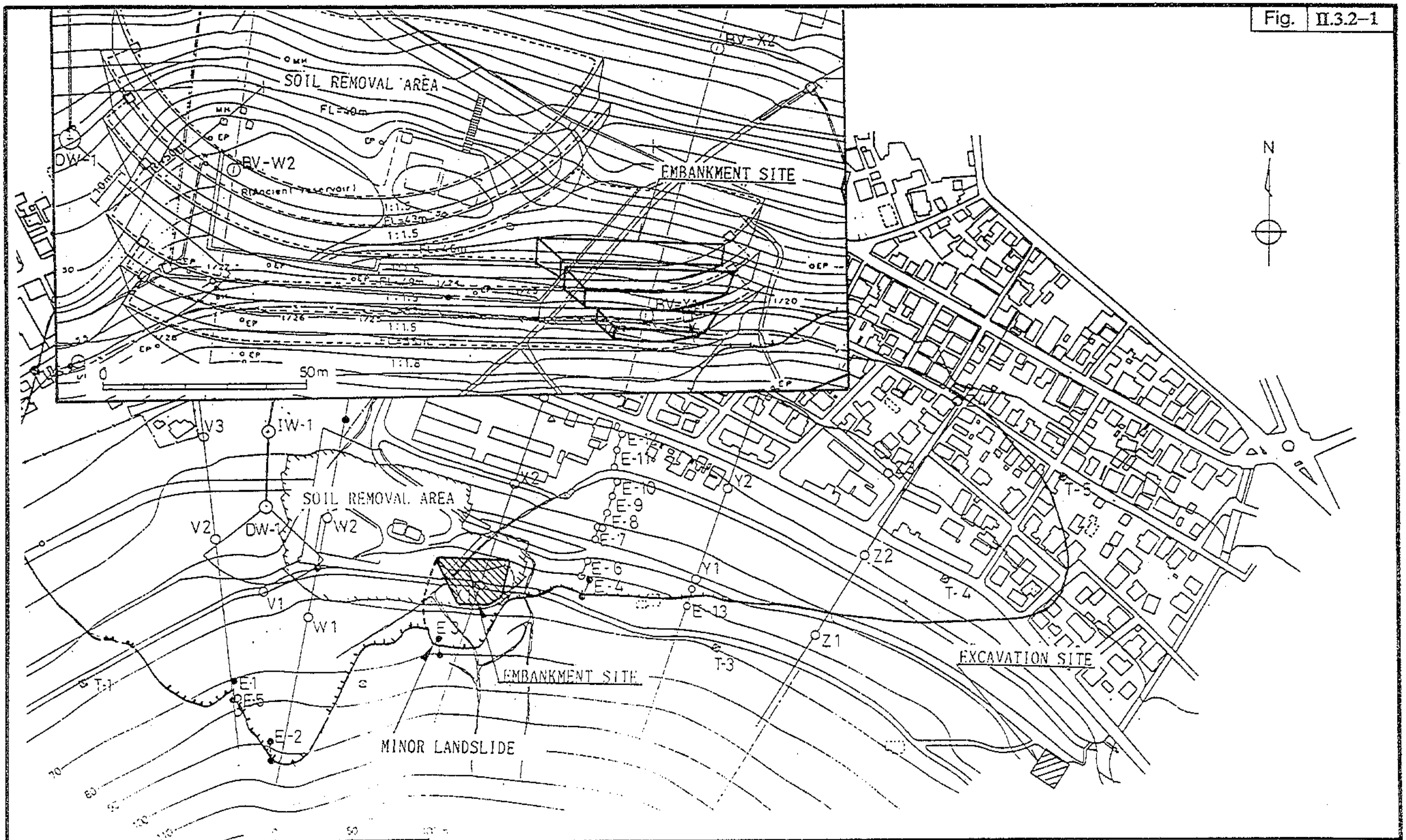
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.3.1–2



LOCATION MAP OF SOIL REMOVAL AREA AND DUMPING AREA	GOVERNMENT OF MAURITIUS LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
	JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.3.2-1

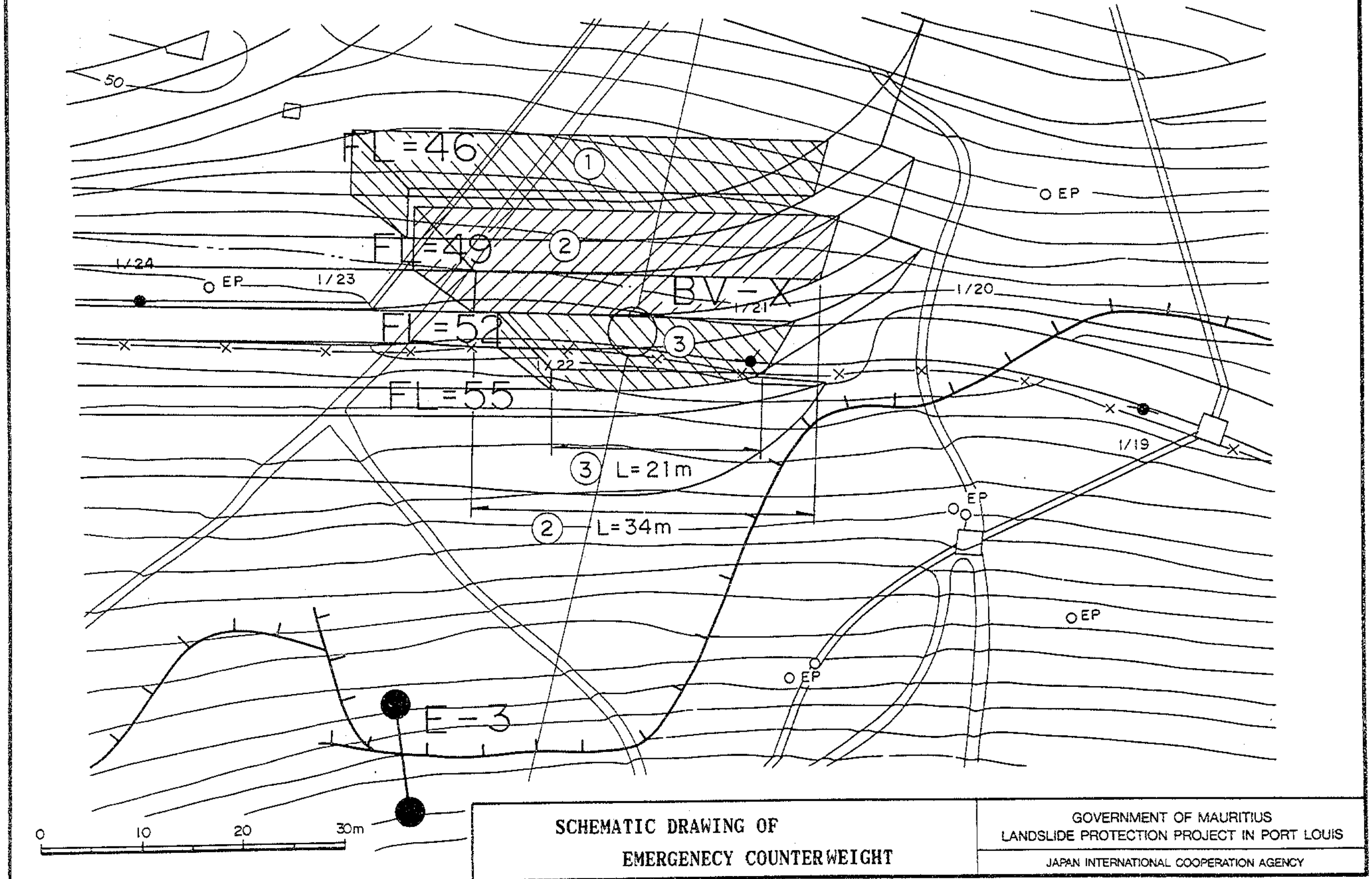


LOCATION MAP OF EMERGENCY SOIL EXCAVATION AND EMBANKMENT SITES

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.3.2-2

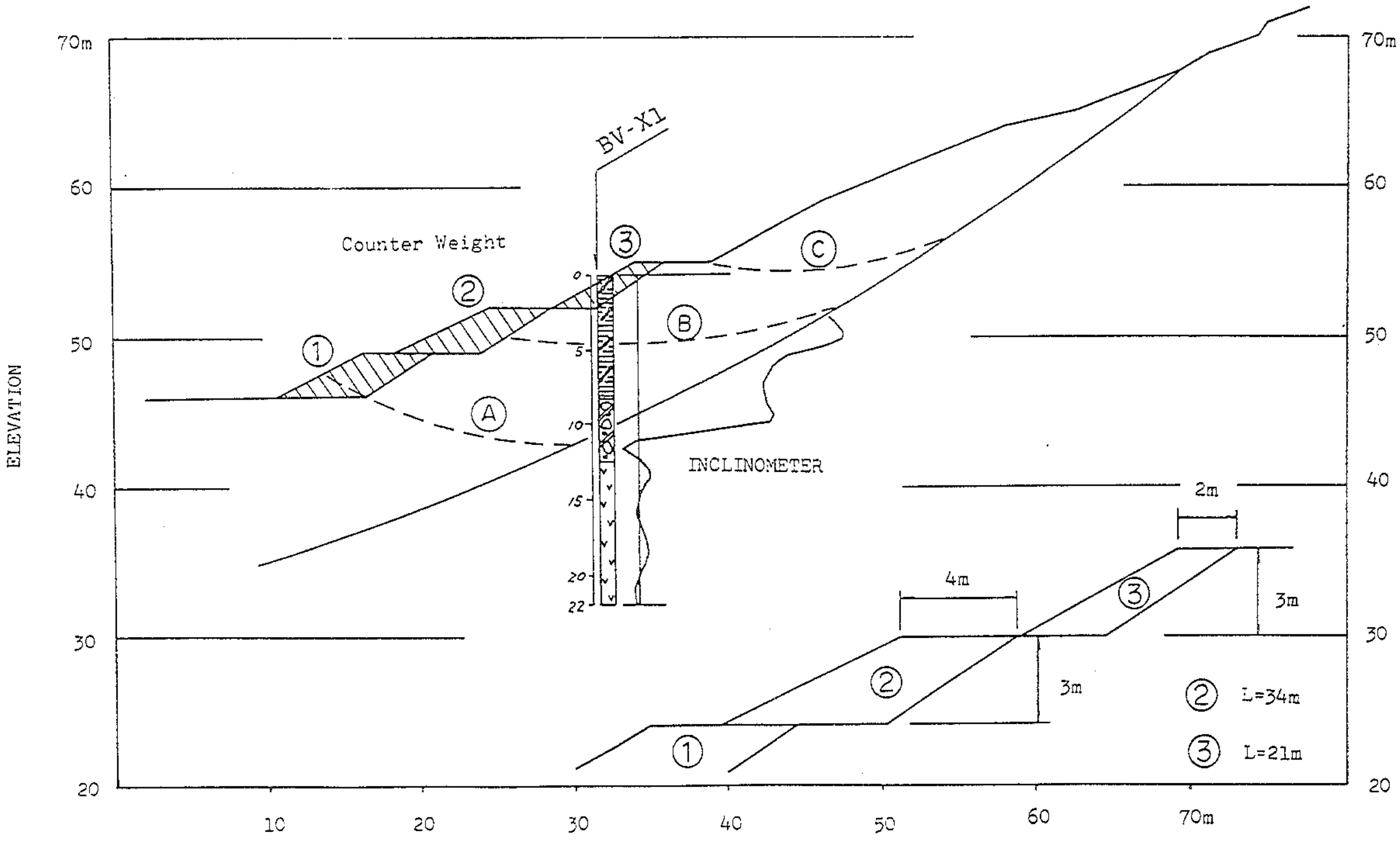


SCHEMATIC DRAWING OF
EMERGENECY COUNTERWEIGHT

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. II.3.2-3



PROFILE OF EMERGENCY COUNTERWEIGHT

GOVERNMENT OF MAURITIUS
LANDSLIDE PROTECTION PROJECT IN PORT LOUIS
JAPAN INTERNATIONAL COOPERATION AGENCY

SUPPORTING (III)

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III.1 INTRODUCTION

III.1.1 General

Planning of long term protective measures for the landslide at La Butte was the final target for this study. The planning of long term protective measures was prepared on the basis of results obtained from the field investigation carried out in Stage-1 study and from the experimental investigation and the urgent protective measures which were performed in Stage-2.

This Supporting Report (III) describes the planning and design of the long term protective measures. The cost estimate and construction plan for the long term protective measures and results of project justification based on the cost estimate are also described in this report.

III.1.2 Planning of the Long Term Protective Measure

Long term protective measures were planned on the basis of results obtained from the field investigations carried out in the first stage study period, the experimental investigation and the urgent protective measures provided in the second stage.

The soil removal works which were made as one of the urgent protective measures are considered to have contributed to stabilization of the landslide from the analysis results of the obtained monitoring data. On the other hand, it is difficult to evaluate the efficiency of the drainage well which was constructed in Stage-2 as an experimental investigation because there was no heavy rainfall to cause a significant recovery of groundwater levels since completion of the drainage well. However, it is believed that the drainage well will functionate effectively to drain groundwater from the landslide area if the groundwater levels recovered to the levels which were measured in the start of this study.

The safety of the landslide was evaluated by stability analysis along observation lines which were aligned to cross the landslide area in a north-south direction. The planned safety factor for long term protective measures is F.s=1.2 in general. However, according to the stability analysis results, the estimated improvement in the safety factor by the soil removal works and the experimental investigation is not sufficient to achieve the planned safety factor of F.s=1.2.

It is expected that construction of additional drainage wells and steel piling works as the long term protective measures will ensure a sufficient safety factor in the future.

The works required for the long term protective measures are: construction of three (3) additional drainage wells with groundwater collection boreholes for 2100 m in total; drilling of horizontal boreholes for draining shallower groundwater for 1670 m in total; and installation of steel piles, 8996 m (416 piles) in total length. The location of the construction site for the long term protective measures is shown in Fig.III.2.2-1.

III.1.3 Construction Plan, Cost Estimate and Project Justification

Taking the urgency of the project into consideration, the long term protective measures were considered on the assumption that the construction would be completed within 22 months.

The total project cost is estimated to be Rs.272.3 x 10^6 on the basis of the financial cost. For the cost estimate availability of local materials, machinery, labor and so on were examined beforehand. The disbursement schedule is divided into two years, the first year and the second year.

For project justification the occurrence of a landslide at La Butte is assumed just after completion of the long term protective measures. A time horizon of 35 years is taken for the project evaluation. The results of project justification were obtained by three methods with the following results:

Method	Value
Cost-benefit ratio method (CBR)	1.96
Net present value (NPV)	Rs.214.1
Internal-rate-return (IRR)	47.7 %

According to the obtained results project viability is emphasized and early implementation of the project is recommended.

III.2 LONG TERM PROTECTIVE MEASURES

III.2.1 Stability Analysis for Long Term Protective Measures

For the stabilization of the whole landslide at La Butte, installation of surface drain channels and soil removal works were performed already. Installation of surface drainage channels and soil removal works were included into urgent protective measures for the whole landslide. Construction of one drainage well was included into the experimental investigation.

On the other hand, emergency counterweights were provided for a small secondary landslide near extensometer E-3. The planning of the long term protective measures was prepared with consideration of expectable effects from the protective measures conducted.

(1) Planned safety factor

The general approach to planning landslide protective measures, is first to decide the necessary safety factors for stabilization of landslides, and then to plan protective measures which will be able to secure the required safety factors. The necessary safety factors mentioned above are called the planned safety factors.

The planned safety factors for securing stabilization of slopes by providing landslide protective measures are generally required to be F.s=1.1 to 1.2 except for urgent protective measures. A planned safety factor of 1.2 was selected for the landslide at La Butte because there are many important facilities in the area concerned such as houses, roads, transmission lines, water supply pipes and so on. On the other hand, a planned safety factor of 1.1 was selected for the small secondary landslide because there was no important facility at risk.

(2) Selection of protective measures

Owning to the topographic and geological conditions and the assumed features of the slide surface in La Butte landslide area, protective measures for the landslide were selected as a combination of groundwater drainage and steel piling works. The groundwater drainage was divided into drainage well works for deeper groundwater and horizontal boring works for shallower groundwater.

Steel piling was selected also for the protective measures for the small secondary landslide due to the topographic and geological conditions.

(3) Stability analysis for long term protective measures

1) Strength of clayey materials along slide surfaces

Stability analyses were made for the whole landslide and the small secondary landslide separately. The stability analysis for the whole landslide was made along five observation lines, V, W, X, Y and Z with the assumption that the safety factor was F.s=1.0 for all observation lines before the soil removal works conducted in the experimental investigation. Slide surfaces along the observation lines were assumed from results of core drilling.

Groundwater levels were assumed to be the levels observed in June 1989 when landslide movements were ceasing. Based on the thickness of soil masses above the slide surface and results of soil mechanical test in this study, cohesion of soil materials along the assumed slide surface is estimated to be c=1.0 t/m^2, and internal friction angles of the materials was calculated with using the obtained cohesion.

The extent of the small secondary landslide was assumed from the topographic conditions. Cohesion of c=1.0 t/m^2, which was estimated for the whole landslide area, was also adopted for the clayey materials along the slide surface of the small landslide. Pore pressures among the materials above the slide surface were ignored because the groundwater levels were estimated to be much deeper than the slide surface from the topographic conditions.

2) Safety factor

Stability analysis of the landslides was made by following the same procedure as described in Supporting Report-1. The safety factors before providing protective measures were assumed to be F.s=1.0 along all the observation lines V, W, X, Y and Z. Improvement of the safety factors by the soil removal works was expected for the Line-W and Line-X. The safety factors after the soil removal works were estimated to be 1.031 for Line-W and 1.07 for Line-X.

Three additional drainage wells are planned in the landslide area as one of the protective measures in the long term. A 2 m drawdown of groundwater levels from the levels observed at the beginning of this study is expected by providing these drainage wells. Safety factors will be expected to improve to some extent by drawdown of groundwater levels in the landslide area. The expected safety factors by drawdown of groundwater levels are as follows for all the observation lines. Among these all observation lines the expected safety factors for Line-W and Line-X consist of accumulated values of the soil removal works and drainage works.

LINE	SAFETY FACTOR (F.s)
V	1.071
W	1.092
X	1.134
Y	1.084
Z	1.094

(4) Required deterrent force for steel piling works

The planned safety factor is F.s=1.2 for all the observation lines as a long term protective measure. The difference between the planned safety factors and the calculated safety factor mentioned above is the insufficient safety factor which has to be compensated by steel piling works.

The required deterrent force (Pr) is calculated by multiplying the insufficient safety factors and force along the tangent line of each slice of the slice analysis method. The equation is given below.

$$Pr = (PF.s - F.s) \times T$$

where, Pr : required deterrent force (t/m)
PF.s : planned safety factor
F.s : safety factor before providing protective measures
T : force along tangent line (t/m)

Required deterrent forces for all the observation lines were calculated as follows. The required deterrent force for the small secondary landslide is shown below also.

REQUIRED DETERRENT FORCE FOR EACH OBSERVATION LINE

LINE	PF.s	F.s	T (t/m)	Pr (t/m)
V	1.20	1.071	975.1	125.83
W	1.20	1.092	1508.3	162.82
X	1.20	1.134	1152.8	75.94
Y	1.20	1.084	683.2	79.25
Z	1.20	1.094	494.2	52.39
small landslide	1.10	1.000	478.3	47.40

Judging from contour maps of bedrock surface and slide surface prepared by using core drilling results and extension of open cracks of the landslide, landslide is considered to be one block rather than the landslide composed of several landslide blocks. Therefore, steel piling works are planned on the basis of the total required deterrent forces of one landslide block.

Steel piling works have to be performed in compressive zones at lower parts of landslides in general. The total length along which piling works will be made is about 750 m in total in La Butte landslide.

The required total deterrent force is calculated by multiplying the deterrent force for each observation line by the section length between each observation line. The calculated total deterrent forces are summarized below.

Observation Line	Required Deterrent Force (t/m)	Section Length (m)	Total Required Deterrent Force (t)
V :	125.83	180	22649.40
W :	162.82	120	19538.40
X :	75.94	120	9112.80
Y :	79.25	120	9510.00
Z :	52.39	210	11001.90
TOTAL		750	71812.50

Since total required deterrent force for the whole landslide is about 72000 tons and the total section length is about 750 m, required deterrent force for the unit section length is 95.75 t/m.

III.2.2 Planning of Long Term Protective Measures

(1) Planning of drainage well

The purpose of the constructing drainage wells is to mitigate landslide movements by draining groundwater in deeper zones near bedrock surfaces. The most important cause for landslide movement is considered to be increasing of pore pressure among moving earth masses above slide surfaces by rising groundwater levels. Landslide movements have been confirmed to accompany with heavy rainfalls in La Butte landslide, there is no room for doubt about the close relation between landslide movements and rising of groundwater levels.

Drainage well works are for drawdown of groundwater levels by draining groundwater in the whole landslide area and to secure landslide stability. Many drainage wells will be required essentially in landslide areas accordingly. However, an additional three drainage wells are planned in La Butte landslide area effective groundwater drainage in the landslide area. Groundwater levels are estimated to decrease by about 2 m on an average from the groundwater levels in June 1989 which seemed to trigger the landslide movement.

The drainage well works were planned as follows on the basis of field reconnaissance results and analysis of collected data in this study.

1) The siting of the drainage wells was chosen as shown in Fig.III.2.2-1 with particular attention to the following points:

   a. The locations are at the foot of tension cracks for effective drainage.
   b. These locations enable the depth of the drainage wells to be minimized.
   c. The ground surface surrounding the location is stable and easy for transportation of construction equipment and materials.

2) The depth of the drainage wells was decided to be 10 m to 15 m with attention to the following points.

   a. The depth of the drainage wells has to be shallower than the assumed slide surface for avoiding damage to the drainage wells by shearing of the slide surfaces.

b. The depth has to be as deep as possible for effective groundwater drainage.

3) The diameter of the drainage wells was decided as 3.5 m for efficiency and economy of the works and following experience in Japan.

4) The excavated wall of the drainage wells shall be protected by perforated liner plates except ground surface and the bottom portions of the wells for draining groundwater from the zone surrounding the drainage wells.

5) The liner plates are corrosion-proof galvanized plates. The stiffeners are galvanized also.

6) The first section of 50 cm liner plate is to be assembled above the ground surface for prevention of mud flowing into the wells.

7) Steel covers shall be provided on top of the wells in order to prevent material from falling into the wells.

8) Spiral ladder will be provided in the wells for the future inspection.

9) Groundwater collection boreholes of 66 mm in diameter will be drilled for 50 m to 60 m from one or two steps in each drainage well.

10) Perforated pvc pipes of 40 mm in diameter will be inserted into the groundwater collection boreholes.

11) Drainage of water from the drainage well to the ground surface shall be gravitational. However, dewatering by pumps shall be made until completion of the drainage boreholes, which penetrate the sections between the drainage well and the ground surface.

12) The outer diameter of the drainage boreholes shall be 116 mm. Steel pipes of 101.6 mm in outer diameter shall be inserted after

completion of drilling.

13) Drilling of very long drainage boreholes seem difficult for geological and topographic reasons. Intermediate well shall be provided at a no more 50 m from the drainage well.

14) The length of the drainage boreholes will be 50 m uniformly.

15) The diameter of the intermediate well shall be also 3.5 m, and the depth shall be 11 m. The intermediate well shall be protected by steel liner plates but perforation of the liner plates will not be required.

(2) Design of the drainage well

1) Procedure for designing

The drainage wells and the intermediate well planned in the landslide area have the same size of 3.5 m in diameter using steel liner plates which are of the same type as those used for the wells constructed in the experimental investigation. Since the bottoms of the wells have to be shallower than the assumed slide surface for about 2 m, the maximum depth of the drainage well will be 15 m and the depth of the intermediate well will be 11 m.

The design of the drainage well was performed by following the same procedure of calculation methods as carried out in the experimental investigation of which details are given the Supporting Report (2).
The design of the drainage well structure was made for securing sufficient safety against buckling of the wells and compressive stress on the circular section on the basis of the calculation of horizontal earth pressure and allowable stress of the steel liner plates. In designing of drainage wells for the long term protective measures, uneven earth pressure of 10 t/m was added to the horizontal earth pressure, which was examined in designing of the drainage well for the experimental investigation, for safety of the wells and following actual achievements in Japan.

2) Specification and quantity of materials for wells

The materials for the drainage well and the intermediate well are specified as follows and a summary of the required quantity of materials is shown in Table III.2.2-1. The structures of drainage well and the intermediate well are shown in Fig.III.2.2-2 to Fig.III.2.2-7.

a. Steel liner plate

The wells of 3.5 m in diameter will require 7 liner plates for one section. The liner plate has to be galvanized against corrosion and perforated for groundwater collection. The perforated holes for groundwater collection shall be arranged at 80 cm intervals. The liner plate is shown in Fig.III.2.2-8. The liner plates that will be used are as follows:

Specification	: SS34 (JIS G3101)
Standard	: P10 section (circle 1570 mm round; height 500 mm; thickness 2.7 mm)
Quantity	: 7 plates/section/50cm x (15.5m + 10.5m + 10.5m +11.5m) = 672 plates (perforated type, 301 plates for 21.5 m)
Weight	: 27.43 kg / plate x 672 plates = 18433.0 kg

b. Stiffener

Stiffeners will be composed of H-shape steel and consist of stiffener rings and vertical stiffeners. These are all bolted together. The stiffeners that will be used are as follows. The liner plate and the stiffener ring are shown in Fig.III.2.2-9.

Specification	: SS41 (JIS G3101)	
Standard	stiffener ring	H-125x125x6.5x9mm, L=2747.5mm
	vertical stiffener	H-175x175x7.5x11mm, L=6.0m, 4.5m, 4.0m, 2.5m
	connecting plate	330x125x12mm, 340x175x12mm,

		340x140x6mm
Quantity	: stiffener ring	4 x 26 sections (drainage well 20 + intermediate well 6) = 104
	vertical stiffener	L=6m(20), L=4.5m(4), L=4.0m(8), L=2.5m(4)
	connecting plate	drainage well (224) + intermediate well (64) = 288
Weight	: stiffener ring	65.4 x 104 = 6801.6kg
	vertical stiffener	(241.2 to 100.5) x (20 to 4) = 7236.0 kg
	connecting plate	(3.89 x 208)+(2.24 to 5.6) x 40 =1122.6 kg

c. Bolt and nut

Bolts and nuts, which will fix liner plates with stiffeners, were selected by considering the thickness of liner plates and stiffeners. The detail of the connection of liner plates with stiffener rings is shown Fig.III.2.2-10 and summarized below.

Specification: M16 - M20
Strength : 4T(tension strength, 41 to 50 kg/mm^2), 7T(70 kg/mm^2)
Quantity : drainage well (8960 pcs) + intermediate well (2760 pcs) = 11720 pcs.
Weight : 0.146 to 1.07 kg x 12136 = 2255.4 kg
(for drainage well 1729.9 kg)

d. Steel cover

Covers will be provided for prevention of falling materials. The cover is shown in Fig.III.2.2-11.

Specification : expanded metal
Standard : outer diameter 3600 mm
Quantity : 4(drainage wells 3, intermediate well 1)
Weight : 610 x 4 =2440 kg

e. Ladder

Ladders are for inspection of wells after completion of the well construction. Materials for the ladders are summarized below.

Specification	:	steel
Standard	:	spiral type (H=1 to 2m, width 0.5m)
Quantity	:	4 sets
Weight	:	spiral type 1502.6 kg

(3) Availability of local material

Availability of local materials was examined for the preparation of the experimental investigation in this study. Details of the availability are referred to the Supporting Report (2).

III.2.3 Drainage Work

(1) Construction of drainage well and intermediate well

Construction of the drainage wells and the intermediate well will follow the same methods as described in full for the experimental investigation in the Supporting Report (2).

(2) Groundwater collection borehole

The groundwater collection boreholes will have the most important function of draining groundwater from the landslide areas to outside landslide areas. Groundwater collection boreholes are drilled from inside drainage wells into the mountain side for groundwater collection. The total drilling length of the groundwater collection boreholes in the concerned area is planned as from 500 m to 1000 m for each drainage well.

The drilling length for each groundwater collection borehole will be 50 m to 60 m which is estimated to penetrate about 10 m after reaching the assumed slide surfaces. The groundwater collection boreholes will be drilled at levels of about 1 m and 4 m above the bottoms of the drainage wells where drilling is planned in two stages and at about 1 m in only one stage. The arrangement of the boreholes is shown in Fig.III.2.3 and summarized in Table III.2.3.

The angle of elevation of groundwater collection boreholes will be about 5 deg. to 10 deg. in general. However, the angle for the planned boreholes will be 3 deg. in the direction the mountain side to ensure that the ends of the boreholes are able to penetrate the slide surfaces.

Perforated pvc pipes, having an inner diameter of 40 mm and an outer diameter of 48 mm, will be inserted into the drilled groundwater collection boreholes.

The lateral opening angle between boreholes will be about 15 deg. in general, but 12.5 deg. is designed for effective draining of groundwater where subsurface drainage channels are assumed to be developed complicatedly.

III.2.4 Drainage Boreholes

Four drainage boreholes are planned in the sections between the drainage wells and the drain pits, the drainage wells and the intermediate well, and the intermediate well and the drain pit. Steel pipes of SGP80A to SGP100A will be used for protection of the drilled drainage boreholes. The drilling diameter for the steel pipes is 116 mm.

In the landslide area gravel materials are frequently included in the scree deposits. Therefore the drilling length of the drainage boreholes will be no more than 50 m. The drilling quantities for drainage boreholes are summarized in Table III.3.1. The drainage boreholes are planned to be horizontal between the drainage wells and the intermediate well.

The section between the drain pits and ditch along the existing road will be excavated to about 2 m maximum depth in open channels. The open channel is planned to be protected by masonry works.

III.2.5 Horizontal Borehole for Drainage of Shallow Groundwater

Groundwater collection boreholes are for draining of groundwater from deeper zones in the landslide area, while horizontal boreholes into the mountain slopes or from excavated slope surfaces in the soil removal area are for draining groundwater from shallower zones for protection of slope surfaces and for prevention of groundwater from infiltrating into deeper subsurface zones.

The horizontal boreholes will be drilled from 11 locations, along the route of an old water supply pipe line and the upper most berm in the soil removal area at about 52 m in elevation. The number of horizontal boreholes will be 3 to 6 holes at each point, and the depth of the boreholes will range from 30 m to 50 m. Quantities of horizontal boreholes are summarized as follows:

REQUIRED QUANTITY OF HORIZONTAL BOREHOLES

Location	Depth (m)		Holes No.		Sites No.		Total depth (m)
along the old pipe line trail	50	x	3	x	2	=	300
along Line-W	50	x	6	x	1	=	300
along berm at 55 m in elevation	50	x	4	x	2	=	400
- do -	30	x	3	x	1		
plus	40	x	1			=	130
- do -	30	x	3	x	2	=	180
along berm at 46 m in elevation	30	x	4	x	3	=	360
Total			24		11		1670 m

Horizontal boreholes are planned to be drilled at 11 sites. The location of the sites is shown in Fig.III.2.2-1. Drainage of collected groundwater is planned to lead to the existing drainage channels. Additional drainage channels will be planned where there are no existing drainage channels beside the drilling sites. Typical drawings of the drainage channel and the drain pit for the additional drainage channels are shown in Fig.III.2.5.

III.2.6 Steel Pile Work

(1) Planned safety factor and required deterrent force

For the preparation of stability analysis for the long term protective measures, groundwater levels are assumed to be lowered by about 2 m on average in the whole landslide area by providing drainage works including installation of surface drainage channels, construction of drainage wells, and drilling of horizontal boreholes. The effects expected from the soil removal works are also considered in the zone between Line-W and Line-X.

Taking important location of the landslide area into consideration, the "planned safety factor" was decided as F.s=1.2 or more to be achieved by conducting steel piling works as the long term protective measures. On the assumption mentioned above, required deterrent force (Pr) was calculated for each observation line as follows:

Line	Pr (t/m)
V	125.83
W	162.82
X	75.94
Y	79.25
Z	52.39

Steel piling works will be conducted in the compressive zones in the lower slopes of the landslide. The total alignment length for steel piling works is about 750 m giving the total required deterrent force for each observation line as follows:

Line	Total Pr (t)
V	22649.4
W	19538.4
X	9112.8
Y	9510.0
Z	11001.9
Total	71812.5

Required total deterrent force for unit length is Pr=95.75 t/m in the whole landslide area accordingly.

(2) Examination of diameter and interval of steel pile

The outer diameter of the steel piles for landslide prevention will be 300 mm from considerations of efficiency and experience in Japan. The interval of steel piles is determined by the relationship between depth of the sliding earth masses and the diameter of the steel piles. Accordingly the interval will be less than 3 m when the sliding mass has a depth of more than 10 m to 20 m in general subject to also being less than 8 times the diameter generally.

Since steel piles of 300 mm outer diameter have been selected, the interval of steel piles should be less than 2.4 m (0.3x8=2.4), but the interval of 2.0 m will be adopted in the actual construction works since the interval of steel piles for landslide prevention should be less than 2.0 m by Japanese standards.

(3) Selection of steel pile

Steel piling works have to resist sliding forces by shear strength of the steel piles on the basis of a long term allowable stress intensity. Steel piles are classified into thin piles and thick piles. If the shear stress is small, thin steel piles of SKK41 or the same quality may be selected. If the the shear stress is large, thick steel piles must be used such as welded type centrifugal cast-iron pipes (SCW50-CF) and seamless steel pipes (SKK-50).

Judging from the required unit deterrent force of 95.75 t/m, thin steel piles will not be sufficient to prevent the concerned landslide, and thick steel piles which have a larger shear strength have to be selected.

Required shearing yield strength for each pile is calculated as follows when steel piles of 300 mm in outer diameter are used at 2.0 m interval.

$$Pr = 95.75 \times 2.0 = 191.50 \text{ t/pile}$$

Since the ground surface at the steel piling work sites is flat, the required cross sectional area for each steel piles is calculated as follows:

$$A = Pr \times D / s$$

where, A: required cross sectional area for each pile (cm^2)
Pr: shearing yield strength for each pile (t/m)
D: interval of piles (m)
s: shearing stress intensity for a long term of steel piles (1270 kg/cm^2)

$$A = 95.75 \times 1000 \times 2 / 1270$$
$$= 150.79\ cm^2$$

According to the calculation results and the attached Table III.2.6 Standard of Steel Pile, diameter and thickness of the required steel piles are decided to be 300 mm and 17 mm.

(4) Length of steel pile and length of embedment of steel pile

The subsurface of the landslide area is composed of basaltic rocks, weak clayey soil, and scree deposits from deeper subsurface zones. The slide surface is assumed to lie along the upper surface of the clayey layer in the lower part of the landslide. Accordingly the length of embedment in the zone deeper than the slide surfaces should be more than one third of pile length, and the length of embedment into bedrock should be 2 m in minimum length also. The head of the steel piles should be about 1 m below the ground surface and with the earth filled back after penetration of the piles.

(5) Quantity of steel pile

Required quantity of steel piles of 300 mm in outer diameter and 17 mm in thickness are summarized as follows. Arrangement of the steel piles is shown in Figs.III.2.6-1 and III.2.6-2.

REQUIRED QUANTITY OF STEEL PILE

Outer dia x thickness (mm)	Unit weight (kg/m)	Shear stress (t)	Interval of pile (m)	Pile (No.)	Pile length (m)	Total length (m)	Total weight (t)
300x17	118.6	191.5	2.00	380	12-36	8420	998.61

III.2.7 Plan of Steel Pile Work

(1) Steel pile work for the main landslide

Steel pile works for the main landslide are to prevent movement of the whole landslide. Taking accessibility and ease work into consideration, the alignment of the piling works is planned to pass along existing roads. The alignment will be divided into 12 sections according to the required pile length. The sections are shown in Fig.III.2.6-1. The 300 mm diameter piles will be for this work and total length of the piles will be 8420 m.

(2) Steel pile work for the small landslide

For prevention of the small landslide which occurred below extensometer E-3, steel piling works are also required for a total length of 576 m. The piling work is planned along the berm at El.=55 m in the soil removal site. 16 m steel piles of uniform length of 300 mm diameter are required on a straight line for this work. Alignment of the steel pile work is shown in Fig.III.2.6-2.

(3) Procedure for steel piling work

Steel piles will be inserted into boreholes after completion of drilling at the landslide area. The work schedule for piling works will be generally as follows:

1. Decision of location for piling work
2. Temporary works : preparation
   transportation of materials
   temporary works (leveling of ground, scaffolding, and water supply and draining)
3. Drilling works : drilling
   bentonite
4. Installation of piles
5. Mortar filling : washing
   mortar filling
6. Dismantle and cleaning

1) Temporary work

Temporary works are divided into preparatory works, transportation works, temporary works, and safety measure works. The preparatory works include land acquisition, survey works for piling work sites, and preparation of materials. The transportation works indicate loading and unloading of machines and equipment mainly composed of drilling machines. An arrangement of working site is shown in Fig.III.2.6-3.

Temporary works are preparatory works for ground leveling, scaffolding, water supply and draining, bentonite plant, electric power facilities, assembly and dismantle of machines, and preparation of steel piling facilities. Water supply and mud water treatment facilities are shown in Fig.III.2.6-4.

a. Ground leveling and scaffolding

Footing of piling works are prepared by ground leveling and scaffolding. Ground leveling may be required to create a flat site but it can be obtained by excavation. The drilling machine has to be assembled on square timbers (0.2x0.3x3.0 m) not directly on the excavated ground surface for prevention of unequal settlement of the machine.

Working stages have to be assembled by logs, steel pipes and H-beams. Working stages have to have a size of more than 2.5 times of machine sizes and have to be sufficiently strong for the loading.

b. Water supply and mud water facility

Securing of the water supply source is very important because much water, 100-500 l/min. will be required for drilling of boreholes and for washing of boreholes after completion of borehole drilling in general.

The mud water facility (mainly using bentonite) needs more than 100-500 l/min. of water for protection of boreholes, prevention of leakage, removal of slimes, and protection of drill bits. The density and the viscosity of the bentonite have to be prepared according to the geological conditions. Bentonite, of which the grain size is larger than #200 is used in general with the addition of some kinds of regulating materials.

c. Electric power facility

Electric power for the concerned site is expected to be supplied from C.E.B (Central Electricity Board).

2) Drilling of large diameter borehole

The required machines for drilling of large diameter of boreholes are summarized in Table 2.7.

a. Selection of machine

Large diameter boring machine:

A drilling machine of the 30 kw class is required for the work judging from the geological conditions and drilling depth for piles installation.

Drill bit:

Selection of drill bits will accord to the following table.

GEOLOGICAL CLASSIFICATION AND DRILL BIT

Geology \ Drill bit	Wing bit	Metal crown	Tricorn bit
Sand and clayey soil	*	*	x
Sandy soil with gravel	*	*	*
Sandy soil with boulder	x	*	*
Soft rock	*	*	*
Medium hard rock	x	*	**
Hard rock	x	x	**

**: very suitable *: suitable x: not suitable

Crane or winch:

A truck crane (hydraulic type: 10-11 tons) or a winch (3 tons) is required for installing steel piles or for moving a large diameter drilling machine.

b. Drilling is started after completion of preparatory works for drilling machine assembly, arrangement of drill bits and mud water facility. After opening the borehole, trial drilling will be made for 3 m to 5 m. Bits may then be replacing if necessary and drilling continued.

3) Installation of steel piles

Steel piles have to be inserted into the drilled boreholes immediately after completion of borehole drilling to prevent collapse of the borehole walls.

Steel piles will be inserted under their own weight up to the target depth by connecting 4 m long sections by welding. Steel piles will be suspended by a winch attached to a drilling machine or a truck crane. In this case the capacity of the winch is required to be about 3 tons or a truck crane of 10 tons to 11 tons.

4) Connection of steel piles

The steel piles will be transported to the site in lengths of 4 m, and the required length will be obtained by welding these together. The welding connection is most important for the steel piling works.

Welding will be done by an automatic or semi-automatic welding method with using an electric welding machine of about 50 kva class. Semiautomatic welding is often used for ease of operation, reduction of operation time, decreasing of air locks, easy removal of slag and so on. Automatic welding is an excellent method of reducing requirements for labor and quality control. However, adoption of this method will depend on conditions at the work sites.

5) Concrete filling

After placing the piles will be filled with concrete or mortar both inside and outside between the piles and the borehole walls. This work will be done for consolidation between piles and ground surrounding boreholes and for reinforcement of piles. Mortar filling work will be performed by filling mortar after washing out bentonite and slimes by injecting clean water into the bottoms of boreholes.

Mortar filling will be done where the groundwater level is low as in the concerned landslide area in general. Grout injection will be made into the space between the piles and the borehole walls by using grout pipes (2-3 cm in dia.) installed in the steel piles beforehand. Mortar (sand : cement = 1 : 0.5-0.8) will be injected at a pressure of 2-3 kg/cm^2 for consolidation between piles and ground.

III.3 CONSTRUCTION PLAN

III.3.1 Principal Feature and Major Work Quantities

The construction works for the Project with consist mainly of drainage wells, horizontal boring and piling works. The salient features and the work quantities of the construction works are summarized in Table III.3.1.

III.3.2 Construction Conditions

(1) Public supply for construction work

Existing roads will be utilized as access roads for construction purposes in general. Unpaved or narrow roads will be required for periodical repair and maintenance.

Electric power cable lines are well distributed near the construction sites and they have enough capacity to accept new demand for construction use. However, since the construction period for the Project will have to be limited to around one (1) year because of the urgency of the works to prevent landslides, a diesel generator will be installed at each site to supply electric power for the construction works.

Water for construction use is assumed to be supplied from a water tank to be installed at each construction site. Radio communication will also have to be provided at each construction site to connect with the main office of the contractor of the Project.

(2) Construction method

All the construction works for the Project will be executed on a contract basis employing a contractor to be selected through an international competitive bidding (ICB). Mechanized construction will be applied on principle because for work efficiency. All the construction works will be supervised by an engineering consulting firm.

(3) Temporary construction facilities

Temporary construction facilities will have to be provided prior to commencement of construction works such as:

- Offices for the Client, the Engineer and the Contractor
- Power supply, water supply and a radio communication system
- A repair shop, motor pool, workshops, warehouses and laboratory

(4) Workable days and working hours

Based on the need to suspend work on Sundays and National holidays, the workable days for purposes of construction planning are assumed to be 23 days per month or 276 days per year.

Daily working hours will be 8 hours on Mondays to Fridays and 5 hours on Saturdays. Total working hours per month are fixed at 45 hours.

(5) Volume change factor of earth materials

From the characteristics of the soil materials in the project area for the wells and piling sites, the volume change factor for earth materials are assumed to be as shown below:

Materials	Loose/Bank	Compact/Bank
Clayey & sandy soil	1.20	0.90
Gravely soil	1.20	0.90
Cobble stone	1.40	1.20
Soft rock II	1.45	1.20

Rock is classified into : soft rock I
soft rock II
semi-hard rock
hard rock

(6) Concrete mix proportions

The types of concrete mix proportions are assumed as shown below.

Type	Gmax	W/C	s/a	Unit Weight (kg/m^3)				
	(mm)	(%)	(%)	C	W	G	S	A
A	40	55	34	250	135	1300	679	0.625
B	25	51	37	280	145	1220	710	0.700
C	20	51	44	300	155	1060	830	0.750

Gmax: maximum size of coarse aggregate
W/C : water-cement ratio
s/a : fine aggregate portion against total aggregate volume
C: cement W: water G: gravel S: sand A: add mixture

Note : Type A for top portion of well
Type B for bottom portion of well
Type C for pile filling

III.3.3 Construction Plan and Schedule

(1) Implementation time schedule

The pre-construction program for the Project broadly consists of loan arrangement, selection of consultant and selection of contractor. The program will start with loan arrangement which will require about 2.5 months in parallel with selection of a consultant. Selection of a contractor through an international competitive bidding (ICB) and contract signing are assumed to require about 4 months. Notice to proceed (NTP) is assumed to be issued by the Government of Mauritius within 1 month after contract signing.

Immediately after the routine procedure of contract signing between the Client and the Contractor, preparatory works will be started with mobilization. Following that, the main civil works will be commenced, and this construction period is assumed to be about 15.5 months, the construction period being decided on account of the urgency of the Project. Above mentioned implementation time schedule is shown in Figure III.3.3.

(2) Construction plan

1) Drainage well

There will be four (4) wells in total, namely, three drainage wells (No.3 to 5) and one intermediate well (No.6). Construction of the drainage wells will be divided into three stages. In the first stage, portal protective works will be carried out in the first two meters. Excavation in the well portion and liner installation will then follow. Finally the groundwater collection boreholes and the drainage boreholes will be drilled by a boring machine installed on a staging in the well.

The main items of equipment required for one unit of well construction works are listed in Table III.3.3-1.

The estimated period for construction of the four wells is given in Table III.3.3-2 on the assumption of a moderate rate of progress. The required period is summarized for items such as site preparation, excavation, installation, bottom concrete, fence installation, and site clearance.

Construction of the drainage well will require use of two sets of equipment. First, No.3 well (DW-4) construction works will be carried out in parallel with No.4 well (DW-5) construction works. Immediately after resetting of the gantry crane and other necessary equipment, No.5 well (DW-6) and No.6 well (IW-2) construction works will be commenced in parallel.

The required period for drilling of the groundwater collection boreholes in the three (3) drainage wells and drainage boreholes is expected to be as given in Table III.3.3-3 on assumption of slow progress because of the limited space in the wells. The drilling works will include groundwater collection boreholes, drainage boreholes, and installation of protective pipes. The construction of boring works will be carried out by use of two sets of equipment.

2) Horizontal boring

Drilling of horizontal boreholes will be carried out on the ground surface, employing the same procedure as described above for the groundwater collection boring in the construction plan for the drainage wells. The main items of equipment required for horizontal borehole drilling works at ground level will be as summarized in Table III.3.3-4.

The required period for drilling the horizontal boreholes at ground level will be as estimated in Table III.3.3-5 on the assumption of a moderate rate of progress. Drilling work progress is considered separately for different materials such as gravely soil, cobble stone and soft rock.

Installation of borehole protective pipes will be conducted in parallel with borehole boring works. The drilling will be carried out by use of set of equipment.

3) Piling works

Piling works will be divided into three stages. In the first stage, a vertical hole will be bored after leveling the construction sites. In the second stage, a steel pile will be carefully installed in the borehole. The pile will be then filled with concrete after the voids between pile and borehole will be filled with mortar. In the final stage the pile head will be plugged with specified materials.

The main items of equipment required for the piling works are listed in Table III.3.3-6. The equipment is summarized for vertical drilling, pile installation, disposal of drilling mud and slimes, and concrete and mortar filling.

Required period for all the piling works is estimated in Table III.3.3-7 on the assumption of a moderate rate of progress. The required period includes site preparation, boring, pile installation, and resetting of equipment.

If only one set of equipment were used, the piling works would take 4587 days. Since the construction period is limited to 13 months, and if the working hours per day are set at 10 hours (1.25 times normal conditions) ten sets of equipment will be required for the piling works.

III.4 COST ESTIMATE

III.4.1 Conditions for Cost Estimate

(1) Price level and exchange rates

The construction cost of the project is estimated at the price level of January, 1990.

The exchange rates of one (1) United States dollar ($) applied in the conversion into Mauritian Rupees (Rs.) and Japanese Yen (JYE) are Rs.15.3 and JYE 146.0 respectively, based on the Mean Monthly Telegraphic Transfer Selling (TTS) rate on January in 1990.

(2) Currency of cost estimate

The construction cost is estimated separately for the foreign and local currency components according to the origin of the material.

The currency for cost estimate is expressed in Mauritian Rupees for local currency component and in Japanese Yen for the foreign currency component, respectively. The total construction cost is expressed in Mauritian Rupees.

The local and the foreign currency components include the following items;

1) Local currency component

- Labor cost,
- Cost of local materials,
- Local mechanics and spare parts cost for repair of equipment,
- Contractor's indirect cost,
- Project administration expense,
- Local portion of price escalation,
- Local portion of physical contingency,
- Local portion of engineering service, and
- Local portion of interest during construction

2) Foreign currency component

- Labor cost,
- Cost of imported materials,
- Cost of equipment,
- Contractor's indirect cost,
- Freight charge and insurance cost,
- Foreign portion of physical contingency,
- Cost of engineering service, and
- Foreign portion of interest during construction

(3) Constitution of the project cost

Project cost is estimated in accordance with the construction cost, and the costs for the project administration and the engineering service costs are also estimated. Contingencies are provided for price inflation and physical changes of work conditions. Interest during construction is also estimated in the project cost. Constitution of the construction cost is as follows:

1) Construction cost of the project facilities
- General items
- Drainage well
- Horizontal boring
- Piling

2) Administrative expenses

3) Price escalation

4) Physical contingencies

5) Engineering services costs

6) Interest during construction

(4) Tax and duty

Import tax and duties for construction plant and equipment procured from foreign countries are assumed to be exempted on the condition that such plants and equipment shall be exported immediately after completion of the project.

Sales tax for domestic materials such as fuel and cement are include in the financial project cost estimate.

III.4.2 Unit Price

The direct construction cost is estimated on an unit price basis by multiplying the unit price of works by the corresponding work quantity.

The unit price is estimated on the basis of the construction method. The unit price of each work item consists of the costs of material, labor and equipment. The contractor's indirect costs and mark up are also incorporated in these unit prices.

(1) Labor cost

The local labor cost is computed in the local currency component in the cost estimate. The rates of labor wages shown in Table III.4.2-1 include all fringe benefits, such as vacation and sick leaves, charges for insurance, medicare, living allowances and others. Foreign labor wages are computed in foreign and local currencies taking into account annual salaries, air fares living allowances, etc.

(2) Material cost

Prices of materials required for construction were canvassed from Port Louis City area, referring to market prices in Mauritius and the prevailing foreign market prices as well. These prices are included in the local and foreign currency components according to their origin.

The unit costs of the main construction materials with their local and foreign currency components are listed in Table III.4.2-2.

(3) Equipment expense

The equipment expenses consist of depreciation cost, repair and annual administration costs, which are calculated using F.O.B. prices at shipping places in foreign countries (tentatively using Japan) or C.I.F. price at Port Louis. Hourly or daily major equipment expenses thus calculated on an hourly or daily basis are shown in Table III.4.2-3.

(4) Contractor's indirect cost

The contractor's expenses are included in every unit price proportionally. These expenses are assumed to be twenty-five (25) percent of the direct cost to cover the following costs:

- Field administration and supervision (12%),
- Corporate overhead and profit (8%),
- Security and safety control (3%), and
- Other incidentals (2%)

III.4.3 Estimated Project Cost

(1) Total project cost

The total project cost comprises (i) the construction cost including general items, (ii) administration expenses, (iii) price escalation, (iv) physical contingencies, (v) engineering services costs, and (vi) interest during construction. The total financial project cost is shown in Table III.4.2-4.

The project cost required for the proposed development plan of the whole project totals Rs.272.3 million comprised of Rs.219.5 million (81%) and Rs.52.8 million (19%) in foreign and local currencies respectively as summarized below:

(Unit: Rs. million)

Items	F/C	L/C	Total
A. Construction Cost	178.3	29.3	207.6
B. Administration Expense	0.0	6.3	6.3
C. Price Escalation	0.0	5.2	5.2
D. Physical Contingency	17.8	4.1	21.9
E. Engineering Service	16.5	2.4	18.9
F. Interest during Construction	6.9	5.5	12.4
Total	219.5	52.8	272.3

(2) Construction cost

The total construction cost is estimated at Rs.207.6 x 10^6 of which the foreign currency component is Rs.178.3 x 10^6 (86%) and the local currency component is Rs.29.3 x 10^6 (14%) respectively.

(3) Administration expense

The administration expenses consist of the Government's direct administration cost and indirect costs for running cost of office, stationery, office consumables and so on. The total cost of administration expense is estimated at Rs.6.3 x 10^6 which cost is entirely included in local currency portion. The estimated cost is summarized below.

(Unit: Rs. million)

Item	First year Amount	Second year Amount	Total Amount
Administration expenses			
(1) Salary and charges	0.9	2.2	3.1
(2) Others	1.4	1.8	3.2
Total	2.3	4.0	6.3

(4) Price escalation

The annual price escalation rate is taken as zero (0) percent for the foreign currency component and 8.3 percent for the local currency component. The price escalation rate of 8.3 % was decided by reference to the records of "International Financial Statistics" by the International Monetary Fund (IMF). The total cost of price escalation is estimated at Rs.5.2 x 10^6 which is entirely in the local currency portion.

(5) Physical contingencies

Physical contingencies are assumed to be ten (10) percent of the construction cost, administration expense and price escalation both for foreign and local currency portions. The total for physical contingencies is estimated at Rs.21.9 x 10^6 of which the foreign currency component is Rs.17.8 x 10^6 (81%) and the local currency component is Rs.4.1 x 10^6 (19%) respectively.

(6) Engineering services cost

The engineering services cost for the construction supervision is estimated based principally on the all necessary construction supervision works for the project including the pre-construction stage and construction stage assuming that these services are provided by expatriate consultants. The total engineering service costs are estimated at Rs.18.9 x 10^6 of which the foreign currency component will be Rs.16.5 x 10^6 (87%) and the local currency component Rs.2.4 x 10^6 (13%), as shown below.

(Unit : Rs. million)

ITEM	First year			Second year			Total		
	F/C	L/C	total	F/C	L/C	total	F/C	L/C	Total
1.Remuneration	4.2	0.0	6.2	5.9	0.0	5.9	10.1	0.0	10.1
2.Others	2.1	0.8	2.9	2.8	1.1	3.9	4.9	1.9	6.8
sub-total	6.3	0.8	7.1	8.7	1.1	9.8	15.0	1.9	16.9
3.Price escalation	0.0	0.1	0.1	0.0	0.2	0.2	0.0	0.3	0.3
4.Physical contingency	0.6	0.1	0.7	0.9	0.1	1.0	1.5	0.2	1.7
Total	6.9	1.0	7.9	9.6	1.4	11.0	16.5	2.4	18.9

(7) Interest during construction

Capital cost for the calculation of interest during construction is the sum of the construction cost, administration expenses, contingencies and engineering service costs of the year and interest on the previous year. The interest rates are 2.5 percent per year for the foreign currency portion and 11.0 percent for the local currency portion. The total interest during construction is estimated at Rs.12.4 x 10^6 of which the foreign currency component is Rs.6.9 x 10^6 (56%) and the local currency component is Rs.5.5 x 10^6 (44%).

III.4.4 Implementation Agency

The Government of Mauritius (GOM) will be responsible for implementation of the Project and will act as the execution agency for the Project in cooperation with the Municipality of Port Louis. A project office will be established under GOM for smooth operation and progress of the Project.

An organization system shall be established between the Client, the Engineer and the Contractor in accordance with the organization chart.

III.4.5 Annual Disbursement Schedule

The fiscal year for the disbursement schedule is assumed to start in July and end in June the following year in accordance with Mauritian Fiscal Year. According to the construction time schedule, the construction cost for the project are assumed to be disbursed as shown in Table III.4.3-1.

A summary of the annual disbursement schedule of the total project cost is shown below.

(Unit: Rs. million)

Year	F/C	L/C	Total
First year	51.2	13.1	64.3
Second year	158.3	39.7	208.0
Total	219.5	52.8	272.3

The economic disbursement schedule is assumed to be disbursed as shown in Table III.4.3-2. The fiscal year for the economic disbursement schedule is assumed to start in January and end in December for the purpose of economic analysis.

III.5 ECONOMIC EVALUATION

III.5.1 Project Justification

(1) General

The damage from a major landslide would be of two kinds: the threat of the disaster which would be caused by a landslide; and the substantial damage caused by a landslide. The former is mainly the threat to the human lives, and the main problem of the latter is how to compensate for the loss of human lives, even of there is other damage such as destruction of buildings, infrastructures and so forth.

Although the damage caused by a landslide would involve intangible factors such as the loss of human lives which is hard to evaluate in monetary values, the project must try to evaluate this in terms of the national and regional economies.

The project evaluation is based on the with-project and without-project principle; that is, project benefits are potential damage which would be caused by a landslide, whilst project costs are the ones required for the measures to protect from a landslide. The potentially damaged area is shown in Fig.III.5.1. The potentially damaged zone is estimated to have almost the same width as the lower slope of the moving zone of the landslide. The anticipated potentially endanger area is expected to include the area where structures such as houses and roads might be damaged directly and even mud flows might be spread out if a landslide occurs.

The economic viability of the project is assessed by applying three discounting techniques; the cost-benefit ratio method (CBR), the net present value method (NPV) and the internal-rate-of-return method (IRR). The prime discount rate applied for the first two methods is 10 %, which represents social opportunity costs.

A question in any disaster prevention project relates to when the disaster is assumed to occur. If the precautions against a landslide are not taken immediately, the threats to loss of human life could be enormous, causing negative effects for regional and national development. These negative effects will be accumulated by the time when the precautionary measures against a landslide are taken.

It is therefore prudent to assume the occurrence of a landslide just after completion of precautionary measures (i.e. year 1992 in this project, if the precautionary measures are commenced in 1990) to minimize the threat of disaster by the landslide. The time horizon for evaluation is also taken to be 35 years from commencement of construction of the precautionary measures. The cash flow for this project in this period of 35 years is given in Table III.5.1-1 on the basis of the annual disbursement schedule shown in Table III.5.1-2.

(2) Project benefits

Assuming that landslide will occur at La Butte as discussed above, the potential damage which would be caused would include nine items such as buildings and properties, traffic service, water supply, electric supply, land value, loss of human life, regional economic activities, increase in employment, and social psychological damage as listed in Table III.5.1-3. Quantification of the nine potential sources of damage was estimated as given in Table III.5.1-4, in which items 5 to 8, land value, loss of human life, regional economic activities and increase in employment were treated as intangible. In fact, the loss of human lives is unaccountable.

Table III.5.1-4 furthermore depicts potential damage computed to be Rs.417.11 million, of which Rs.403 million represents the potential cost of damage in the event of a landslide, and social psychological damage of Rs.14.08 million in the annual gain for the time horizon of 35 years.

(3) Project cost

The Project cost required for landslide protective measures was estimated at Rs.253.5 million as given in Table III.5.1-2. The project cost was further disbursed for the construction period of 2 years on the assumption that the outlay follows the progress of construction.

(4) Evaluation results

Economic viability of the project was evaluated by three methods, CBR, NPV and IRR, showing 1.96 in CBR, Rs.214.10 million in NPV and 47.7 % in IRR as given in Table III.5.1-5. These results confirm that the project is highly viable in relation to the discount rate of 10 % which represents the social opportunity cost.

(5) Sensitivity test

The benefits and costs so estimated involve uncertainties to some extent. The viability of the project was assessed by the three methods combined with 10 % to 90 % increases in costs and 10 % to 60 % decreases in benefits as depicted in Table III.5.1-6. The project shows an IRR of 11.4 %, in the critical case, i.e. 35 % cost up and 35 % benefit down, which is still higher than the marginal discount rate of 10 %. Therefore the project is assessed to be viable in economic terms.

(6) Overall project evaluation

As discussed in preceding sub-section "Project benefits", five out of nine items, namely land value, loss of human lives, regional economic activities and increase of job opportunity, were treated intangible. In consideration of importance of these, and especially loss of human lives, early implementation of the project is recommended.

TABLES

TABLE Ⅲ.2.2-1(2/2) REQUIRED QUANTITY OF MATERIALS FOR THE WELLS

MATERIAL		SPECIFICATION	UNIT WEIGHT (kg)	DRAINAGE QUANTITY	WELL-2 WEIGHT (kg)	DRAINAGE QUANTITY	WELL-3 WEIGHT (kg)
Steel plate		P10 t=2.7mm	27.43	70plts	1920.1	....	....
		perforated	27.43	77plts	2112.1	161plts	4416.2
Stiffener ring		H-125, L=2747.5mm	65.4	24pcs	1569.6	24pcs	1569.6
Stiffener		H-175					
		L=6000mm	241.2	4pcs	964.8	4pcs	964.8
		L=4500mm	180.9	....	.....	4pcs	723.6
		L=4000mm	160.8	4pcs	643.2	....	.....
		L=2500mm	100.5	....	.....	....	.....
Connecting plate							
for ring		330x125x12mm	3.89	48plts	186.7	48plts	186.7
for stiffener		340x175x12mm	5.60	8plts	44.8	8plts	44.8
- do -		340x140x 6mm	2.24	8plts	17.9	8plts	17.9
Bolt		M16x35mm	0.146	1568pcs	228.9	1372pcs	200.3
		M16x45mm	0.160	420pcs	67.2	420pcs	67.2
		M20x50mm	0.283	528pcs	149.4	528pcs	149.4
		Nut for M20	.....	96pcs	.....	96pcs	....
		U-bolt M16	1.07	48pcs	51.4	48pcs	51.4
Ladder	A-type	h=1500mm	37.8	1pc	37.8	1pc	37.8
	B-type	h=2000mm	48.5	3pcs	145.5	3pcs	145.5
	C-type	h=1000mm	27.5	1pc	27.5	2pcs	55.0
	Step		41.4	1pc	41.4	1pc	41.4
	Handrail	h=1000mm	17.6	1pc	17.6	1pc	17.6
	Metal fixture		2.5	19pcs	47.5	22pcs	55.0
Steel cover		Dia=3600mm	610.0	1pc	610.0	1pc	610.0
Sub-total (kg)					8883.4		9411.4
Total weight (kg)						39791.1	

TABLE Ⅲ.2.2-1(1/2) REQUIRED QUANTITY OF MATERIALS FOR THE WELLS

MATERIAL		SPECIFICATION	UNIT WEIGHT (kg)	DRAINAGE QUANTITY	WELL-2 WEIGHT (kg)	DRAINAGE QUANTITY	WELL-3 WEIGHT (kg)
Steel plate		P10 t=2.7mm	27.43	70plates	1920.1	70plates	1920.1
		perforated	27.43	147plates	4032.2	77plates	2112.1
Stiffener ring		H-125, L=2747.5mm	65.4	32pcs	2092.8	24pcs	1569.6
Stiffener		H-175					
		L=6000mm	241.2	8pcs	1929.6	4pcs	964.8
		L=4500mm	180.9	.....	.....	.....	.....
		L=4000mm	160.8	.....	.....	4pcs	643.2
		L=2500mm	100.5	4pcs	402.0	.....	.....
Connecting plate							
for ring		330x125x12mm	3.89	64plates	249.0	48plates	186.7
for stiffener		340x175x12mm	5.60	16plates	89.6	8plates	44.8
- do -		340x140x 6mm	2.24	16plates	35.8	8plates	17.9
Bolt		M16x35mm	0.146	2408pcs	351.6	1568pcs	228.9
		M16x45mm	0.160	560pcs	89.6	420pcs	67.2
		M20x50mm	0.283	800pcs	226.4	528pcs	149.4
		Nut for M20	.....	128pcs	.....	96pcs	.....
		U-bolt M16	1.07	64pcs	68.5	48pcs	51.4
Ladder	A-type	h=1500mm	37.8	1pc	37.8	1pc	37.8
	B-type	h=2000mm	48.5	5pcs	242.5	3pcs	145.5
	C-type	h=1000mm	27.5	2pcs	55.0	1pc	27.5
	Step		41.4	2pcs	82.8	1pc	27.5
	Handrail	h=1000mm	17.6	1pc	17.6	1pc	17.6
	Metal fixture		2.5	32pcs	80.0	19pcs	47.5
Steel cover		Dia=3600mm	610.0	1pc	610.0	1pc	610.0
Sub-total (kg)					12612.9		8883.4
Total weight (kg)							

TABLE Ⅲ.2.2-2 DESIGN EARTH PRESSSURE

DEPTH (m)	DESIGN EARTH PRESSURE (tf/m^2)
0.00	10.00
0.50	10.45
1.00	10.90
1.50	11.35
2.00	11.80
2.50	12.25
3.00	12.70
3.50	13.15
4.00	13.60
4.50	14.05
5.00	14.50
5.50	14.95
6.00	15.40
6.50	15.85
7.00	16.30
7.50	16.75
8.00	17.20
8.50	17.65
9.00	18.10
9.50	18.55
10.00	19.00

DEPTH (m)	DESIGN EARTH PRESSURE (tf/m^2)
10.00	19.00
10.50	19.45
11.00	19.90
11.50	20.35
12.00	20.80
12.50	21.25
13.00	21.70
13.50	22.15
14.00	22.60
14.50	23.05
15.00	23.50

TABLE Ⅲ.2.2-3 ALLOWABLE EXTERNAL PRESSURE

THICKNESS (mm)	STIFFENER RING SIZE (mm)	STIFFENER RING INTERVAL (m)	ALLOWABLE PRESSURE FOR BUCKLING (tf/m^2)	ALLOWABLE PRESSURE FOR COMPRESSION (Ⅰ) (tf/m^2)	ALLOWABLE PRESSURE FOR COMPRESSION (Ⅱ) (tf/m^2)
2.7	......	....	8.84	40.90	8.22
	H-125	2.0	42.03	56.48	23.94
	H-125	1.5	53.09	61.68	28.18
	H-125	1.0	75.22	72.07	36.18
	H-125	0.5	131.59	103.25	58.57
3.2	......	....	10.51	48.47	9.74
	H-125	2.0	43.70	64.05	25.90
	H-125	1.5	54.76	69.25	30.28
	H-125	1.0	76.89	79.64	38.50
	H-125	0.5	143.26	110.82	61.28

* (Ⅰ) : in the case that only compressive strength is considered.
(Ⅱ) : in the case that bending moment is considered.

TABLE Ⅲ.2.3 SUMMARY OF THE WELLS

WELL No.	LOCATION		DEPTH (m)	GROUNDWATER COLLECTION BOREHOLE	DRAINAGE BOREHOLE
	(Line - Line)			(depth, hole, stage)	
DW-2	W	X	15	50 x 10 x 2 = 1000	50m (to IW-2)
IW-2	W	X	11	....	50m (to road)
DW-3	X	Y	10	50 x 10 x 1 = 500	50m (to road)
DW-4	along Line-Y		10	60 x 10 x 1 = 600	50m (to road)
TOTAL 4 wells			46m	2100m	200m

TABLE Ⅲ.2.6 STANDARDS STEEL PILES

Outer × Thickness dia.	Sectional area	Unit weight
D × t (mm) (mm)	A (cm²)	W (kg/m)
300 × 8	73.4	57.6
300 × 9	82.3	64.6
300 × 10	91.1	71.5
300 × 11	99.9	78.4
300 × 12	108.6	85.2
300 × 13	117.2	92.0
300 × 14	125.8	98.7
300 × 15	134.3	105.4
300 × 16	142.8	112.1
300 × 17	151.1	118.6
300 × 18	159.5	125.2
300 × 19	167.7	131.7
300 × 20	175.9	138.1
300 × 21	184.1	144.5
300 × 22	192.1	150.8
300 × 23	200.2	157.1
300 × 24	208.1	163.4
300 × 25	216.0	169.5
300 × 26	223.8	175.7
300 × 27	231.6	181.8
300 × 28	239.3	187.8
300 × 29	246.9	193.8
300 × 30	254.5	199.8
300 × 31	262.0	205.7
300 × 32	269.4	211.5
300 × 33	276.8	217.3
300 × 34	284.1	223.0
300 × 35	291.4	228.7
300 × 36	298.6	234.4
300 × 37	305.7	240.0
300 × 38	312.8	245.5
300 × 39	319.8	251.0
300 × 40	326.7	256.5
300 × 42	340.4	267.2
300 × 44	353.9	277.8
300 × 46	367.1	288.1
300 × 48	380.0	298.3
300 × 50	392.7	308.3

TABLE Ⅲ.2.7 EXAMPLE OF MACHINE ARRANGEMENT

Machine	Standard	Quantity	Remarks
Large diameter drill rig		1 unit	
Grout pump		1 unit	for bentonite
Bit		....	
Sand pump		1 unit	
Bentonite mixer	0.3 m³ x 2 units	1 unit	
Water tank	5 m³	1 unit	
Grout pump	37 - 100 l/min	1 unit	for mortar
Grout mixer	200 l x 2	1 unit	
Mud screen	3.7 kw	1 unit	
Water supply pump	D80 11kw	1 unit	if required
Electric welding machine	500 A	1 unit	- do -
Truck crane	hydraulic, 10-11 ton	1 unit	- do -
Winch	3 ton	1 unit	- do -
Tower		1 set	

TABLE Ⅲ.3.1 PRINCIPAL FEATURES AND MAJOR WORK QUANTITIES

Item	Dimensions of Structures			Quantities
Ⅰ. Drainage Well			(total of No.1 to 6)	422 cu.m
1. Drainage Well			(sub-total of No.1 to 5)	322 cu.m
(1) DW-2(No.1)				0 cu.m
(2) DW-3(No.2)				0 cu.m
(3) DW-4(No.3)	Diam.=3.5m	L=15m		142 cu.m
(4) DW-5(No.4)	Diam.=3.5m	L=10m		90 cu.m
(5) DW-6(No.5)	Diam.=3.5m	L=10m		90 cu.m
2. Intermediate Well				
(1) DW-2(No.6)	Diam.=3.5m	L=11m	(sub-total of No.6)	100 cu.m
3. Metal works				
(1) Liner plate	0.5m×1.57m×7pcs./ring			48 lin.m
(2) Ring stiffener	H-125×125			26 sets
(3) Vertical stiffener	H-175×175			4 sets
4. Horizontal boring				
(1) Water collection	Diam.=66mm	L=50-60m		2,100 lin.m
(2) Water drainage	Diam.=116mm	L=50m		200 lin.m
Ⅱ. Horizontal Boring				
1. Horizontal Boring				
(1) Water collection	Diam.=66mm	L=30-50m		1,670 lin.m
Ⅲ. Piling				
1. Vertical boring (416 nos.)			(total of section 1 to 13)	9,376 lin.m
(1) Section 1	Diam.=350mm,	L=13m×49 nos.		637 lin.m
(2) Section 2	Diam.=350mm,	L=17m×18 nos.		306 lin.m
(3) Section 3	Diam.=350mm,	L=21m×5 nos.		105 lin.m
(4) Section 4	Diam.=350mm,	L=25m×5 nos.		125 lin.m
(5) Section 5	Diam.=350mm,	L=29m×5 nos.		145 lin.m
(6) Section 6	Diam.=350mm,	L=33m×9 nos.		297 lin.m
(7) Section 7	Diam.=350mm,	L=37m×41 nos.		1,517 lin.m
(8) Section 8	Diam.=350mm,	L=33m×20 nos.		660 lin.m
(9) Section 9	Diam.=350mm,	L=25m×65 nos.		1,625 lin.m
(10) Section 10	Diam.=350mm,	L=25m×56 nos.		1,400 lin.m
(11) Section 11	Diam.=350mm,	L=21m×41 nos.		861 lin.m
(12) Section 12	Diam.=350mm,	L=17m×66 nos.		1,122 lin.m
(13) Section 13	Diam.=350mm,	L=16m×36 nos.		576 lin.m
2. Pile installation (416 nos.)		(total pile length)		8,996 lin.m
(1) Steel pile	Outer diam.=300mm,	t=17mm×380 nos.		8,420 lin.m
(2) Steel pile	Outer diam.=300mm,	t= 9mm× 36 nos.		576 lin.m
3. Plug works				
(1) Concrete filling	inside of piles	for 416 nos.		661 cu.m
(2) Mortar filling	outside of piles	for 416 nos.		254 cu.m
(3) Pile head plug	earth materials	for 116 nos.		11 cu.m
(4) Pile head plug	crushed stone	for 264 nos.		24 cu.m
(5) Pile head plug	asphalt	for 264 nos.		3 ton

TABLE Ⅲ.3.3-1 MAIN EQUIPMENT FOR WELL CONSTRUCTION WORK

1. (Well excavation)

Equipment	Spec.	Nos.	Works
Gantry crane	2 t	1	muck loading
Hopper	5 m^3	1	stock of muck
Air compressor	3.5 m^3	1	air supply source
Diesel generator	60 kva	1	power source
Sand pump	3.7 kw	1	dewatering
Blower	50 m^3	1	air supply
Pick hammer	8 kg	4	excavation
Leg hammer	30 kg	2	excavation
Gas sensor		1	gas sensoring
Dump truck	4 t	1	hauling of muck
Bulldozer	3 t	1	spoil banking

2. (Drilling)

Equipment	Spec.	Nos.	Works
Boring machine	30 kw	1	boring
Diesel generator	60 kva	2	power source
Sand pump	3.7 kw	2	dewatering
Blower	50 m^3	1	air supply
Boring pump	11 kw	1	water supply
Gas sensor		1	gas sensoring
Gantry crane	2 t	1	loading & unloading

TABLE Ⅲ.3.3-2 REQUIRED PERIOD OF WELL CONSTRUCTION

Work	Q'ty	Progress rate (m^3/day)	Period (day)
(Site preparation per one well)			7
(Excavation)			
Gravely soil above water level	205 m^3	3.76	55
Cobble stone above water level	76 m^3	1.44	53
Gravely soil under water level	36 m^3	2.47	15
Cobble stone under water level	107 m^3	1.31	82
Total (for four wells)	424 m^3		205
Period (per one well)			52
(Installation)			
Liner plate	48 m	1.0	48
Ring stiffener	26 sets	2.5	11
Vertical stiffener	180 m	3.0	60
Lateral strut	8 sets	2.0	4
Staircase	44 m	15.0	3
Total (for four wells)			126
Period (per one well)			32
(Bottom concrete per one well)			3
(Fence installation per one well)			3
(Site clearance per one well)			5
Total period per one well (warkable days)			102
Total period per one well (calendar days)			133

TABLE Ⅲ.3.3-3 REQUIRED PERIOD FOR GROUNDWATER COLLECTION BOREHOLE

Work	Q'ty (m)	Progress rate (m/day)	Period (days)
(Drilling for ground water collection boreholes)			
Gravely soil	100	5.6	18
Cobble stone	1100	3.5	314
Soft rock Ⅱ	900	5.0	180
Total	2100		512
(Drilling for water drainage boreholes)			
Gravely soil	75	5.0	15
Cobble stone	125	3.2	39
Total			54
(Installation of protection pipes)			
pvc pipe, 40 mm	2100	50	42
SG pipe, 100 mm	200	50	4
Total			46
Total period per one well (warkable days)			612
Total period per one well (calendar days)			798

TABLE Ⅲ.3.3-4 MAIN EQUIPMENT FOR HORIZONTAL BOREHOLE DRILLING

Equipment	Spec.	Nos.	Works
Boring machine	30 kw	1	boring
Diesel generator	60 kva	2	power source
Sand pump	3.7 kw	1	dewatering
Boring pump	11 kw	1	water supply

TABLE Ⅲ.3.3-5 REQUIRED PERIOD FOR HORIZONTAL BOREHOLE DRILLING

Work	Q'ty (m)	Progress rate (m/day)	Period (days)
(Boring)			
Gravely soil	920	6.6	139
Cobble stone	500	4.1	122
Soft rock	250	5.8	43
Total (warkable days)			304
Total (calendar days)			397

TABLE Ⅲ.3.3-6 MAJOR EQUIPMENT FOR PILING WORK (FOR MAIN LANDSLIDE AND SMALL LANDSLIDE)

1. (Vertical drilling)

Equipment	Spec.	Nos.	Works
Boring machine	30 kw	1	borehole drilling
Boring pump	15 kw	1	mud water supply
Water pump	3.7 kw	1	water supply
Sand pump	3.7 kw	1	pumping of spilled water
Mud screen	3.7 kw	1	mud screening
Mud mixer	3.7 kw	1	mud mixing
Diesel generator	80 kva	1	power supply
Boring tower		1	setting of equipment
Water tank	5 m^3	1	storage of water

2. (pile installation)

Equipment	Spec.	Nos.	Works
Boring machine	30 kw	1	pile holding
Boring tower		1	pile installation
Diesel generator	80 kva	1	power supply
Welder	400 a	1	welding of pile

TABLE Ⅲ.3.3-7 REQUIRED PERIOD FOR PILING WORK (FOR MAIN LANDSLIDE AND SMALL LANDSLIDE)

Work	Q'ty (m)	Progress rate (m/day)	Period (days)
(Site preparation)	6 sites x 7 days		42
(Boring)			
Sandy & clayey soil	463	8.3	56
Gravely soil	2114	4.0	529
Cobble stone	4897	2.3	2129
Soft rock Ⅱ	1902	3.75	507
Sub-total			3221
(pile installation)			
thickness = 17 mm	8420	45	187
thickness = 9 mm	576	84	7
Sub-total			194
(resetting of equipment)	416 times / 7 times		60
Total period (warkable days)			3517
Total period (calendar days)			4587

TABLE Ⅲ.4.2-1 LABOR WAGES

Exchange Rate : 1.0 US$ = Rl.15.3 = JYE 146.0

No.	Particular	Unit	Foreign Portion (Yen)	Local Portion (Rs.)	Remark
1.	Foreman	m.d.	0	350	local
2.	Operator	m.d.	0	300	
3.	Assis.Operator	m.d.	0	220	
4.	Mechanic	m.d.	0	300	
5.	Electrician	m.d.	0	300	
6.	Concrete worker	m.d.	0	200	
7.	Reinforcement worker	m.d.	0	220	
8.	Carpenter	m.d.	0	220	
9.	Mason	m.d.	0	240	
10.	Skilled labour	m.d.	0	240	
11.	Common labour	m.d.	0	162	
12.	Foreman, foreign	m.d.	24,000	550	foreign

Note :

1. Average daily working hours; 8hours
2. Extra payment for overtime;
   (1) Normal overtime 50 %
   (2) Night 50 %
   (3) Holidays and Sundays 100 %

TABLE Ⅲ.4.2-2 UNIT PRICE OF MAJOR MATERIALS

Exchange Rate : 1.0 US$ = Rs.15.3 = JYE 146.0

No.	Particular	Unit	Foreign Portion (Yen)	Local Portion Net (Rs.)	Local Portion Tax (Rs.)	Local Portion Total (Rs.)
1.	Light oil	lit		4.60	0.00	4.60
2.	Gasoline	lit		7.85	0.00	7.85
3.	Cement	ton		1,530.00	80.00	1,610.00
4.	Deformed bar	kg	76	0.16		0.16
5.	Water-reduce agent	kg	307	0.46		0.46
6.	Aggregate, fine	ton		223.00	8.00	231.00
7.	Aggregate, coarse	ton		166.00	6.00	172.00
8.	Plywood	cu.m		11,810.00	590.00	12,400.00
9.	Liner plate	lin.m	113,000	77.48		77.48
10.	Ring stiffener	ton	105,000	172.96		172.96
11.	Vertical stiffener	ton	98,500	172.96		172.96
12.	Stair	lin.m	23,700	39.70	2.00	41.70
13.	Steel cover, 3.6m	set	227,000	203.00	10.00	213.00
14.	P.V.C. pipe, 40mm	lin.m	291	0.50		0.50
15.	Gas pipe, 100mm	lin.m	2,640	1.77		1.77
16.	Bentonite	kg	481	0.27		0.27
17.	Steel pile, 300mm, t=17mm, l=4m	pc.	107,000	60.00	3.00	63.00
18.	Steel pile, 300mm, t=10mm, l=4m	pc.	49,100	60.00	3.00	63.00
19.	Metal crown, 86mm	pc.	4,940	1.01		1.01
20.	Metal crown, 116mm	pc.	7,910	1.61		1.61
21.	Metal crown, 350mm	pc.	80,400	16.35		16.35
22.	Core tube, 84mm	no.	20,100	4.09		4.09
23.	Core tube, 114mm	no.	31,800	6.47		6.47
24.	Core tube, 350mm	no.	106,000	21.55		21.55
25.	Boring rod, 73mm	lin.m	40,200	8.18		8.18
26.	Boring rod, 85mm	lin.m	52,200	10.63		10.63
27.	Boring rod, 101mm	lin.m	68,800	14.00		14.00
28.	Casing tube, 144mm	no.	92,700	18.87		18.87
29.	Hammer bit, 86mm	pc.	62,800	12.79		12.79
30.	Hammer bit, 116mm	pc.	87,600	17.82		17.82
31.	Sield pipe, 86mm	no.	24,600	5.01		5.01
32.	Sield pipe, 116mm	no.	55,600	11.32		11.32
33.	Sield crown, 86mm	pc.	34,700	7.06		7.06
34.	Sield crown, 116mm	pc.	43,300	8.81		8.81
35.	Wing bit, 350mm	pc.	301,000	61.34		61.34
36.	Tri-cone bit, 350mm	pc.	664,000	135.18		135.18
37.	Drill collar, 350mm	no.	938,000	190.78		190.78

TABLE Ⅲ.4.2-3 EXPENSES FOR MAJOR EQUIPMENT

Exchange Rate : 1.0 US$ = Rs.15.3 = JYE 146.0

No.	Particular	Specification	Unit	Equipment Foreign Portion (Yen)	Expense Local Portion (Rs.)
1.	Bulldozer	3 t	hr	1,960	20.70
2.	Backhoe	0.4 m^3	hr	3,080	30.30
3.	Dump truck	4 t	hr	1,090	9.60
4.	Truck crane	4.9 t	hr	2,430	16.40
5.	Truck crane	20 t	hr	5,980	40.30
6.	Concrete mixer	0.5 m^3	day	3,640	48.90
9.	Vibrating roller	0.5 t	hr	615	6.40
10.	Plate compactor	90 kg	day	616	6.40
15.	Gantry crane	2 t	day	5,970	73.40
16.	Hopper	5 m^3	day	5,190	39.50
17.	Air compressor	3.5 m^3	day	3,250	32.90
18.	Air compressor	10.5 m^3	day	9,650	97.90
20.	Diesel generator	60 kVA	day	3,430	26.10
21.	Diesel generator	80 kVA	day	4,130	31.50
22.	Blower	50 m^3	day	112	0.90
23.	Sand pump, 80mm	3.7 kW	day	545	11.70
24.	Sand pump, 80mm	5.5 kW	day	853	18.30
25.	Water pump	3.7 kW	day	673	11.80
26.	Turbine pump	3.7 kW	day	755	13.30
27.	Submersible pump	11 kW	day	780	14.10
28.	Pick hammer	8 kg	day	110	0.60
29.	Leg hammer	30 kg	day	823	4.50
30.	Boring machine	30 kW	day	7,790	76.60
31.	Boring pump	11 kW	day	2,310	23.40
32.	Boring pump	15 kW	day	3,860	39.20
33.	Grout mixer	7.5 kW	day	2,810	28.50
34.	Grout pump	11 kW	day	2,310	23.40
36.	Air hammer	86 mm	day	2,650	14.60
37.	Air hammer	116 mm	day	3,160	17.50
38.	Mud screen	3.7 kW	day	4,930	43.30
39.	Mud mixer	3.7 kW	day	1,200	12.20
40.	Boring tower	4 m	day	4,920	40.40
41.	Water tank	5 m^3	day	2,340	20.50
42.	Welder	400 A	day	657	6.50
43.	Winch	7.5 kW	day	1,980	26.70

TABLE Ⅲ.4.2-4 TOTAL PROJECT COST

Exchange Rate : 1.0US$=Rs.15.3=JYE146.0

Item	Foreign Portion (Rs.1,000)	Local Portion (Rs.1,000)	Total Amount (Rs.1,000)
A. Construction Cost			
A-1 General Item	33,218	6,048	39,266
A-2 Drainage Well	6,549	5,354	11,903
(1) Earth works	792	1,405	2,197
(2) Concrete works	17	116	133
(3) Metal works	1,586	352	1,938
(4) Safety facilities	186	76	262
(5) Water collection boring	3,423	2,412	5,835
(6) Water drainage boring	393	266	659
(7) Borehole protection	152	713	865
(8) Drainage channel	0	14	14
A-3 Horizontal Boring	1,978	1,995	3,973
(1) Water collection boring	1,897	1,450	3,347
(2) Borehole protection	64	518	582
(3) Drainage channel	17	27	44
A-4 Piling	136,566	15,930	152,496
(1) Earth works	54	78	132
(2) Vertical boring	101,929	11,769	113,698
(3) Pile installation	32,133	967	33,100
(4) Reset machinery	50	175	225
(5) Disposal works	609	180	789
(6) Plug works	1,791	2,761	4,552
Total of A	178,311	29,327	207,638
B. Administration Expense	0	6,275	6,275
C. Price Escalation	0	5,200	5,200
D. Physical Contingency	17,789	4,098	21,887
E. Engineering Service	16,500	2,400	18,900
F. Interest during Construction	6,900	5,500	12,400
Total	219,500	52,800	272,300

TABLE Ⅲ.4.3-1 ANNUAL DISBURSEMENT SCHEDULE (Financial Cost)

(Unit : Mil.Rs.) Exchange Rate : 1.0US$ = Rs.15.3 = JY¥146.0

	Total			First year			second year		
	F/C	L/C	total	F/C	L/C	total	F/C	L/C	total
A. Construction Works									
A-1 General Item	33.2	6.0	39.2	20.3	3.6	23.9	12.9	2.4	15.3
A-2 Drainage Well	6.5	5.4	11.9	1.0	0.8	1.8	5.5	4.6	10.1
A-3 Horizontal Boring	2.0	2.0	4.0	0.7	0.7	1.4	1.3	1.3	2.6
A-4 Piling	136.6	15.9	152.5	17.1	1.9	19.0	119.5	14.0	133.5
Total of A	178.3	29.3	207.6	39.1	7.0	46.1	139.2	22.3	161.5
B. Administration Expense	0.0	6.3	6.3	0.0	2.3	2.3	0.0	4.0	4.0
Total of A to B	178.3	35.6	213.9	39.1	9.3	48.4	139.2	26.3	165.5
C. Price Escalation	0.0	5.2	5.2	0.0	0.7	0.7	0.0	4.5	4.5
Total of A to C	178.3	40.8	219.1	39.1	10.0	49.1	139.2	30.8	170.0
D. Physical Contingency	17.8	4.1	21.9	3.9	1.0	4.9	13.9	3.1	17.0
E. Engineering Service	16.5	2.4	18.9	6.9	1.0	7.9	9.6	1.4	11.0
Total of A to E	212.6	47.3	259.9	49.9	12.0	61.9	162.7	35.3	198.0
F. Interest during Construction	6.9	5.5	12.4	1.3	1.1	2.4	5.6	4.4	10.0
Grand Total	219.5	52.8	272.3	51.2	13.1	64.3	168.3	39.7	208.0

TABLE Ⅲ.4.3-2 ANNUAL DISBURSEMENT SCHEDULE (Economic Cost)

(Unit : Mil.Rs.) Exchange Rate : 1.0US$=Rs.15.3 =JY¥146.0

	Total			First year			second year		
	F/C	L/C	total	F/C	L/C	total	F/C	L/C	total
A. Construction Works									
A-1 General Item	33.2	6.0	39.2	20.3	3.6	23.9	12.9	2.4	15.3
A-2 Drainage Well	6.5	5.4	11.9	1.0	0.8	1.8	5.5	4.6	10.1
A-3 Horizontal Boring	2.0	2.0	4.0	0.7	0.7	1.4	1.3	1.3	2.6
A-4 Piling	136.6	15.8	152.4	17.1	1.9	19.0	119.5	13.9	133.4
Total of A	178.3	29.2	207.5	39.1	7.0	46.1	139.2	22.2	161.4
B. Administration Expense	0.0	6.3	6.3	0.0	2.3	2.3	0.0	4.0	4.0
Total of A to B	178.3	35.5	213.8	39.1	9.3	48.4	139.2	26.2	165.4
C. Price Escalation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total of A to C	178.3	35.5	213.8	39.1	9.3	48.4	139.2	26.2	165.4
D. Physical Contingency	17.8	3.5	21.3	3.9	0.9	4.8	13.9	2.6	16.5
E. Engineering Service	16.5	2.4	18.9	6.9	1.0	7.9	9.6	1.4	11.0
Total of A to E	212.6	41.4	254.0	49.9	11.2	61.1	162.7	30.2	192.9
F. Interest during Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	212.6	41.4	254.0	49.9	11.2	61.1	162.7	30.2	192.9

TABLE Ⅲ.5.1-1 CASH FLOW OF THE PROJECT FOR THE LONG TERM PROTECTIVE MEASURES

Social Discount Rate (r)

	r=0 %		r=10 %	
Year	Benefit	Cost	Benefit	Cost
1	0.00	3.60	0.00	3.60
2	14.08	165.70	12.80	150.64
3	14.08	84.40	11.64	69.75
4	417.11	0.00	313.38	0.00
5	14.08	0.00	9.62	0.00
6	14.08	0.00	8.74	0.00
7	14.08	0.00	7.95	0.00
8	14.08	0.00	7.23	0.00
9	14.08	0.00	6.57	0.00
10	14.08	0.00	5.97	0.00
11	14.08	0.00	5.43	0.00
12	14.08	0.00	4.93	0.00
13	14.08	0.00	4.49	0.00
14	14.08	0.00	4.08	0.00
15	14.08	0.00	3.71	0.00
16	14.08	0.00	3.37	0.00
17	14.08	0.00	3.06	0.00
18	14.08	0.00	2.79	0.00
19	14.08	0.00	2.53	0.00
20	14.08	0.00	2.30	0.00
21	14.08	0.00	2.09	0.00
22	14.08	0.00	1.90	0.00
23	14.08	0.00	1.73	0.00
24	14.08	0.00	1.57	0.00
25	14.08	0.00	1.43	0.00
26	14.08	0.00	1.30	0.00
27	14.08	0.00	1.18	0.00
28	14.08	0.00	1.07	0.00
29	14.08	0.00	0.98	0.00
30	14.08	0.00	0.89	0.00
31	14.08	0.00	0.81	0.00
32	14.08	0.00	0.73	0.00
33	14.08	0.00	0.67	0.00
34	14.08	0.00	0.61	0.00
35	14.08	0.00	0.55	0.00
	881.75	253.70	438.09	223.99

r=0 %		r=10 %	
B=	881.75	B=	438.09
C=	253.70	C=	223.99
B−C=	628.05	B−C=	214.10

Net benfit : B−C =214.10

Cost benefit ratio : B／C =1.96

TABLE Ⅲ.5.1-2 SUMMARY OF ANNUAL DISBURSEMENT SCHEDULE (ECONOMIC COST)

(unit: Mill.Rs.) Exchange Rate : US$ 1.0=Rs.15.3=J.Yen 146.0

ITEM	TOTAL	1990	1991	1992
A. Construction Works	207.5	0.0	135.9	72.6
A-1 General Item	(38.3)	(0.0)	(24.9)	(13.4)
A-2 Drainage Well	(22.3)	(0.0)	(15.5)	(6.8)
A-3 Horizontal Boring	(4.0)	(0.0)	(2.6)	(1.4)
A-4 Pilling	(142.5)	(0.0)	(92.2)	(50.3)
B. Administration Expense	6.3	0.4	4.3	1.6
C. Price Escalation	0.0	0.0	0.0	0.0
D. Physecal Contingency	21.3	0.0	14.0	7.3
E. Engineering Service	18.6	3.2	11.5	3.9
F. Interest during Construction	0.0	0.0	0.0	0.0
Grand Total	253.7	3.6	165.7	84.4

TABLE Ⅲ.5.1-3 BASIC CONCEPTS OF ANTICIPATED DAMAGE

ANTICIPATED DAMAGE	CASE without project	CASE with project
1. Building and properties	*	—
2. Traffic service	*	—
3. Water supply	*	—
4. Electric supply	*	—
5. Land value	*	*
6. Loss of human life	*	—
7. Regional economic activities	*	*
8. Increase in employment	—	*
9. Social psychological damage	*	—

* applicable damage for economic evaluation

TABLE Ⅲ.5.1-4 ANTICIPATED DAMAGE BY THE LANDSLIDE OCCURRENCE AT LA BUTTE

(Mill. Ra.)

ANTICIPATED DAMAGE ITEM	VALUE
1. Building and Properties	339.9
2. Traffic service	44.37
a. disruption of traffic service	(31.76)
b. treatment of debris deposits	(8.08)
c. road pavement	(4.53)
3. Water supply	17.64
4. Electric supply	1.12
5. Land value	-
6. Loss of human life	-
7. Regional economic activities	-
8. Increase in employment	-
9. Social psychological damage (each year excluding 1990)	14.08
TOTAL	417.11

TABLE Ⅲ.5.1-5 ECONOMIC EVALUATION BY THREE METHODS

DISCOUNTING TECHNIQUE	VALUE
1. CBR	1.96
2. NPV	Rs. 214.10
3. IRR	47.7 %
Benefit = Mill. Rs. 438.09	
Cost = Mill. Rs. 223.99	

CBR : cost-benefit ratio method

NPV : net present value method

IRR : internal-rate-of-return method

Note : CBR and NPV are measured by principal interest rate of
r = 10 % per annum.

TABLE Ⅲ.5.1-6 RESULT OF SENSITIVITY ANALYSIS

INCREMENT (%) BENEFIT	COST	IRR (%)
—	—	47.7
—	+10.0	40.2
—	+20.0	33.9
—	+30.0	28.6
—	+40.0	24.2
—	+50.0	20.5
—	+60.0	17.4
—	+70.0	14.8
—	+80.0	12.6
—	+90.0	10.8
−10.0	—	40.0
−20.0	—	32.5
−30.0	—	25.6
−40.0	—	19.5
−50.0	—	14.5
−60.0	—	11.0
−20.0	+20.0	22.0
−30.0	+30.0	14.2
−35.0	+35.0	11.4

— : without increment