CHAPTER 3 FEASIBILITY DESIGN OF SEDIMENT STORAGE RESERVOIR

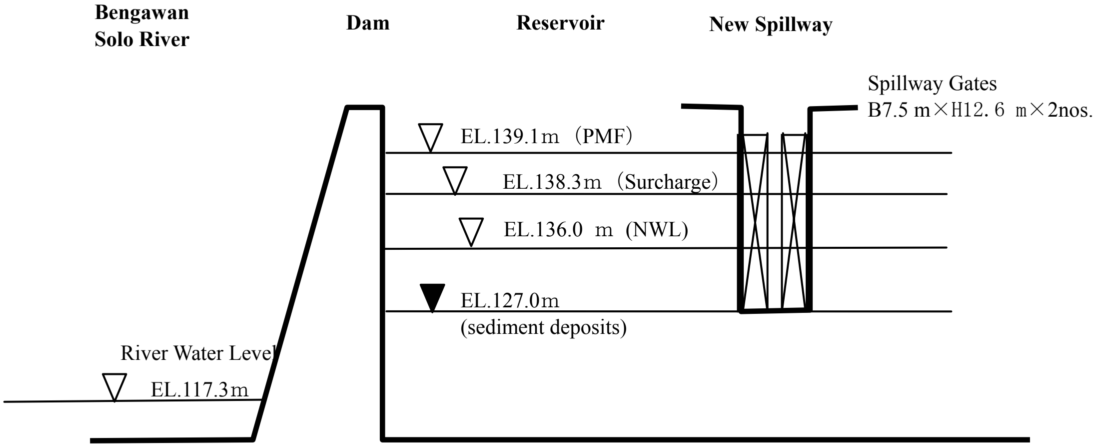
3.1 Design Condition and Criteria

The sediment storage reservoir structures subject to feasibility design are the new spillway, closure dike and overflow dike. The layout of the facilities is shown in Figure 3.1.1. Design conditions and criteria are set out as listed in Table 3.1.1. Design water levels for design of the new spillway structure are illustrated in Figure 3.1.2.

Table 3.1.1 Design Conditions and Criteria

Structure	Item	Condition and Criteria
(1)New Spillway	Type	Front overflow weir
	Elevation of Inlet	EL.127.0 m (Design deposits level)
	Design discharge	Q=1,270 m^3/s (at PMF)
	Water level	EL.139.1 m
(2) Closure Dike	Crest elevation	EL.138.3 m（Surcharge water level）
	Elevation of foundation	EL.127.0 m（Design sediment deposits level）
	Width of crest	W=10.0 m
(3) Overflow Dike	Crest height	Crest Height EL.136.0m
	Design discharge	Q=550 m^3/s (at SHFD) Sediment storage reservoir: EL. 138.1 m Main reservoir: EL. 137.8 m.

Note; Design discharges are discussed in subsection 3.1.6.
Source: JICA Study Team



Source: JICA Study Team

Figure 3.1.2 Design Water Levels for Design of New Spillway

3.2 New Spillway

The new spillway is planned at the right abutment of the Wonogiri dam. Layout plan and profile of the new spillway are shown in Figures 3.2.1 and 3.2.2 respectively.

Required function of the new spillway is to release the design flood discharges safely and to smoothly flush out the sediment-laden flood inflow from the Keduang River as well as the sediment deposits in the sediment storage reservoir. Feasibility design of the new spillway is described as follows:

3.2.1 Layout Plan of New Spillway

(1) Concept of Plan

Concept of layout plan are as follows:

The concept of layout plan is as follows:

a) The new spillway is to be constructed within the premises of PBS or PJT I Bengawan Solo.

b) The inlet of the spillway is placed about 100 m in front of the Wonogiri dam axis to avoid giving negative impacts to the dam body during the construction and the operation after the completion.

c) A training channel is placed from the inlet of spillway to the end of curved portion of the spillway. Gradient of the channel is about 1/108.

d) A chute channel is placed from the end of training channel to the inlet of the energy dissipater. Gradient of the chute channel is 1/108, the same as the training channel.

e) The chute channel is curved to connect smoothly with the Bengawan Solo River.

f) Width of the channel is set out 15 m from the beginning of training channel to end of the chute channel.

(2) Type of Inlet

A front overflow weir type is adopted as the new spillway inlet to secure effective functioning for sediment flushing.

(3) Gate

Gate size has been determined to accommodate the design discharge from the sediment storage reservoir. A radial gate type has been adopted to reduce the impact caused by sediment releasing.

(4) Type of Energy Dissipater

A ski jump type is adopted as the energy dissipater because of the reasons as listed below. Bed elevation of the plunge pool is set at EL.100 m applying the same elevation to the plunge pool as the existing spillway.

a) The area along the spillway channel route is underlain by a very stiff layer (hard rock) suitable for foundation. The ski jump type dissipater requires not little excavation. If a hydraulic jump type dissipater is adopted, the excavation volume might be larger than that of ski jump type.

b) Gradient of the chute channel slope is very gentle at 1/108. Therefore, the flow velocity in the channel is not so high. Flow velocity in the chute channel is around 9.7 m^3/s when the flow is 400 m^3/s.

c) A ski jump dissipater was adopted for the existing spillway.

3.2.2 Design

(1) Inlet of Spillway

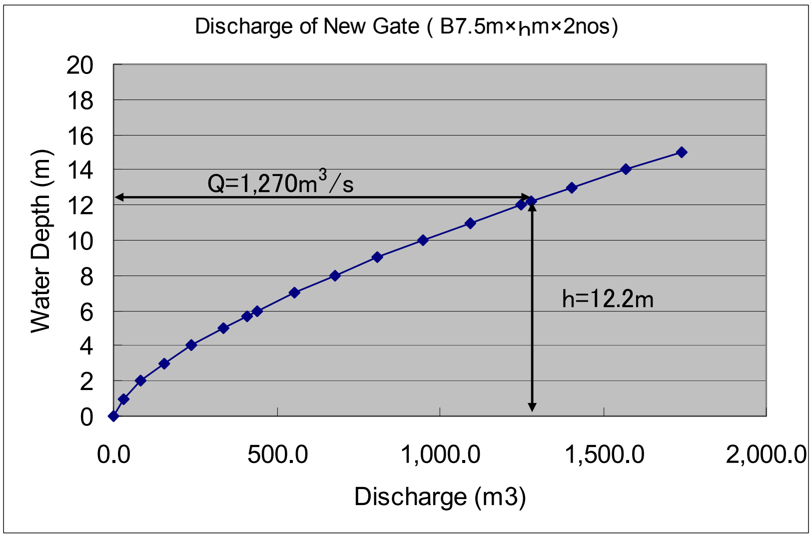
Foundation elevation of the inlet is set at EL.127.0 m, the same elevation as the design level of sediment deposits to allow the sediment flushing function. Maximum design discharge is 1,270 m^3/s at PMF (water level EL.139.1 m). Design discharge to be released is 400 m^3/s at SHFD with a peak discharge of 4,000 m^3/sec.

Width of inlet is required to be more than B=15.0 m to keep the water level, from the overflow weir equation below, under EL.139.1 m at PMF.

In this design, a two gate (B =7.5 m) system is adopted due to maintenance work. Usually, more than two gates are recommended for sediment flushing in terms of maintenance.

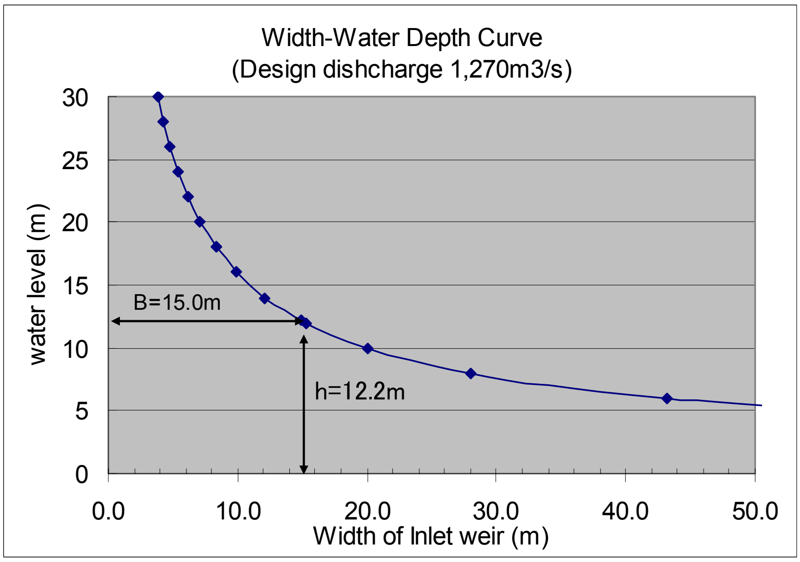
$$Q = CBH^{3/2}$$

where,
C : Coefficient of overflow weir C=2.0
B : Width of inlet (m)
H : Water depth at inlet (m) 139.1-127.0 = 12.1 m
Q : Discharge (m^3/s)



Source: JICA Study Team

Figure 3.2.3 H-Q Curve of New Gates



Source: JICA Study Team

Figure 3.2.4 Width Water Depth Curve of New Gates

(2) Training Cannel Portion

The training channel crosses the dam axis and runs close to the dam body. A gravity type retaining wall is adopted for the training channel. Typical cross section is shown in Figure

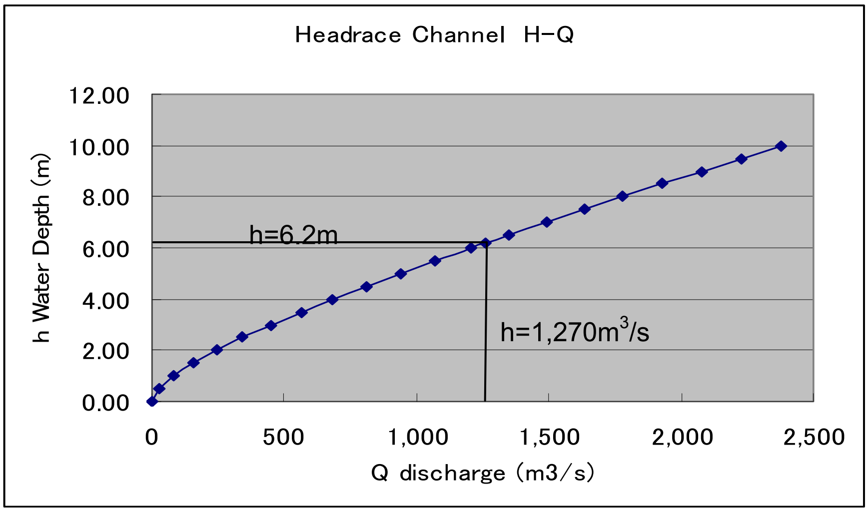
3.2.5. Principal design conditions are set at:

- Slope of back face of the wall is 1:0.7 due to the stability of the wall.
- Slope of training channel is 1/108.
- Design discharge is 1,270 m^3/s.
- Water depth at design discharge h=6.2 m is given from below Manning formula.
- Free board, h=0.8 m is applied.
- Height of wall H=6.2+0.8= 7.0 m.

Manning formula $v = 1/n \cdot R^{2/3} \cdot I^{1/2}$

$$Q = A \cdot v$$

where,
n : Coefficient of roughness, n=0.016 (concrete channel)
A : Flow area (m^2)
V : Velocity (m/s)
Q : Discharge (m^3/s), Design discharge Q=1,270m^3/s
I : Gradient 1/108
R : Hydraulic mean depth (R=S/h)
S : Total edge length in water (m)
H : Water depth (m)
V : Velocity (m/s),V=13.6 m/s at 1,270 m^3/s, V=9.7m/s at 400 m^3/s



Source: JICA Study Team

Figure 3.2.6 H-Q Curve of Training Channel

(3) Chute Channel Portion

Gradient of the chute channel is I=1/108, which is the same with the training channel.

Reinforced concrete walls are adopted for the walls of the chute channel to reduce excavation volume and concrete volume. Typical cross section is shown in Figure 3.2.5. Principal design conditions are set at:

- Slope of chute channel is I=1/108.
- Design discharge is 400 m^3/s at surcharge water level and 1,270m^3/s at PMF.
- Water depth at design discharge h=6.2 m.
- Free board h=0.8 m.

- Height of wall H=6.2+0.8= 7.0 m.
- Velocity V = 9.7 m/s at 400 m^3/s, V = 13.6 m/s at 1,250 m^3/s.

(4) Energy Dissipater

A ski jump type energy dissipater is adopted for new spillway. Target discharge is 400 m^3/s at the SHFD. Flow velocity is 9.7 m/s, which is very low due to gentle chute channel gradient of 1/108. Gradient of 1/108 is categorized as a natural river.

a) Features of ski jump bucket for energy dissipater

This type of energy dissipater has an advantage in the construction cost, while the effectiveness as a dissipater is less compared with the normal type, and the flow regime of the plunge pool and downstream river is unstable.

b) Trajectory and extent of the area of falling jet

Trajectory of free-discharging jet is estimated by the following formula:

$$y = \tan\theta \cdot x - \frac{x^2}{4\cos\theta^2 \cdot KHo}$$

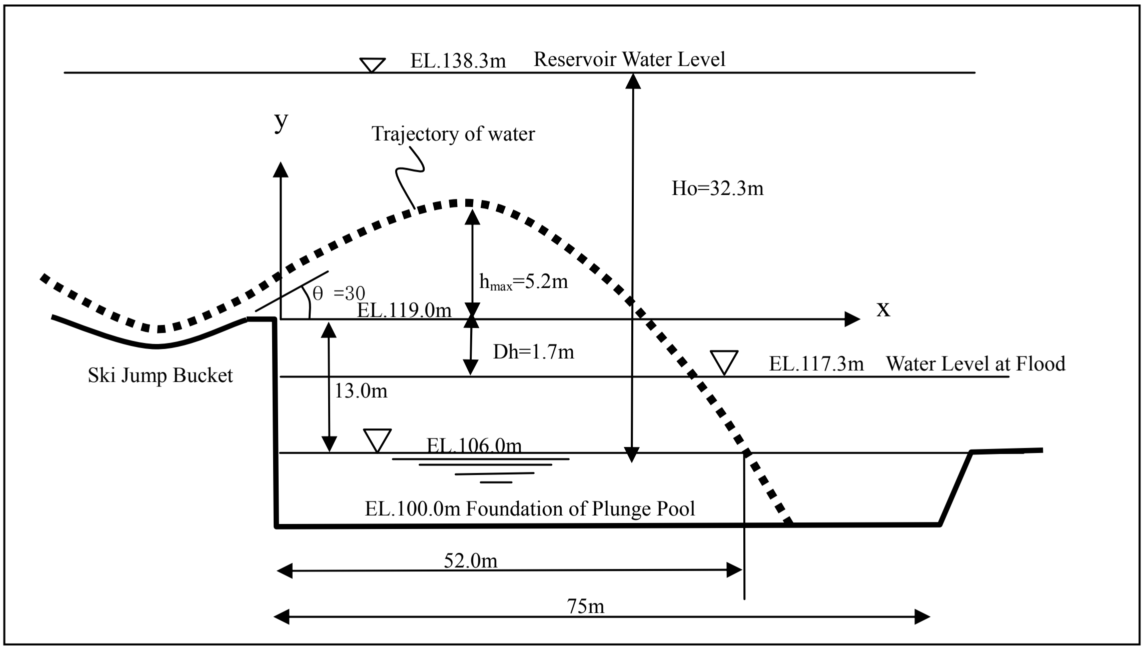
where,

K: Coefficient obtained after deducting friction loss and other losses in the channel from 1.0 are as shown below.

K=0.69 (Q=1,000 m^3/s)
K=0.73 (Q=1,600 m^3/s)
K=0.65 (Q=400 m^3/s)
K=0.71 (Q=1,250 m^3/s)

K values come from the “Report on the Hydraulic Model Test on Revised Spillway of Karangkates Project (1971)”

θ : Angle of Jet jumping θ =30°



Source: JICA Study Team

Figure 3.2.7 Trajectory of Jet Water

Table 3.2.1 Trajectory of Jet Water

Water Level of Reservoir	Water Level of River	Difference △h(m)	Xmax (m)	Ymax (m)
EL.138.3m	EL.106.0m	32.3	52.0	5.19
EL.139.1m	EL.106.0m	33.1	53.0	5.34

Source: JICA Study Team

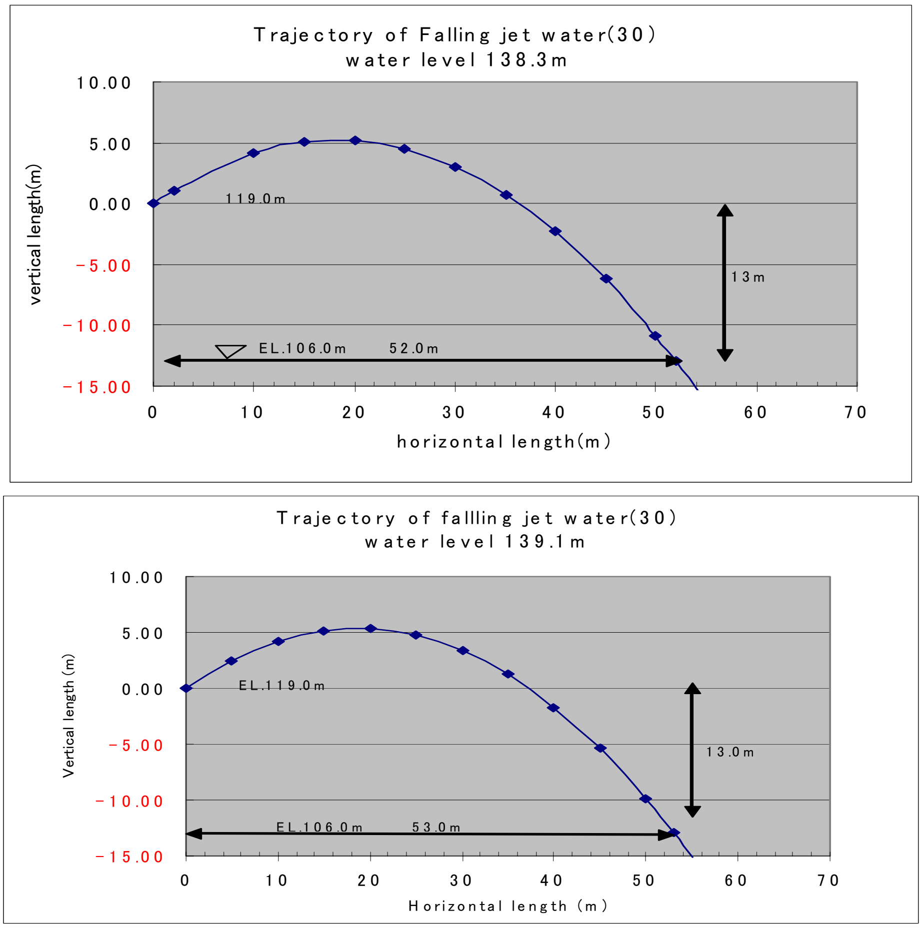
(5) Quantities

Quantities for the closure dike are shown in Table 4.2.2.

Table 3.2.2 Main Quantity of New Spillway

Item	Unit	Quantity
Length of Spillway	m	708.79
Training Channel	m	162.55
Chute Channel	m	452.24
Energy dissipater	m	94
Width of Spillway	m	15.00
Concrete Volume	m^3	93,320
Excavation	m^3	389,240
Backfill	m^3	134,970

Source: JICA Study Team



Source: JICA Study Team

Figure 3.2.8 Trajectory of Falling Jet Water

3.3 Closure Dike

(1) Design Conditions and Criteria

Purpose of the closure dike is to separate the sediment storage reservoir from the Wonogiri main reservoir up to the surcharge water level. However, when the water level is over the surcharge water level, the closure dike is designed to be submerged. A closure dike should be safe from sudden lowering of water level from EL. 136.0 m (normal water level) to EL. 127.0 m (designed sediment deposits level).

Therefore, design condition and criteria shall be as follows,

Height of Closure Dike	: EL.138.3 m (Surcharge water level)
Free Board	: △h=0 m
Foundation height	: EL.127.0 m
Face Slope of Dike	: 1:3.0

(2) Layout Plan

The closure dike is planned to run from the right abutment of the Wonogiri dam to the top edge of the peninsula that is located in front of the dam. Another purpose of the closure dike is to prevent sediment inflow from the Keduang River from flowing into the intake directly and to reduce garbage gathering at in front of the intake.

Layout plan of the closure dike is shown in Figure 3.3.1.

(3) Type of the Closure Dike

The earth-fill cofferdam type is selected for the closure dike for economic reasons and to secure the sand spoil bank resulting from the spillway excavation. However, there will be overflow over the closure dike during floods, from the water level of the Design flood (EL.138.3 m) to the PMF (EL.139.1 m). There might be the possibility of scouring at the foot and face of the closure dike during sediment flushing. Therefore, a double-wall constructed from steel sheet piles with a penetration depth reaching the original ground, is designed to be incorporated at the top of the closure dike. Width of the closure dike is 10 m, which is determined by stability analysis of the double-sheet pile wall.

Face slope of the dike is adopted at 1:3.0 to secure the safety of slope from failure with the rapid lowering of water level from 136 m to 127 m in one day.

Typical cross section of the closure dike is shown in Figure 3.3.1.

(4) Quantities

Quantities for the closure dike are shown in Table 3.3.1.

Table 3.3.1 Main Quantity of Closure Dike

Item	Unit	Quantity
Length of dike	m	658.00
Height of dike	m	Top of dike EL.138.3 m Foundation height EL.127.0 m H_{max} = 11.3 m
Embankment volume	m^3	167,800
Steel sheet pile	t	4,450

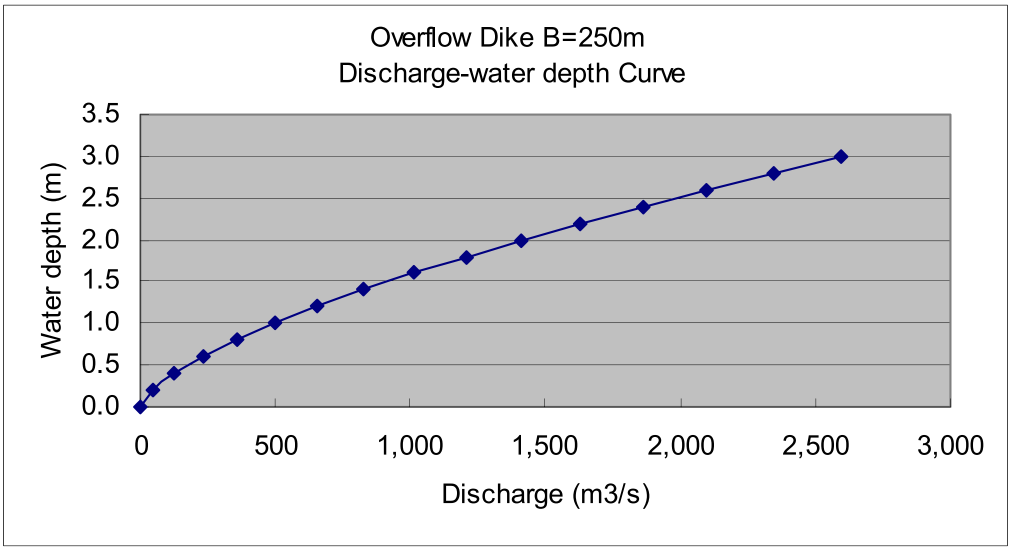
Source: JICA Study Team

3.4 Overflow Dike

(1) Design Condition and Criteria

The overflow dike is designed to transfer water from the sediment storage reservoir to the main reservoir, and vice versa when the reservoir water level is over EL. 136.0 m (normal water level) in the main reservoir. Length of the overflow dike was determined by the flood routing calculation. Plan and typical cross section are shown in Figure 3.4.1. Conditions and criteria are as follows:

- Crest height of overflow dike EL.136.0 m
- Difference in height between the crest and apron is 2.0 m from topographical and geological conditions
- Design discharge Q=550 m^3/s (at water lever EL.138.1 m in the sediment storage reservoir and EL.137.8 m in the main reservoir)
- Direction of flow is both sides



Source: JICA Study Team

Figure 3.4.2 H-Q Curve of Overflow Dike

(2) Layout Plan

Overflow dike is planned to be on the peninsula lying from the opposite shore of the Wonogiri dam. The location of the overflow dike is selected on ridge of peninsula due to geological conditions. Both sides of the overflow dike are embanked up to EL.138.3 m and connected to the closure dike and the shore opposite the dam.

In the overflow dike, a connecting conduit (2.0 m×2.0 m) with a gate is installed to transfer water in the sediment storage reservoir between EL. 136.0 m and 132.0 m to the main reservoir in the dry season. Width of the dike is about 250 m to satisfy the required function. Plan and section of connecting conduit is shown in Figure 3.4.3.

(3) Type of Overflow Dike

A concrete fixed weir type is adopted for the overflow dike because it is maintenance free.

Direction of flow on the dike is considered reversible. Therefore, the layout needs to have apron works on both sides. Distance between both weirs is set at 10 m to secure maintenance and allow an access road.

(4) Quantities

Quantities for the overflow dike are shown in Table 3.4.1

Table 3.4.1 Main Quantity of Overflow Dike

Item	Unit	Quantity
Length of the dike	m	250.00
Height of dike	m	Crest height EL.136.0 m Apron EL.134.0 m
Excavation	m^3	29,750
Concrete	m^3	11,000
Earth filling	m^2	61,600

Source: JICA Study Team

Figure

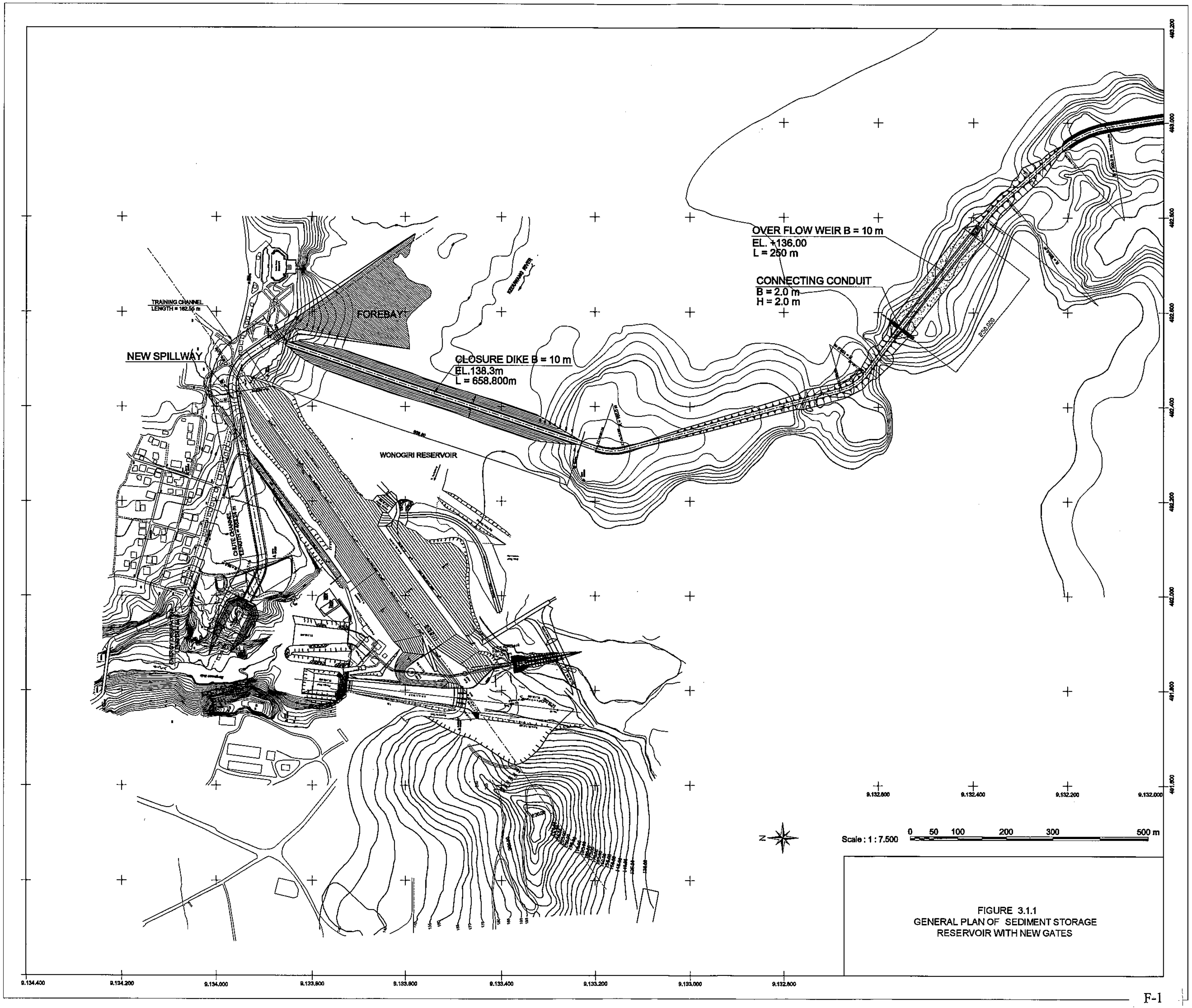


FIGURE 3.1.1
GENERAL PLAN OF SEDIMENT STORAGE
RESERVOIR WITH NEW GATES

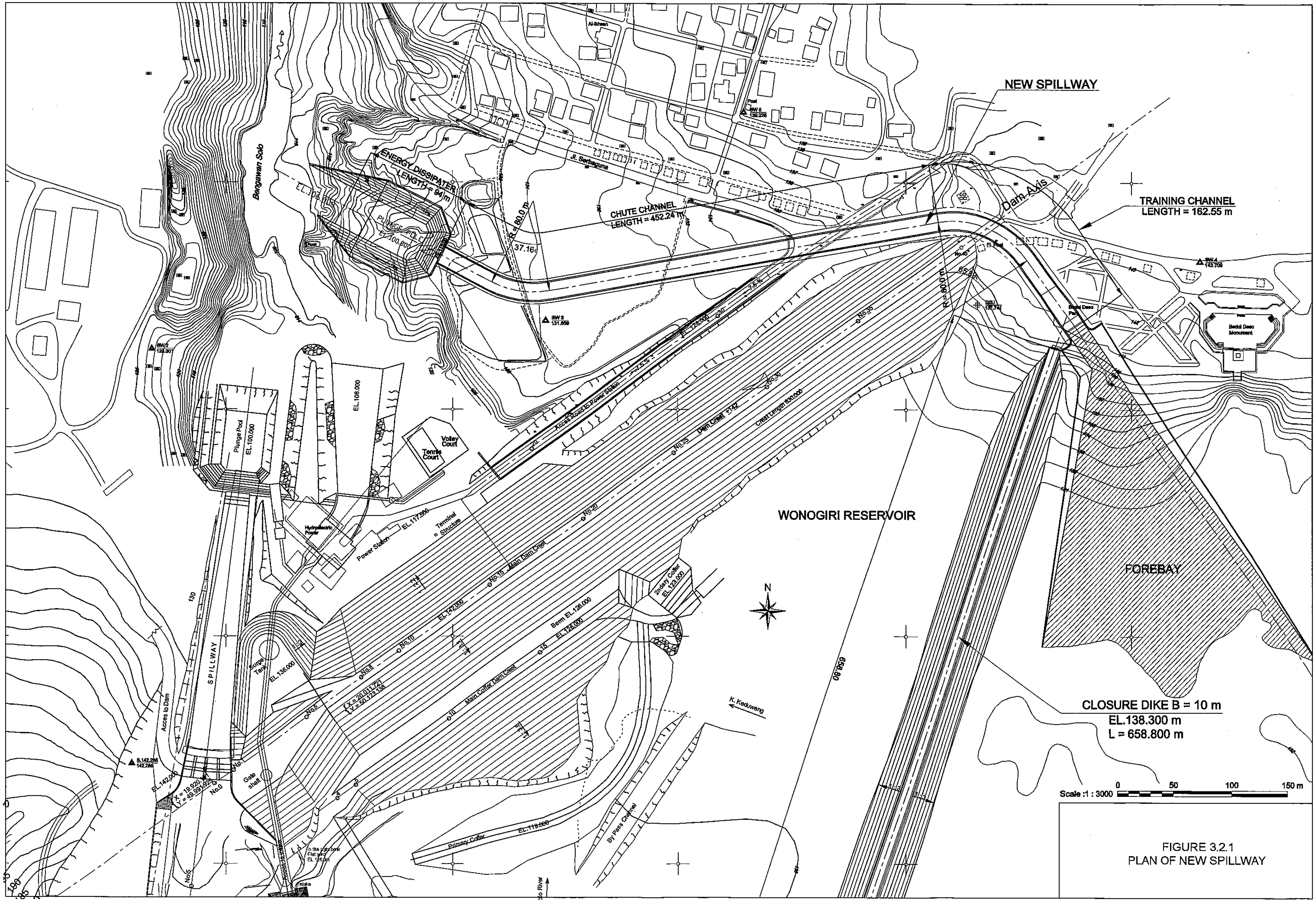
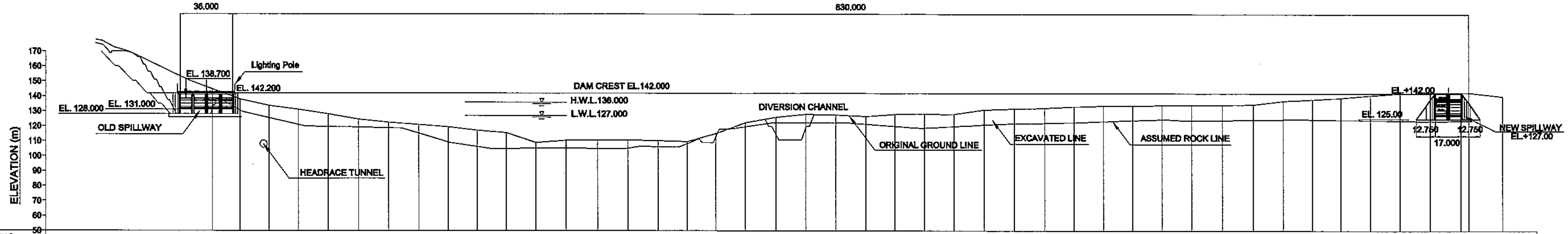
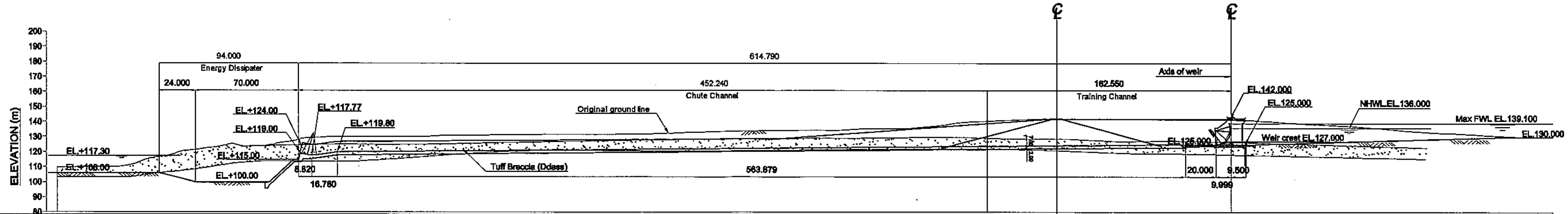


FIGURE 3.2.1
PLAN OF NEW SPILLWAY



STATION NO.	DISTANCE (m)	ACCUM. DISTANCE (m)	GROUND HEIGHT (m)	FORMATION HEIGHT (m)
0	0	0	145.000	
1	20	20	138.000	127.000
2	20	40	133.500	121.500
3	20	60	131.000	119.200
4	20	80	128.000	119.000
5	20	100	124.500	119.200
6	20	120	122.500	117.000
7	20	140	121.000	118.000
8	20	160	119.500	113.300
9	20	180	117.000	112.500
10	20	200	115.500	108.800
11	20	220	109.000	107.500
12	20	240	110.500	105.000
13	20	260	110.500	105.000
14	20	280	110.500	104.000
15	20	300	110.300	102.500
16	20	320	109.500	105.000
17	20	340	115.000	109.000
18	20	360	122.500	114.200
19	20	380	126.000	113.300
20	20	400	128.000	109.700
21	20	420	127.500	113.200
22	20	440	126.500	117.500
23	20	460	128.000	121.100
24	20	480	128.300	123.100
25	20	500	128.000	123.000
26	20	520	131.000	124.000
27	20	540	131.500	124.300
28	20	560	132.000	125.000
29	20	580	133.000	126.000
30	20	600	133.500	126.200
31	20	620	133.500	124.500
32	20	640	134.000	125.000
33	20	660	134.000	125.000
34	20	680	134.000	124.500
35	20	700	134.500	126.800
36	20	720	137.000	124.000
37	20	740	138.000	126.000
38	20	760	139.000	127.500
39	20	780	140.600	130.500
40	20	800	142.000	135.500
41	20	820	142.500	136.000
42	20	840	142.500	136.000
	5	845	142.500	141.500
	22.815	867.815	140.000	141.500

LONGITUDINAL PROFILE DAM CREST



DL. + 80.00

ORIGINAL GROUND LEVEL (EL. m)	ACCUM. DISTANCE (m)	DISTANCE (m)
109.76	0.00	
		39.21
110.00	39.21	
		6.99
108.00	48.20	
		4.11
112.00	50.31	
		7.16
115.00	57.46	
		9.74
117.00	67.20	
		12.11
120.00	79.31	
		24.02
123.14	103.33	
		10.59
125.38	113.92	
		1.64
		7.90
123.48	123.87	
		13.42
124.00	137.09	
		6.83
125.00	143.92	
		18.40
129.00	162.32	
		17.52
130.00	179.84	
		61.03
130.00	240.87	
		155.58
132.18	396.45	
		172.86
136.00	569.31	
		32.94
139.68	602.25	
		50.33
142.00	652.58	
		41.56
142.00	694.13	
		85.70
141.18	779.83	
		82.53
138.00	842.36	
		108.25
131.00	950.61	
		19.91
130.00	970.52	

FORMATION HEIGHT (m) (Top Wall)	FORMATION HEIGHT (m) (Floor)	DISTANCE (m)
126.06	119.00	0.00
		14.79
126.08	119.00	19.48
		50.00
127.23	120.32	69.48
		50.00
127.55	120.77	119.48
		50.00
127.86	121.22	169.48
		50.00
128.18	121.67	219.48
		50.00
128.50	122.12	269.48
		50.00
128.82	122.57	319.48
		50.00
132.47	123.02	369.48
		50.00
136.11	123.47	419.48
		50.00
139.76	123.92	469.48
		33.26
142.00	124.22	502.74
		16.74
142.00	124.37	519.48
		50.00
142.00	124.82	569.48
		50.00
142.00	125.00	619.48

LONGITUDINAL PROFILE OF NEW SPILLWAY

SCALE 1 : 3000 0 20 40 60 80 100 m

FIGURE 3.2.2
PROFILE OF NEW SPILLWAY

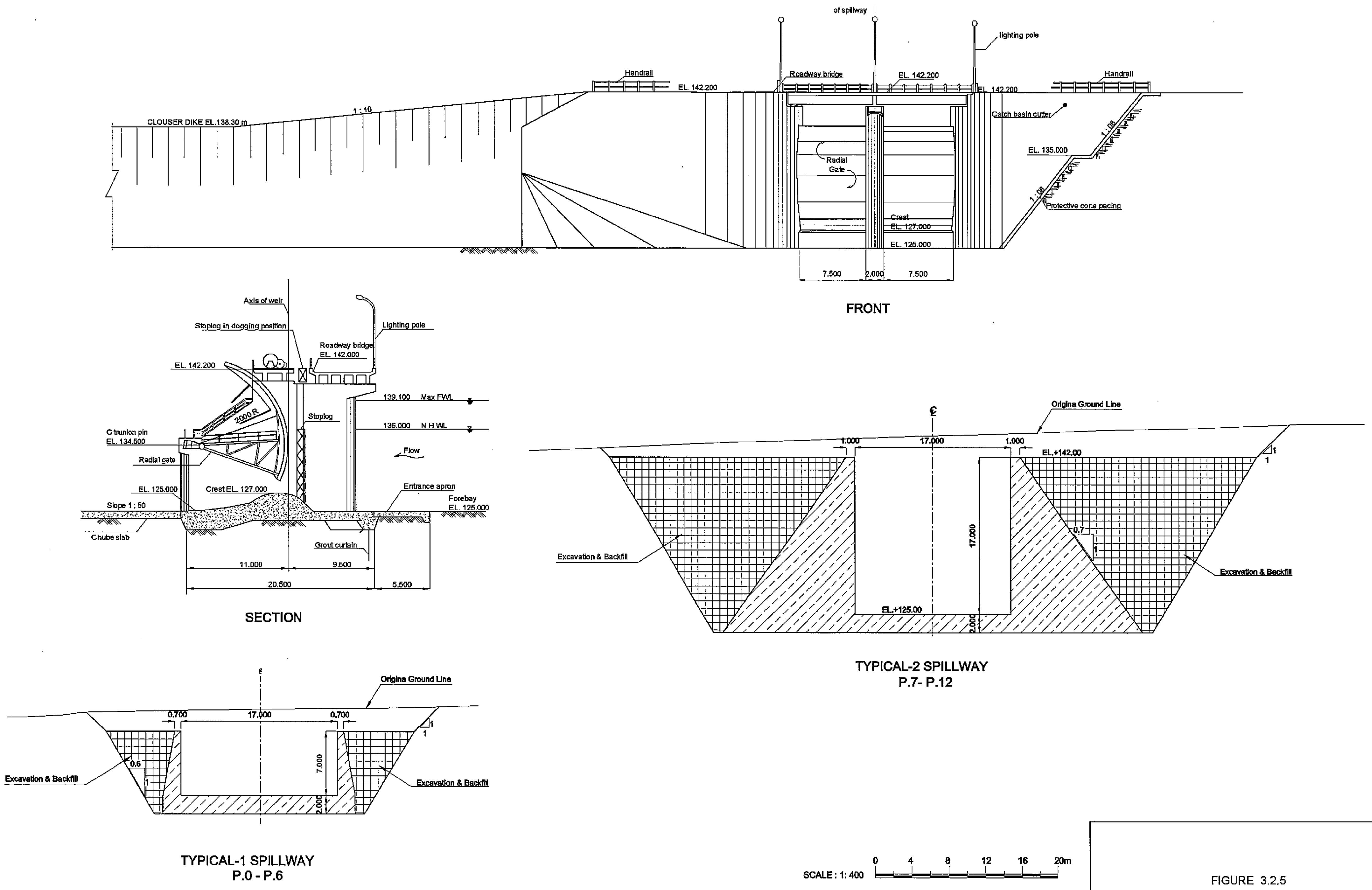
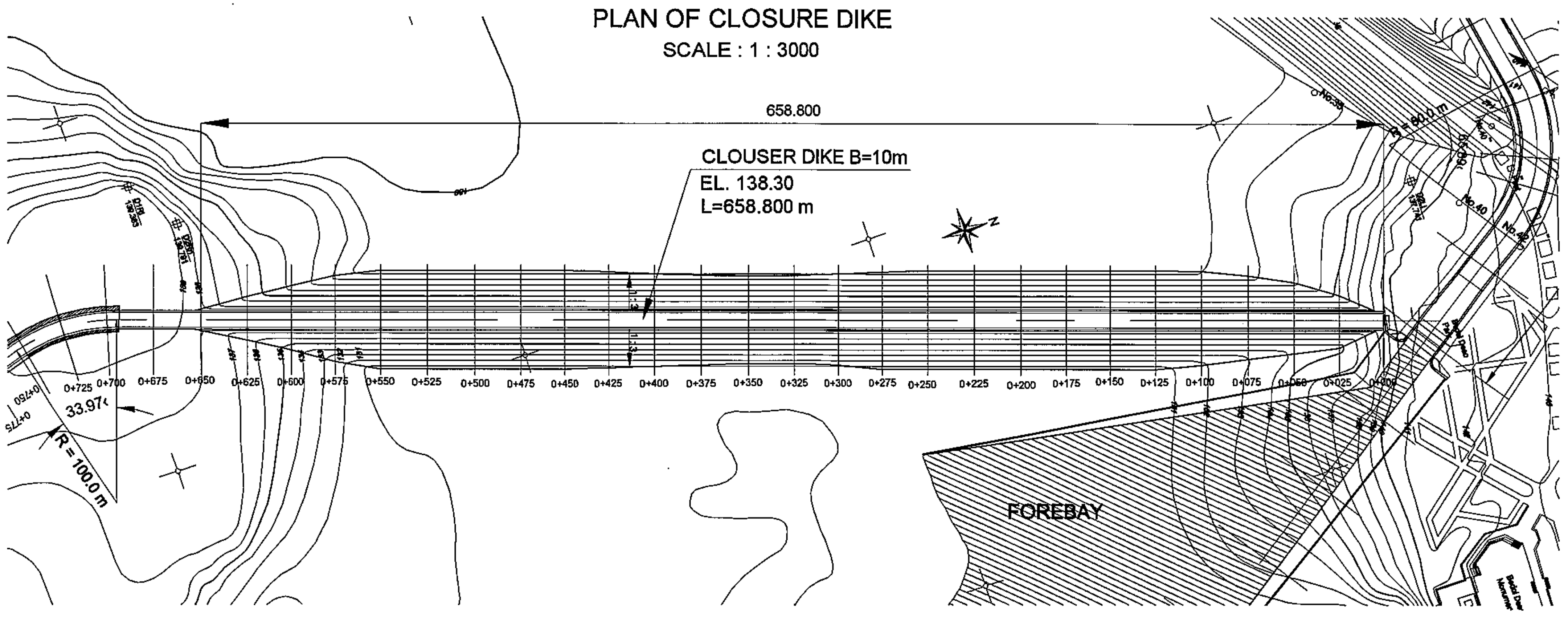
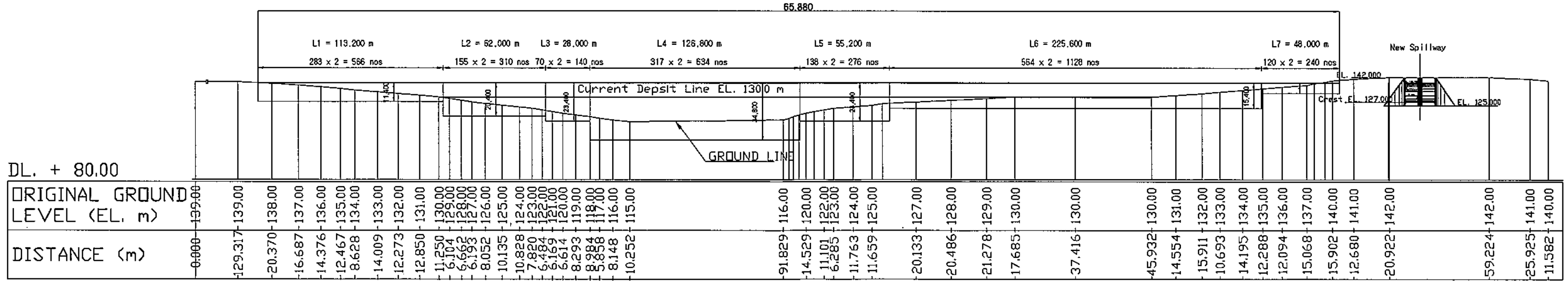


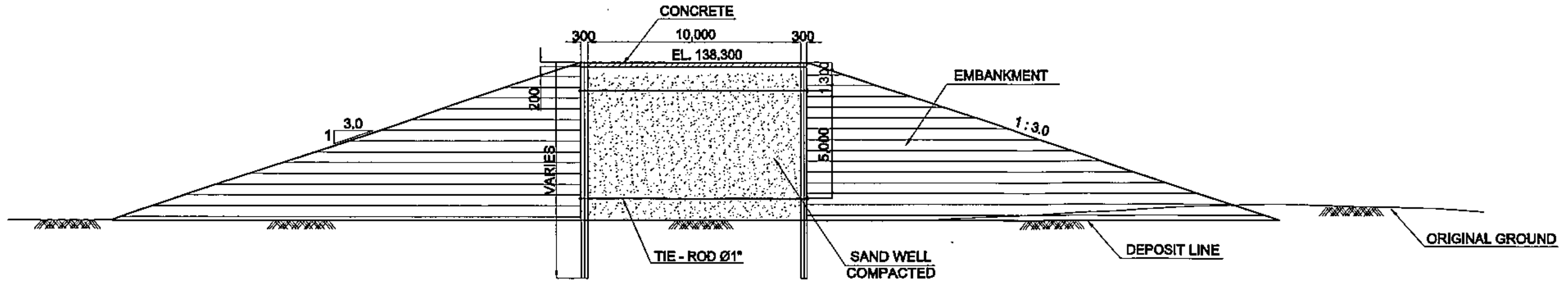
FIGURE 3.2.5
NEW GATE AND TYPICAL CROSS SECTION
OF SPILLWAY





ORIGINAL GROUND LEVEL (EL. m)	DISTANCE (m)
139.00	0.000
139.00	129.317
138.00	20.370
137.00	16.687
136.00	14.376
135.00	12.467
134.00	8.628
133.00	14.009
132.00	12.273
131.00	12.850
130.00	11.250
129.00	6.104
128.00	6.662
127.00	6.193
126.00	8.052
125.00	10.135
124.00	10.828
123.00	7.820
122.00	6.484
121.00	6.169
120.00	6.614
119.00	8.293
118.00	8.984
117.00	5.858
116.00	8.148
115.00	10.252
116.00	91.829
120.00	14.529
122.00	11.101
123.00	6.285
124.00	11.763
125.00	11.659
127.00	20.133
128.00	20.486
129.00	21.278
130.00	17.685
130.00	37.416
130.00	45.932
131.00	14.554
132.00	15.911
133.00	10.693
134.00	14.195
135.00	12.288
136.00	12.094
137.00	15.068
140.00	15.902
141.00	12.680
142.00	20.922
142.00	59.224
141.00	25.925
140.00	11.582

LONGITUDINAL PROFILE OF CLOUSER DIKE
Scale : 1 : 2500



TYPICAL CROSS SECTION
Scale : 1 : 300

Scale : 1 : 2500 0 10 20 40 60 80 100 m

FIGURE 3.3.1
PLAN AND STRUCTURE OF CLOUSER DIKE

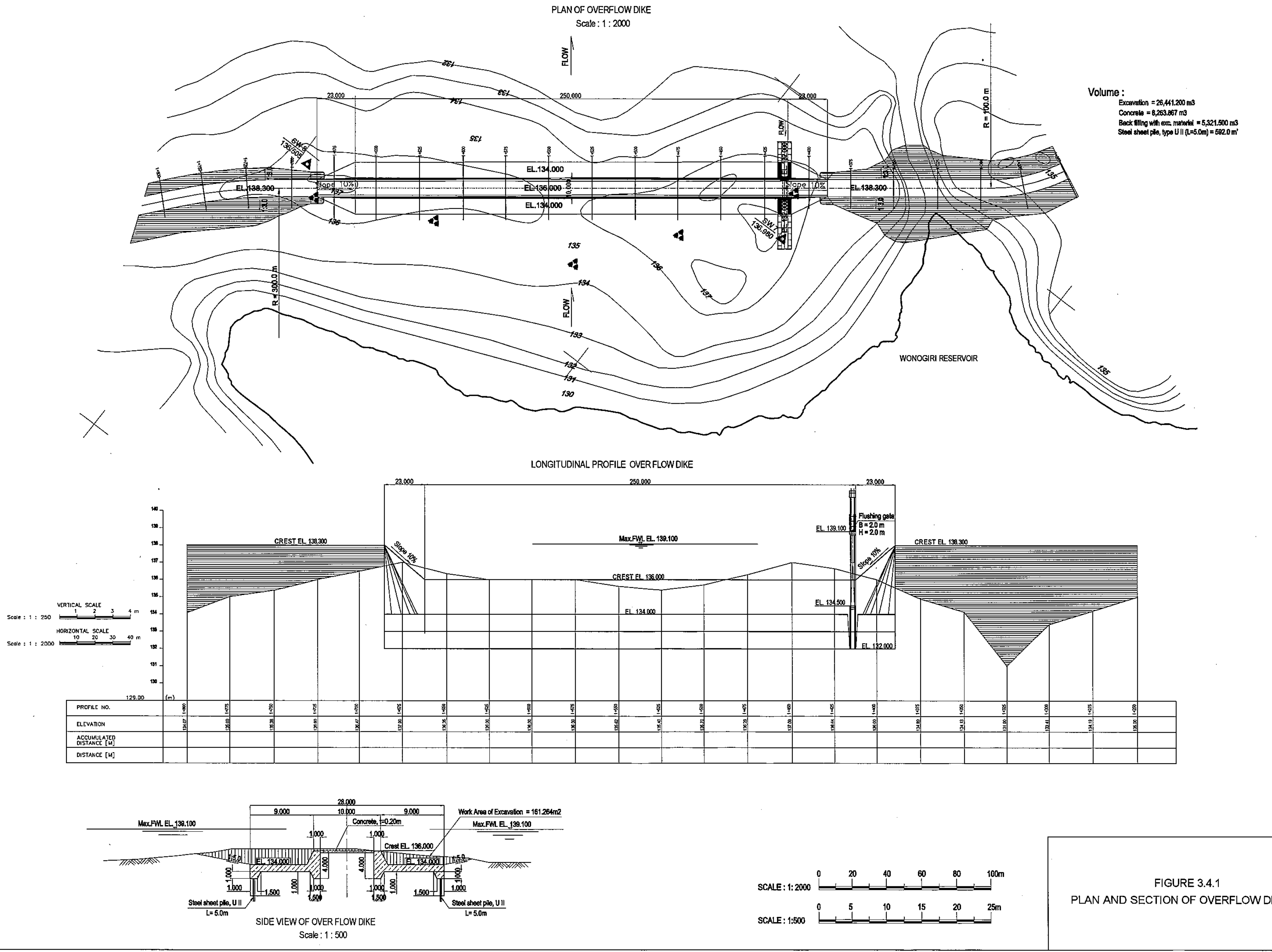


FIGURE 3.4.1
PLAN AND SECTION OF OVERFLOW DIKE

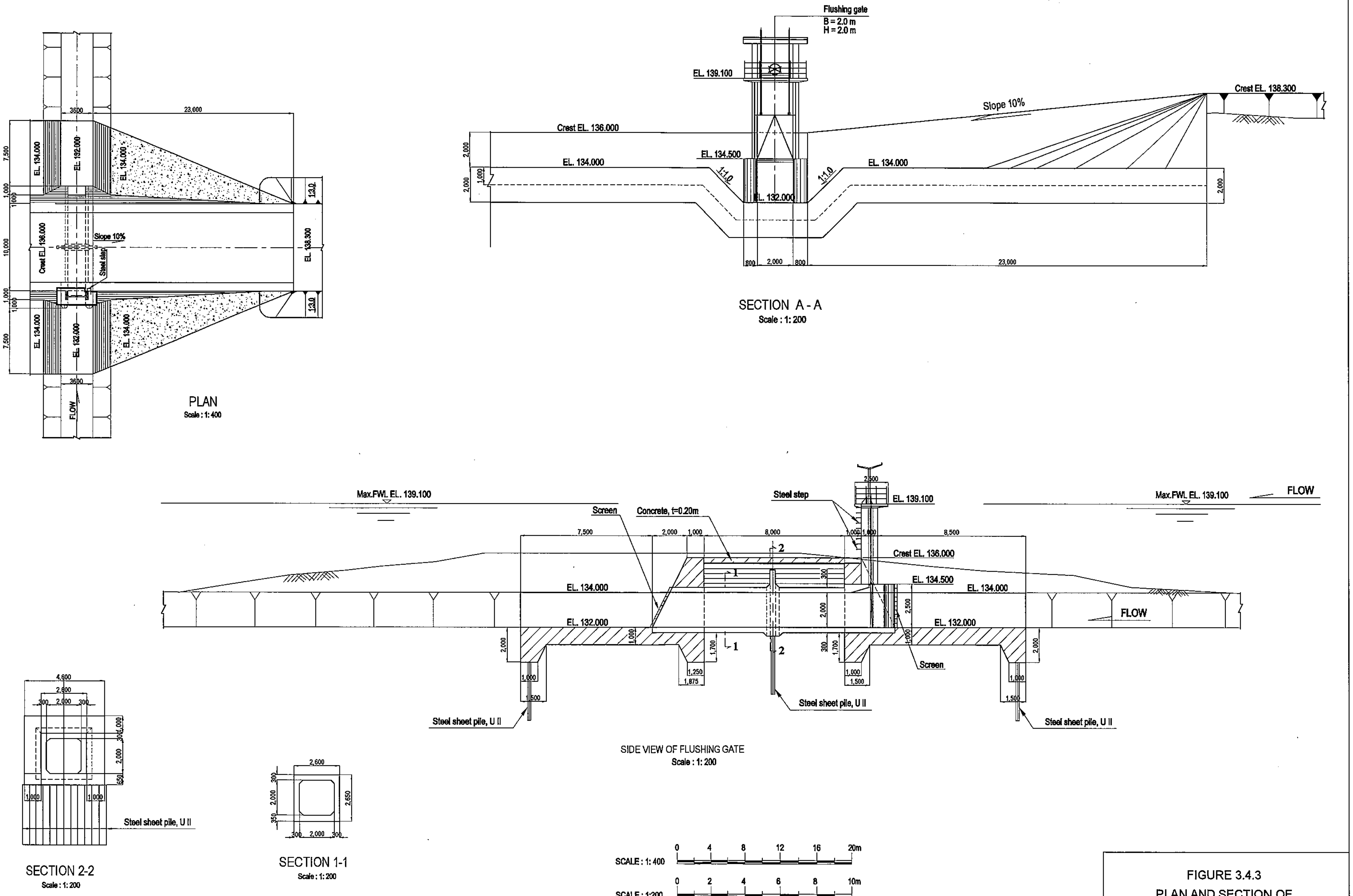


FIGURE 3.4.3
PLAN AND SECTION OF
CONNECTING CONDUIT

Attachment 1

Quantity Calculation (New Spillway)

Volume Excavation & Embankment (Backfill) Spillway

No. Station	Distance	Acc. Distance	Area			Quantity					
			Excavation	Concrete	Backfill	Excavation	Cum. Excavation	Backfill	Cum. Backfill	Concrete	Cum. Concrete
	(m)	(m)	(m²)		(m²)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)
P.0	0	0	333.34	56.90	75.70	-	-	-	-	-	-
P.0+14.79	14.79	14.79	366.04	56.90	75.70	5,171.92	5,171.92	1,119.60	1,119.60	841.55	841.55
P.1	50	64.79	342.22	56.66	74.44	17,706.50	22,878.42	3,753.50	4,873.10	2,839.00	3,680.55
P.2	50	114.79	359.26	56.31	72.62	17,537.00	40,415.42	3,676.50	8,549.60	2,824.25	6,504.80
P.3	50	164.79	353.59	55.93	70.70	17,821.25	58,236.67	3,583.00	12,132.60	2,806.00	9,310.80
P.4	50	214.79	348.96	55.58	68.94	17,563.75	75,800.42	3,491.00	15,623.60	2,787.75	12,098.55
P.5	50	264.79	387.90	55.23	67.18	18,421.50	94,221.92	3,403.00	19,026.60	2,770.25	14,868.80
P.6	50	314.79	409.78	54.88	65.46	19,942.00	114,163.92	3,316.00	22,342.60	2,752.75	17,621.55
P.7	50	364.79	606.80	144.67	193.34	25,414.50	139,578.42	6,470.00	28,812.60	4,988.75	22,610.30
P.8	50	414.79	746.64	209.31	293.26	33,836.00	173,414.42	12,165.00	40,977.60	8,849.50	31,459.80
P.9	50	464.79	1,123.85	288.47	449.42	46,762.25	220,176.67	18,567.00	59,544.60	12,444.50	43,904.30
P.10	50	514.79	1,204.21	352.40	552.00	58,201.50	278,378.17	25,035.50	84,580.10	16,021.75	59,926.05
P.11	50	564.79	1,077.14	325.87	492.94	57,033.75	335,411.92	26,123.50	110,703.60	16,956.75	76,882.80
P.12	50	614.79	1,010.31	320.70	463.25	52,186.25	387,598.17	23,904.75	134,608.35	16,164.25	93,047.05
Total	614.79					387,598.17		134,608.35		93,047.05	

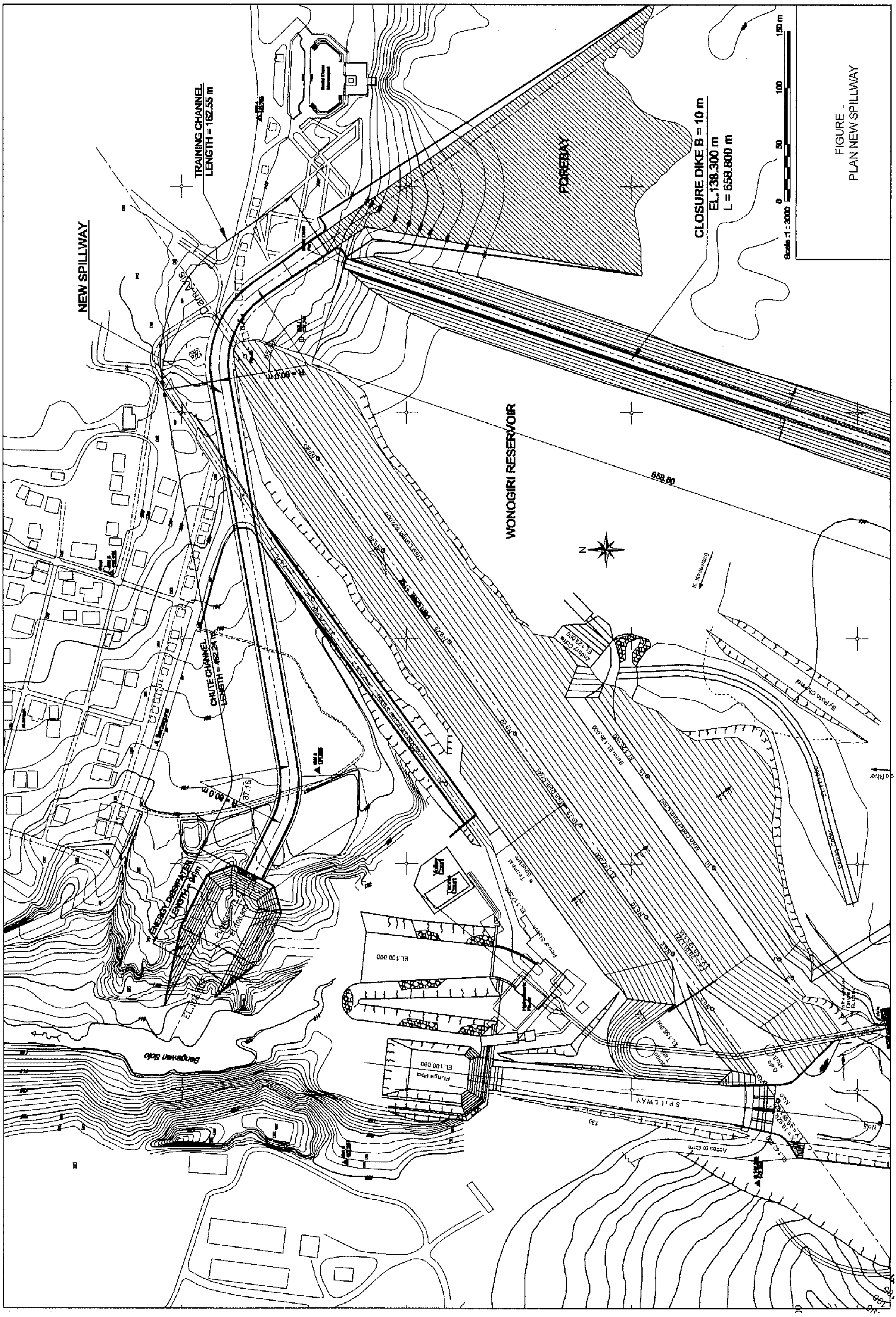
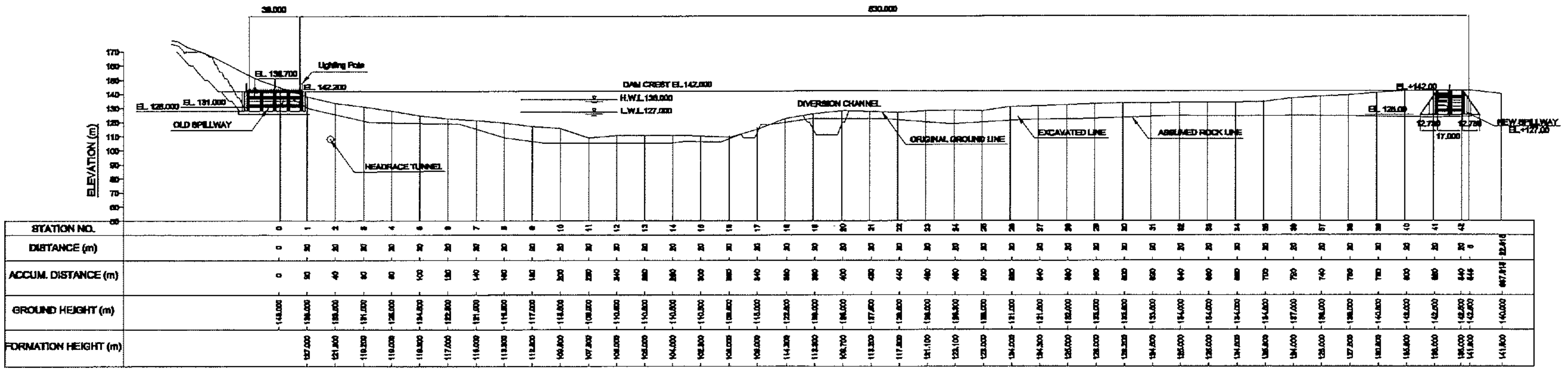
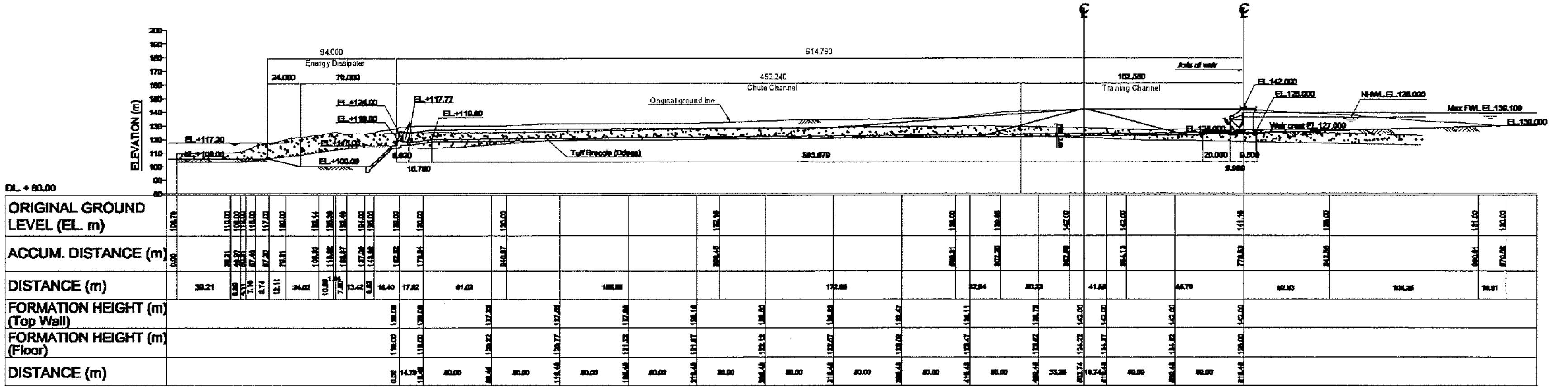


FIGURE .
PLAN NEW SPILLWAY



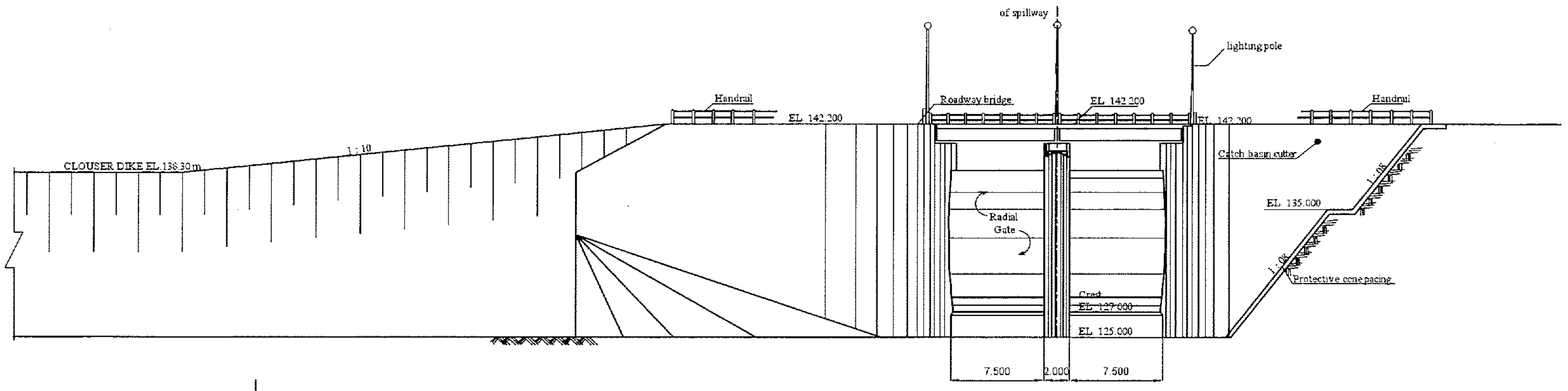
LONGITUDINAL PROFILE DAM CREST



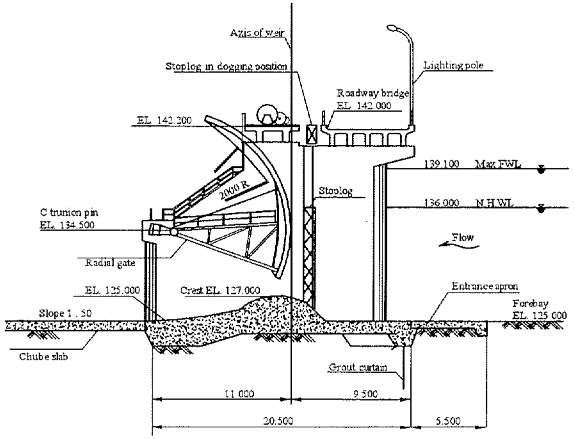
LONGITUDINAL PROFILE OF NEW SPILLWAY

SCALE 1 : 3000 0 20 40 60 80 100 m

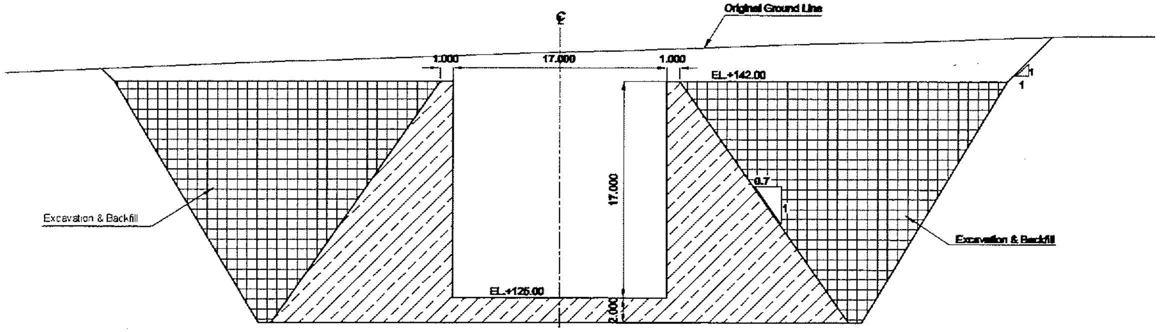
FIGURE
PROFILE OF NEW SPILLWAY



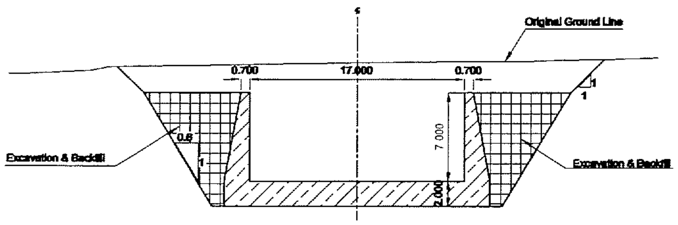
FRONT



SECTION B-B



TYPICAL-2 SPILLWAY
P.7- P.12

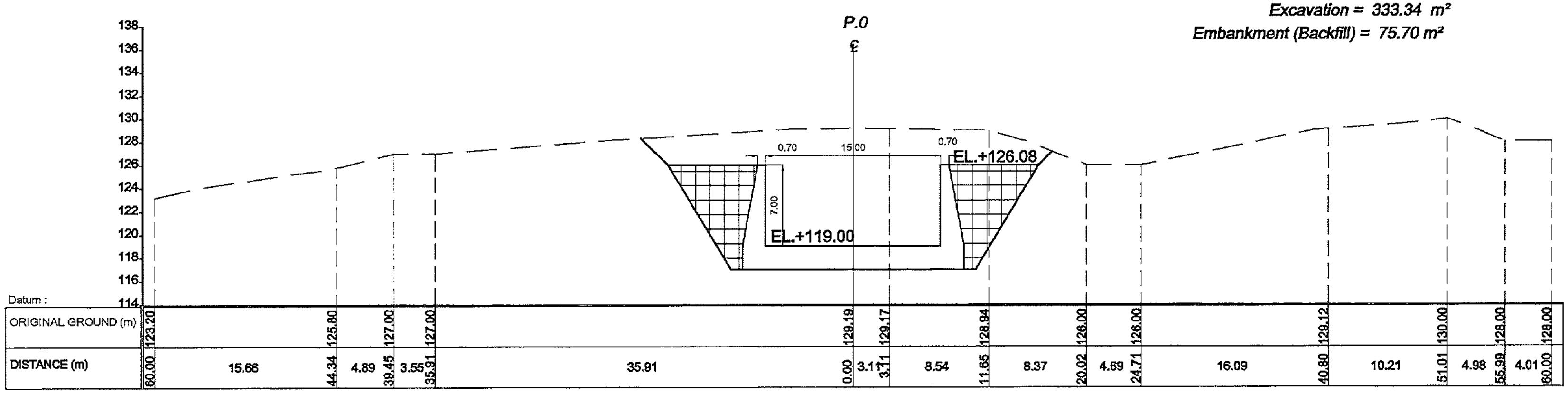


TYPICAL-1 SPILLWAY
P.0 - P.6

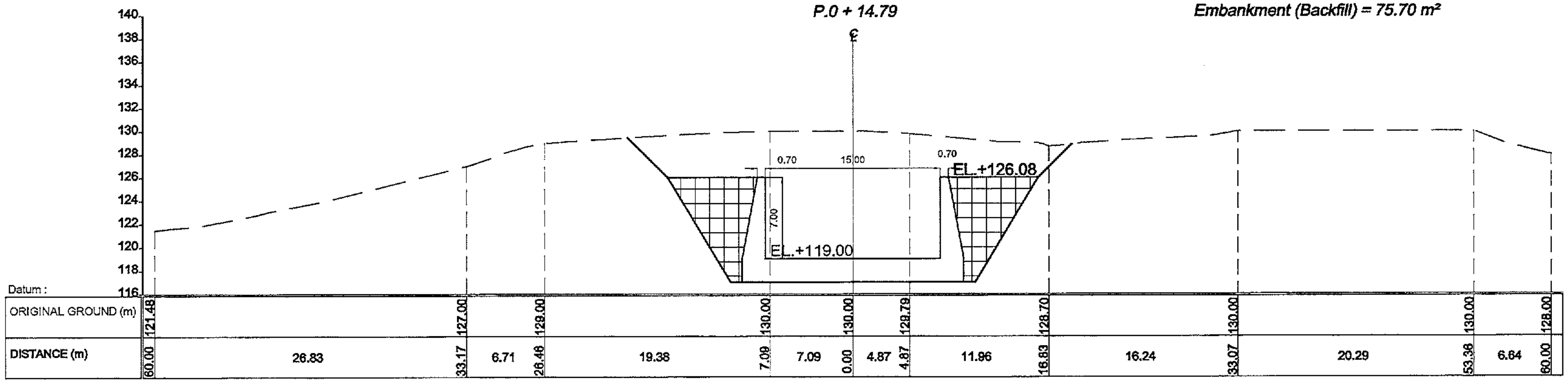
SCALE : 1: 400

FIGURE
GATE AND TYPICAL CROSS SECTION

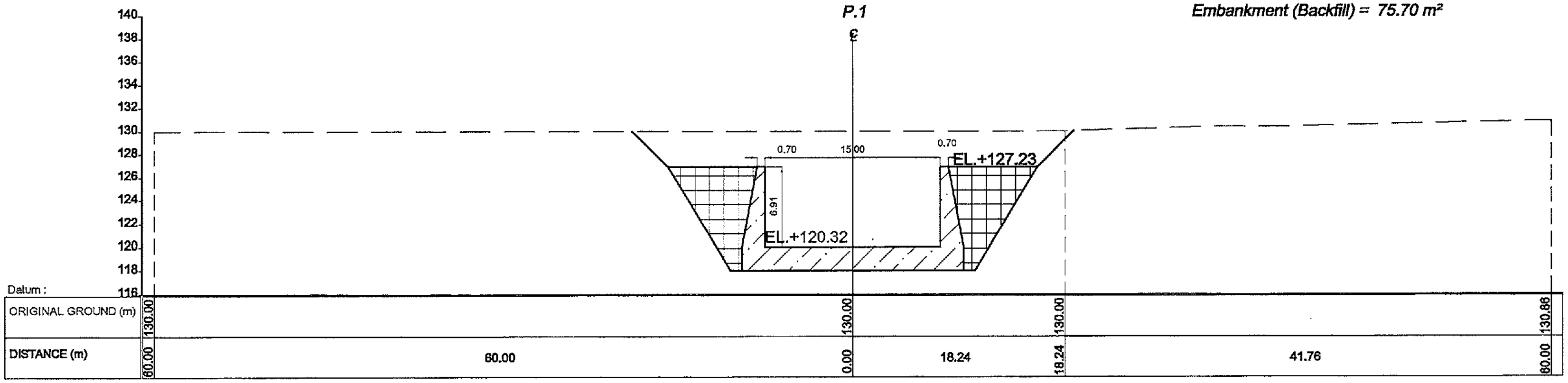
Excavation = 333.34 m²
Embankment (Backfill) = 75.70 m²



Excavation = 366.04 m²
Embankment (Backfill) = 75.70 m²



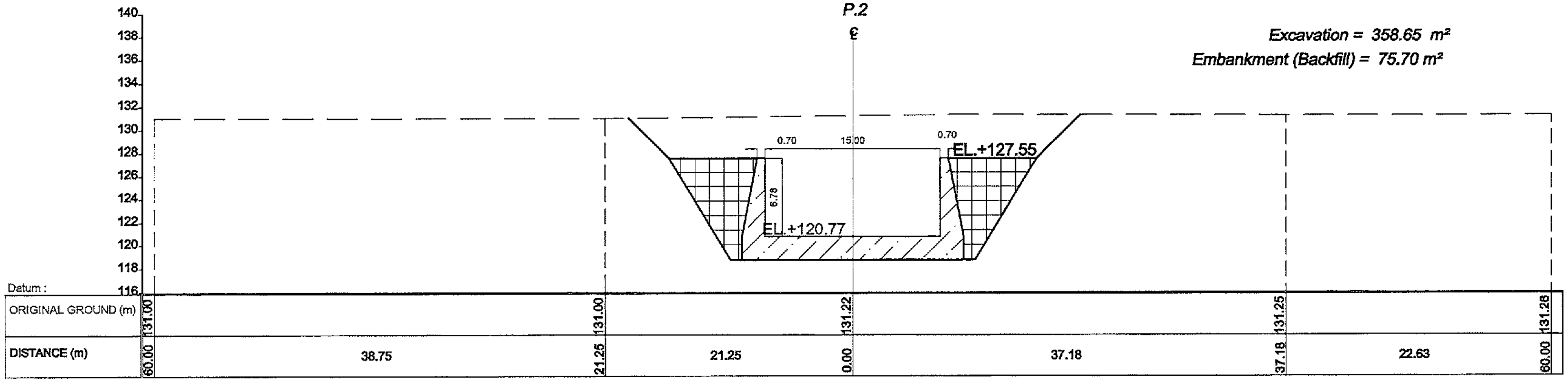
Excavation = 342.01 m²
Embankment (Backfill) = 75.70 m²



Scale : 1:200 0 2 4 6 8 10 12 16 20 m

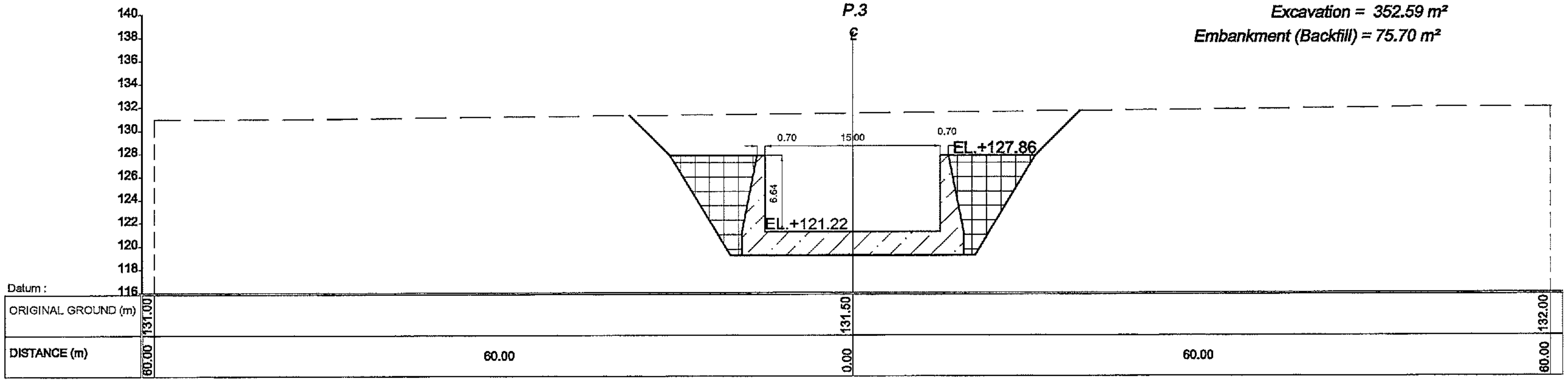
CROSS SECTION SPILLWAY

P.2



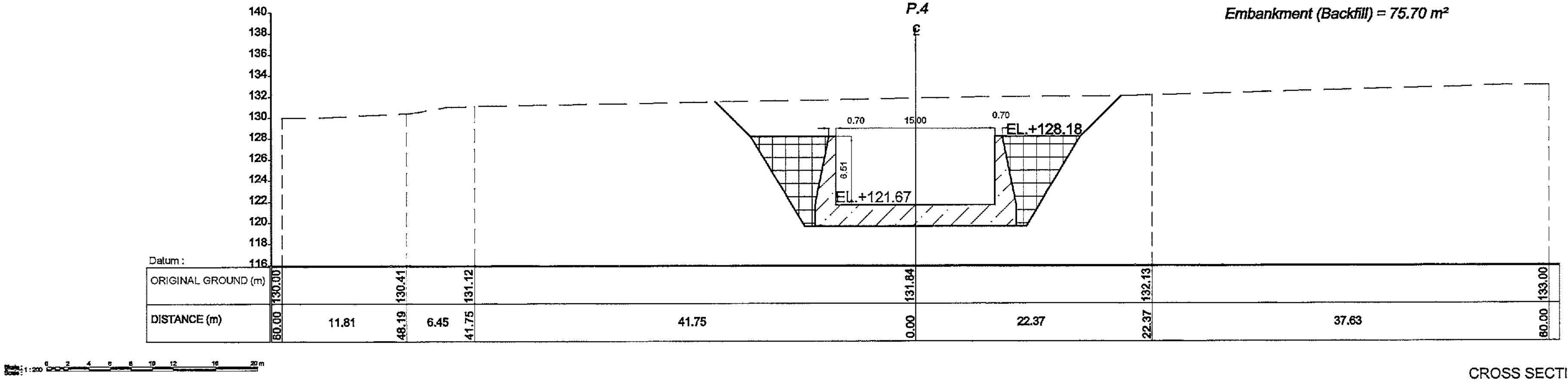
Excavation = 358.65 m²
Embankment (Backfill) = 75.70 m²

P.3



Excavation = 352.59 m²
Embankment (Backfill) = 75.70 m²

P.4

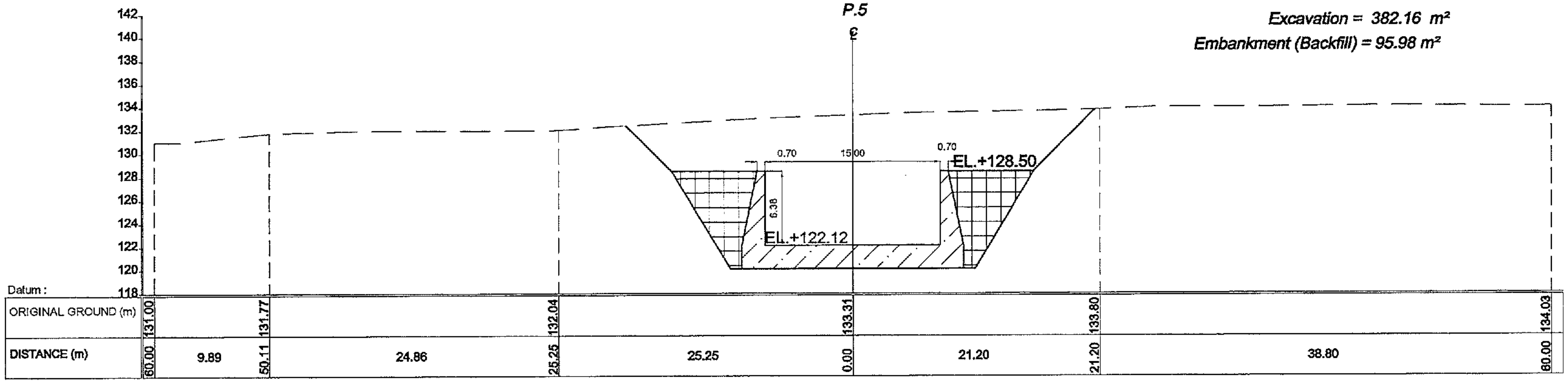


Excavation = 347.65 m²
Embankment (Backfill) = 75.70 m²

CROSS SECTION SPILLWAY

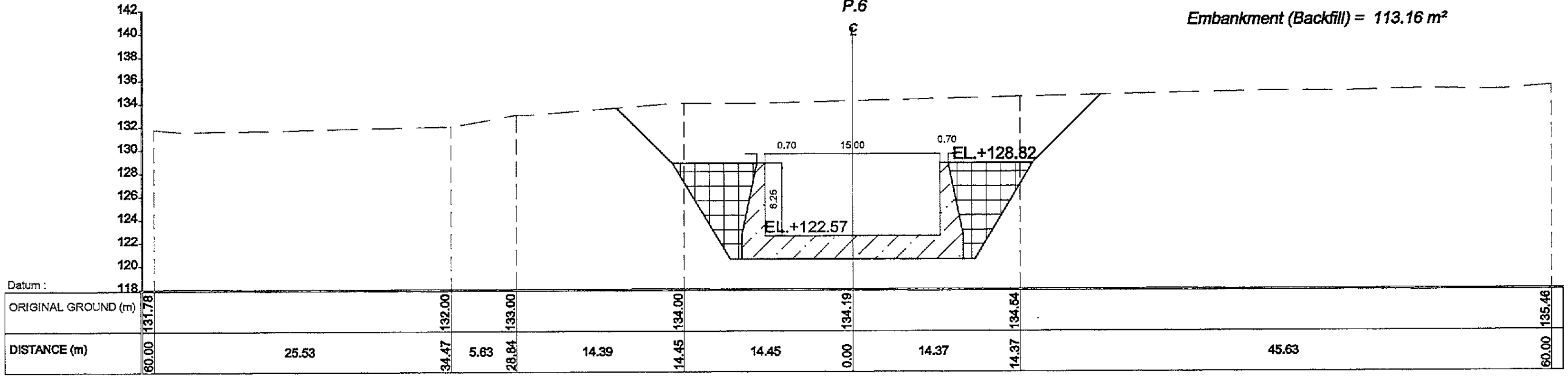
P.5

Excavation = 382.16 m²
Embankment (Backfill) = 95.98 m²



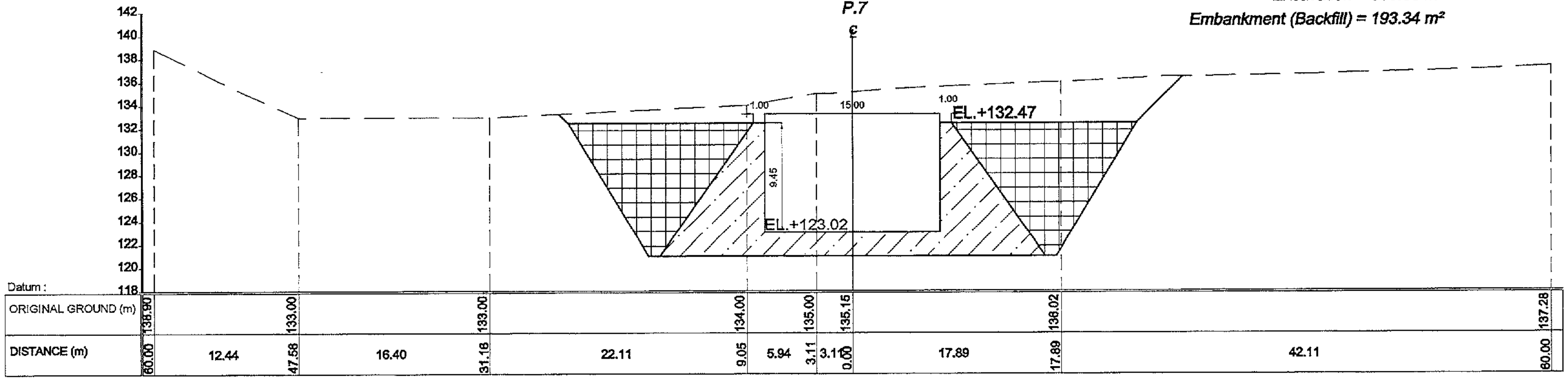
P.6

Excavation = 400.26 m²
Embankment (Backfill) = 113.16 m²



P.7

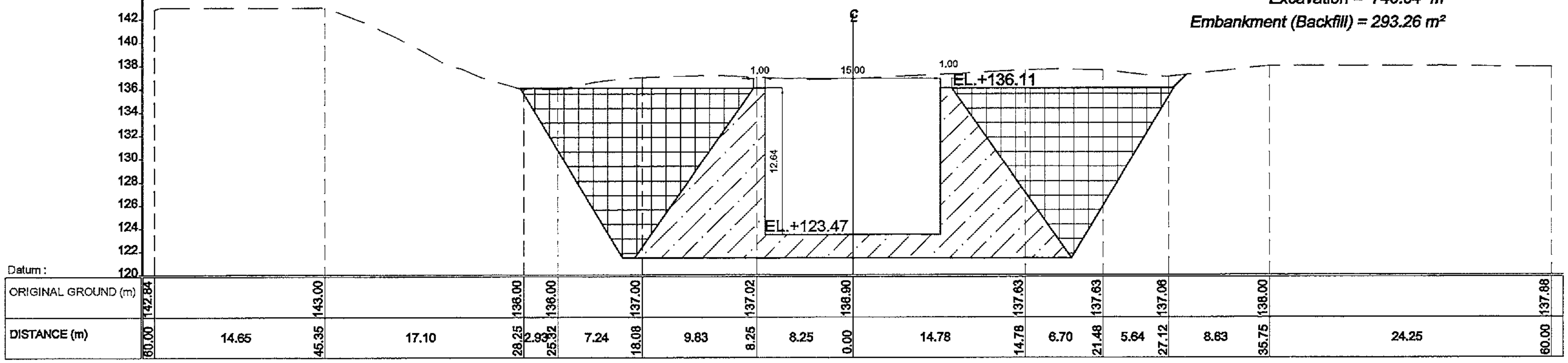
Excavation = 606.80 m²
Embankment (Backfill) = 193.34 m²



CROSS SECTION SPILLWAY

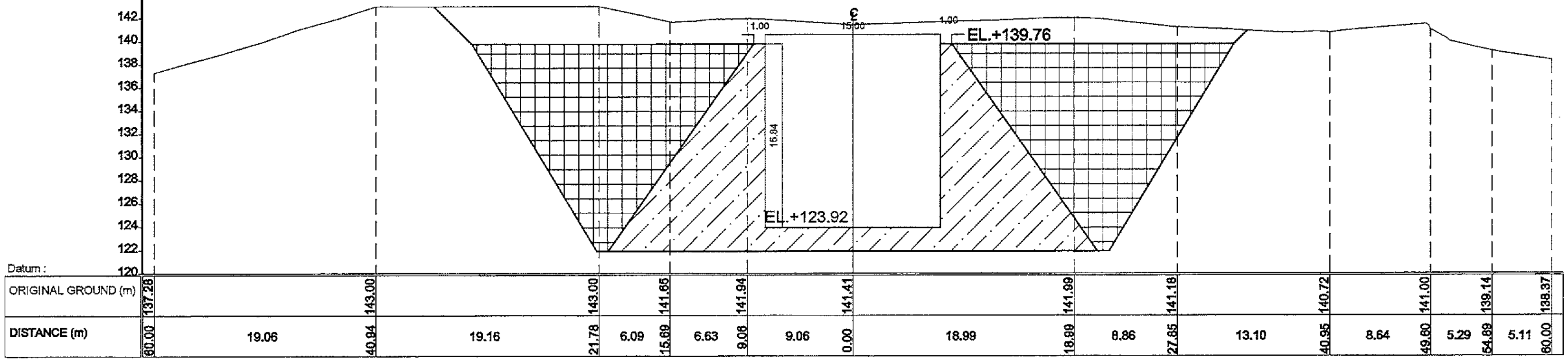
P.8

Excavation = 746.64 m²
Embankment (Backfill) = 293.26 m²



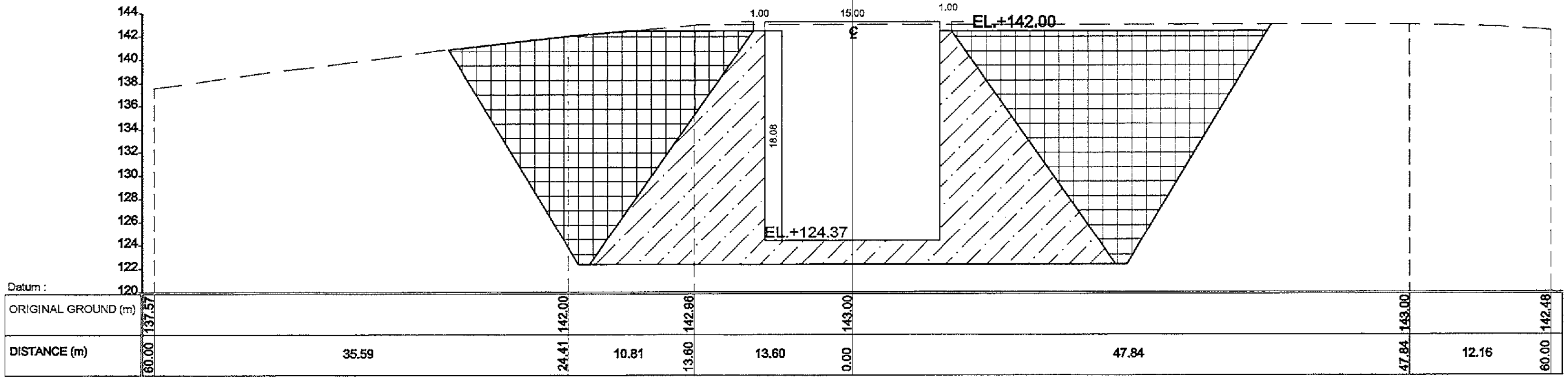
P.9

Excavation = 1,123.85 m²
Embankment (Backfill) = 449.42 m²



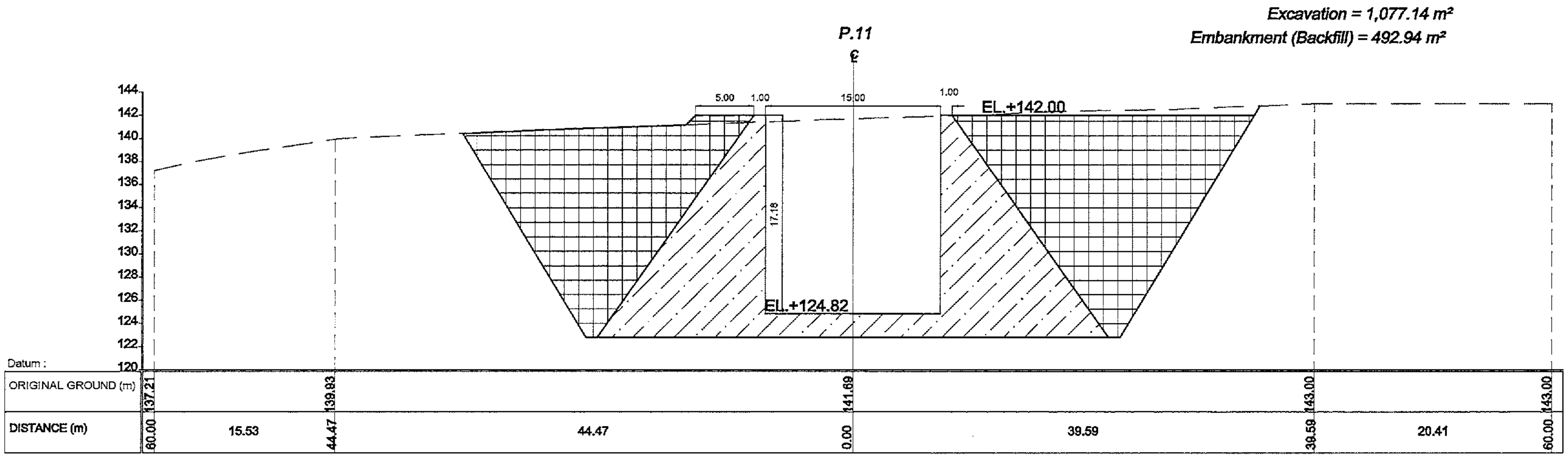
P.10

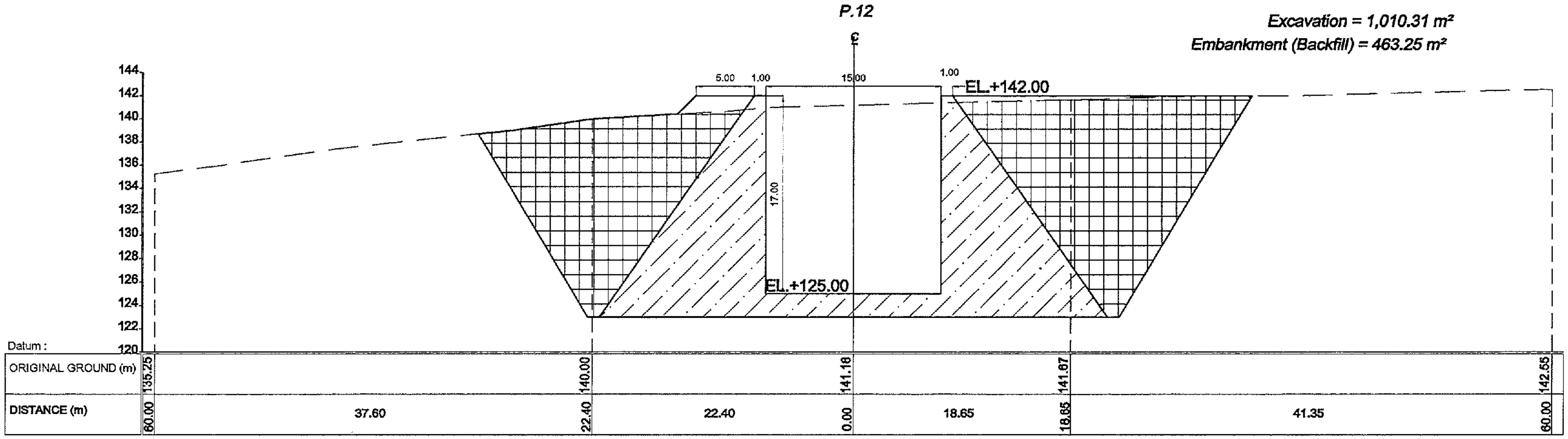
Excavation = 1,204.21 m²
Embankment (Backfill) = 552.00 m²



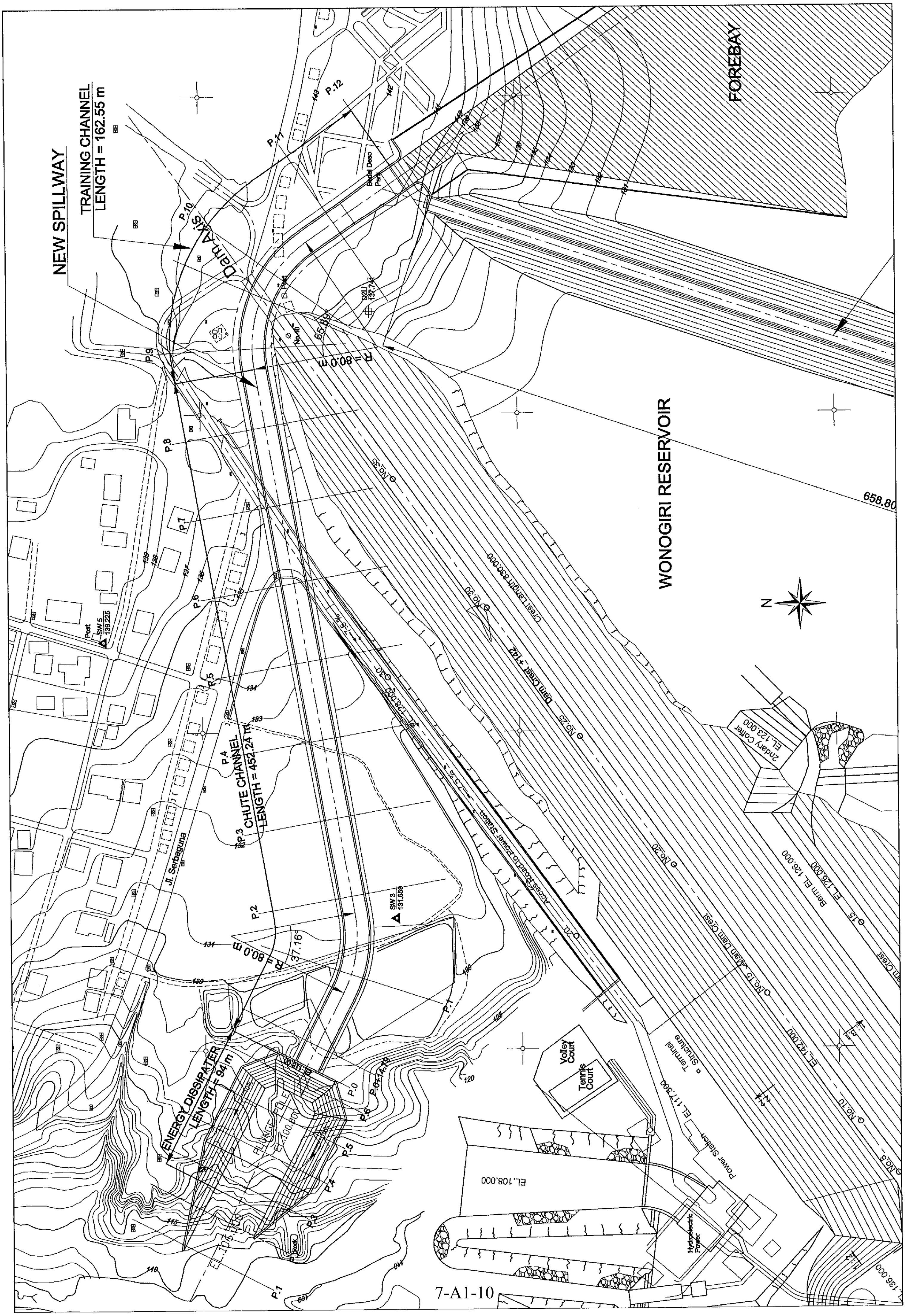
Scale 1 : 200

CROSS SECTION SPILLWAY

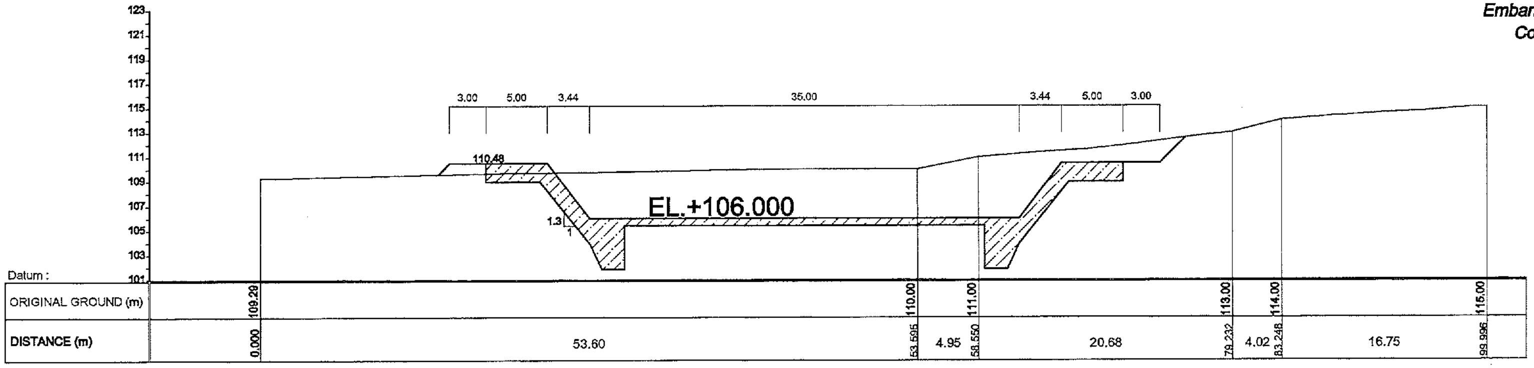




CROSS SECTION SPILLWAY

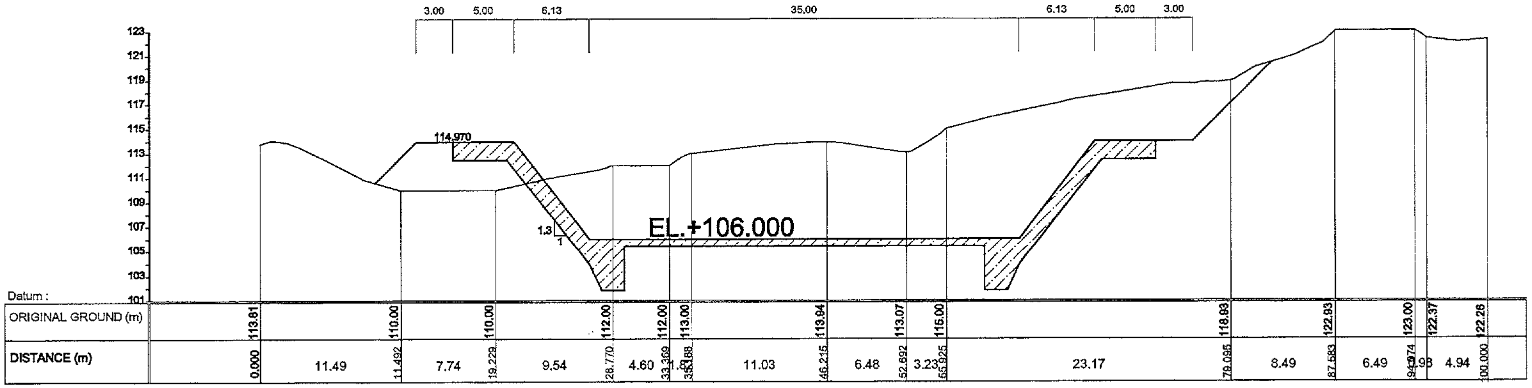

NEW SPILLWAY
TRAINING CHANNEL
LENGTH = 162.55 m
FOREBAY
WONOGIRI RESERVOIR
Dam Axis
R = 80.0 m
65.89°
658.80
CHUTE CHANNEL
LENGTH = 452.24 m
R = 80.0 m
37.16°
ENERGY DISSIPATER
LENGTH = 94 m
PLUNGE POOL
EL.100.000
EL.106.000
Crest Length 830.000
Dam Crest +142
Access Road to Power Station
Jl. Serbaguna
Post
SW 5
139.225
SW 3
131.659
P.1
P.2
P.3
P.4
P.5
P.6
P.8
P.9
P.10
P.11
P.12
P.0
No.40
No.35
No.30
No.25
No.20
No.15
No.10
No.8
2ndary Coffer
EL.123.000
Berm EL.126.000
EL.126.000
Main Dam Crest
EL.142.000
EL.136.000
Volley Court
Tennis Court
Terminal Structure
EL.117.500
Power Station
Hydroelectric Power
EL.108.000
Balai Desa Park
N

Excavation Area = 173.460 m²
Embankment Area = 3.170 m²
Concrete Area = 73.26 m²



P.1

Excavation Area = 367.820 m²
Embankment Area = 29.04 m²
Concrete Area = 84.930 m²

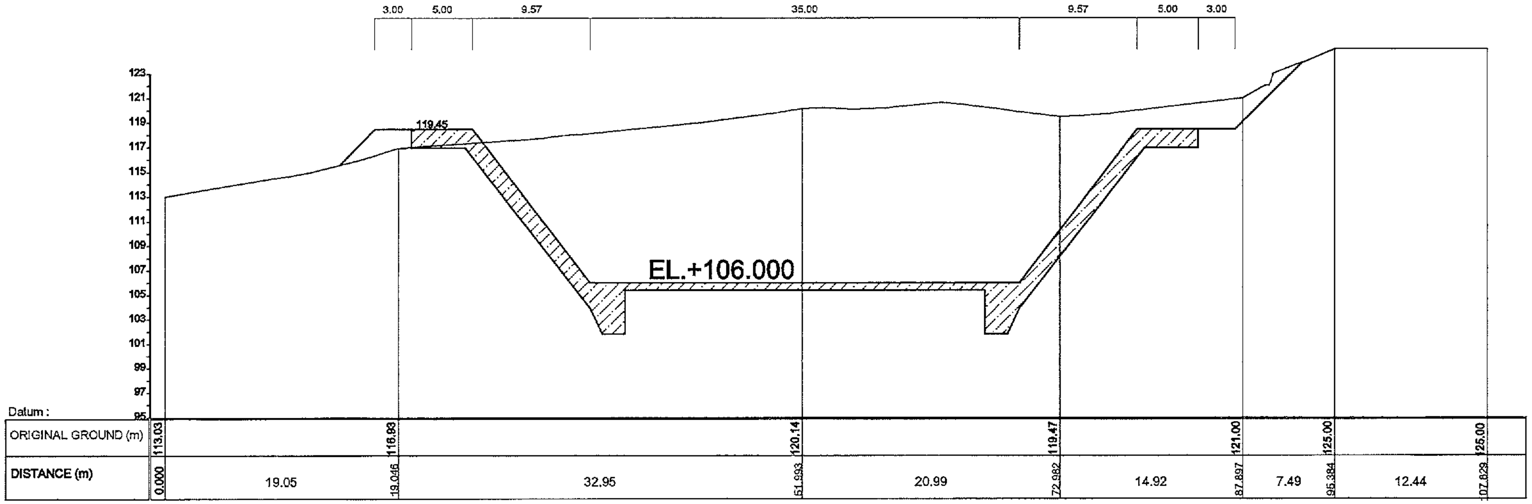


P.2

Skala : 1 : 500 0 2 4 6 8 10 12 16 20 m
Scale :

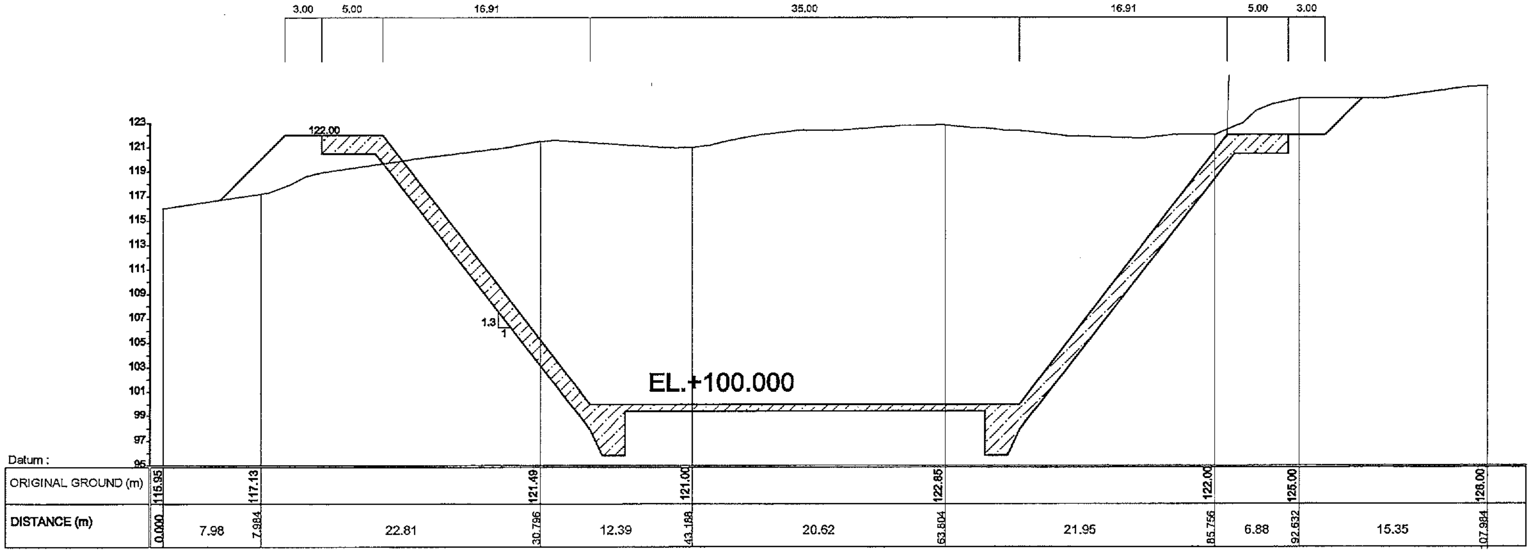
CROSS SECTION OF DISSIPATER

Excavation Area = 624.840 m²
Embankment Area = 25.570 m²
Concrete Area = 96.20 m²



P.3

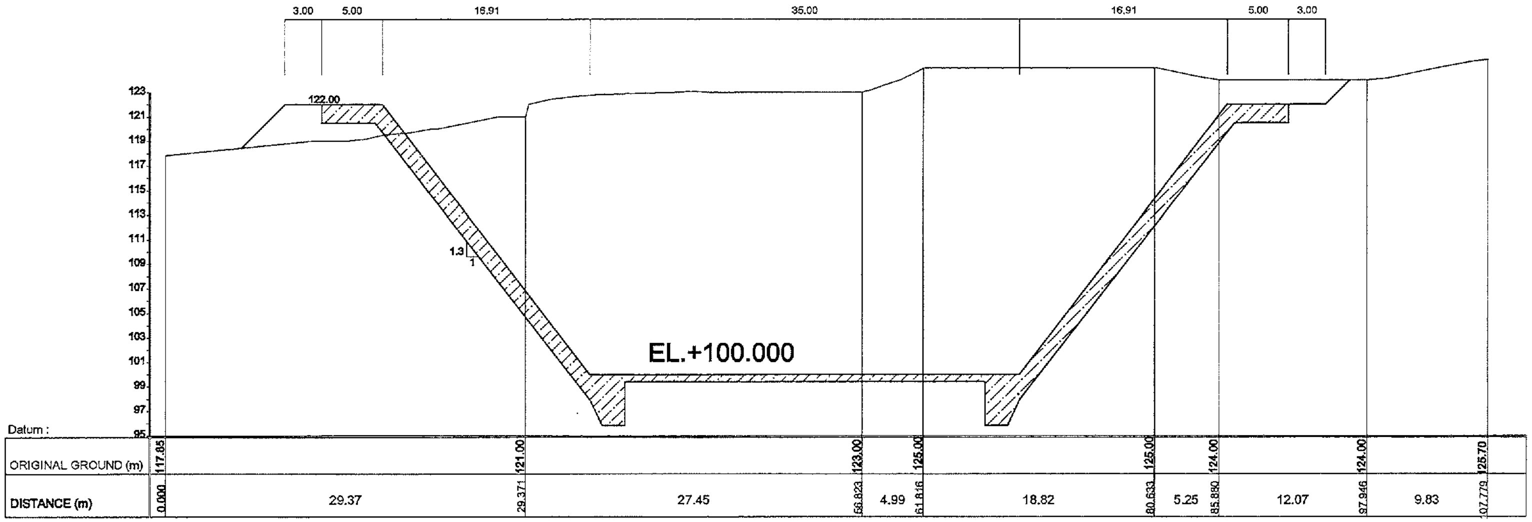
Excavation Area = 1,146.550 m²
Embankment Area = 37.550 m²
Concrete Area = 131.840 m²



P.4

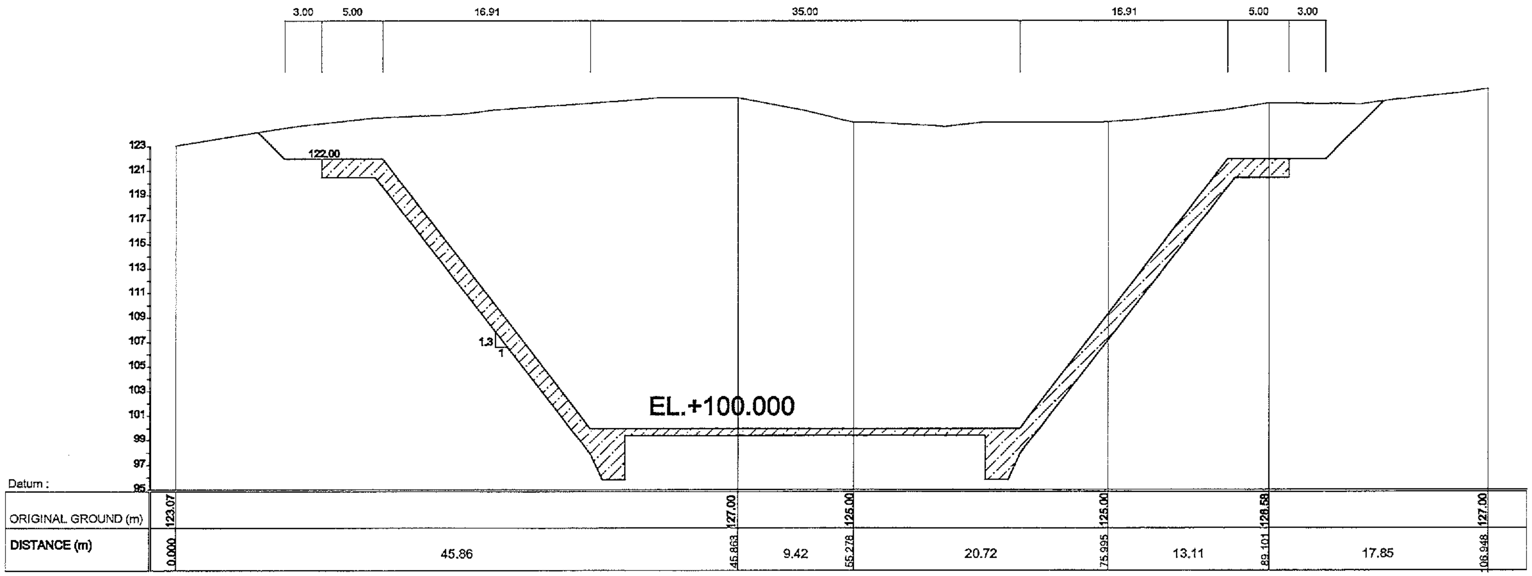
Skala : 1 : 500 0 2 4 6 8 10 12 16 20 m
Scale :

CROSS SECTION OF DISSIPATER



Excavation Area = 1,246.700 m²
Embankment Area = 24.630 m²
Concrete Area = 131.840 m²

P.5



Excavation Area = 1,472.580 m²
Concrete Area = 131.840 m²

P.6

Skala : 1 : 500
Scale :

CROSS SECTION OF DISSIPATER