CHAPTER IV BASIC DESIGN OF CONVEYANCE CANAL

CHAPTER 4 BASIC DESIGN OF CONVEYANCE CANAL AND

4.1 Design Concepts of Conveyance Canal

The project facilities of the conveyance canal that is included in the civil works are as follows;

1) The conveyance canal of 46 km long that leads from KM 86.5 of the Shikh Gaber El Sabah Canal to the northwestern end of the beneficial area so called the El Sir & El Kawareer Zone. The conceptual profile of the conveyance canal is shown in Figure 4.1-1.

   There is no beneficial area commanded between the beginning point and end point of the conveyance canal, and naturally no turnout and no check structure is provided. The beneficial area is planned to be developed in two stages. The required discharge of the Stage I is 32.48 m^3/sec and the required discharge of the full development in Stage II is 52.66 m^3/sec. The design discharge of the Stage I that is agreed upon and decided between NSDO and the Study Team are 52.66 m^3/sec for the conveyance canal except No.7 pumping station and pipeline having a design discharge of 32.48 m^3/sec. The increase of the design discharge of No.7 pumping station and the pipeline including a discharge tank in Stage II will be coped with the increase of number of their facilities.

   Details of settling basin, No.7 pumping station, pipeline and discharge tank will be discussed in Chapter 5.

2) Appurtenant Structures (Spillway System, Bridge, etc.,)
3) Access Roads (Details of the access roads will be discussed in Chapter 7.)

Judging from the function required for the conveyance canal and the condition of the site, the items to be considered in designing the conveyance canal facilities are as follows;

1) To satisfy the given hydraulic and structural requirements.
2) To guarantee the safety against the loose sand foundation with high permeability.
3) To facilitate prevention of drift sand from falling into the canal and removal of sand from the canal.
4) To secure the safety when No.7 pumping station suddenly stops because of power failure.
5) To provide necessary countermeasures against the limits imposed by the structural stability of the designed conveyance canal facilities.
6) To enable the easy operation & maintenance in addition to the provision of necessary safety devices.
7) Not to give hindrance and/or inconvenience to the existing facilities such as roads

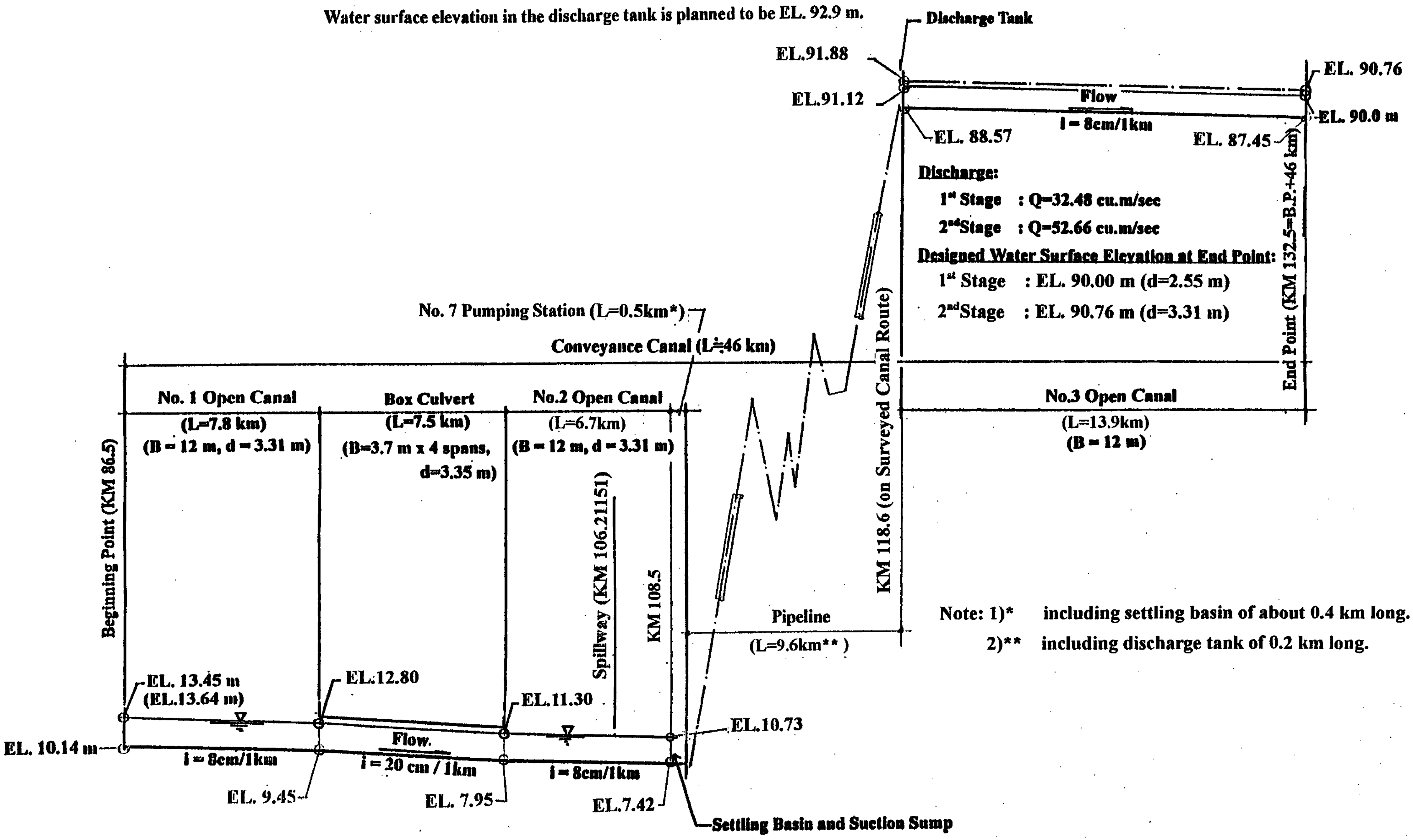


Figure 4.1-1 Conceptual Profile of the Conveyance Canal

The basic concept is to design the facilities of high economy with satisfaction of above mentioned items and is shown in Table 4.1-1.

Table 4.1-1 Basic Concept for Design of the Conveyance Canal

Items to be considered	Basic Design Concept
1) To satisfy the given hydraulic and structural requirements.	-To design the safe and economic facilities with capacity to convey the design discharge mentioned in '3.3.1 Design Discharges'.
2) To guarantee the safety against loose sand foundation with high permeability.	-To adopt concrete lined canal with waterproof sheet to prevent excessive leakage. -To provide slope protection on both cut and fill sections by stone pitching and provide laterite pavement on the berms. -To provide laterite bed for installation of the pipes for the pipeline.
3) To secure safety against drift sand.	-To provide settling basin at immediate upstream of No.7 pumping station . -To adopt box culvert section in the section between KM 94.3 (B.P.+7.8km) and KM 101.8 (B.P.+15.3km) where drift sand dunes are prevailing. -To provide the temporary stockpile for dredged sand along the concrete lined canal. -To plant trees on the both sides of O/M roads and berms in cut and fill sections. -To arrange sand catch forest and/or necessary countermeasures against drifting sand along the conveyance canal when water is available after completion of the conveyance canal. These works are not included in this project.
4) To secure the safety against the sudden stop of pump operation.	-To provide the overflow type spillway at the upstream of No.7 pumping station to automatically control the water level at the time of sudden stop of the pump operation and to provide the spillway outlet channel in order to release excess water and the dike with emergency spillway for creating the detention pond. To provide gated sections to the spillway of conveyance canal to empty the canal for inspection, maintenance, and emergency such as a canal bank failure. -To provide surge tanks at suitable points on pipeline against water hammer for down surge.

5) To enable the flow control for the structural stability.	-To establish the pump operation rule taking into consideration that the canal water surface should not be lowered more than 1.0 m in a day to avoid excessive hydrostatic pressures behind the concrete lining -To provide staff gauges at the beginning point, the end point and the middle points to check the inflow from the preceding upstream canal and the discharge in the conveyance canal
6) To provide necessary facilities for easy operation & maintenance and safety devices.	-To provide O/M roads along the conveyance canal and spillway outlet channel and to provide access roads connecting the O/M road to national highway, running from east to west, located in the north from the conveyance canal. -To provide openings lined canal. -To provide stop-log gates at both ends of box culvert section and at the upstream of the settling basin. -To provide openings at adequate interval along the box culvert section for easy maintenance and easy supply of water necessary to irrigate trees planted along O/M road and/or sand catch forest.. -To provide safety racks at upstream end of box culvert section and trash racks at immediate upstream of No.7 pumping station.
7) To maintain function of existing facilities.	-To provide bridges or to adopt box culvert section at the intersection point of existing roads and conveyance canal or spillway outlet channel.

4.2 Profile of the Canal

4.2.1 Canal Alignment

(1) Study on Conveyance Canal Route

In the F/S report, three delivery water levels of EL. 90m, 100m and 110m are selected for the alternative study of the conveyance canal system by considering ground elevation of the beneficial area. Alternative plans of more than 40 have been studied in the F/S report. As the result of the study, the alternative plan with the delivery water level of EL 110m, which requires the lowest present value of the costs, is selected as the proposed water conveyance canal system. However, the plan with the delivery water level of EL.90m was adopted for this detailed design study in response to NSDO's request.

In the F/S report, four rough routes such as routes A, B, A-C and B-C, as shown in Figure 4.2-1, have been selected by using the maps with a scale of 1/25,000 for the alternative study mentioned above. The route B-C was selected as the most economical route for all of three alternative water delivery levels, although the routes of No. 3 open canal located around downstream end of the conveyance canal are different due to each of planned water delivery levels. The most economical plan for each of canal routes with a water delivery level of EL.90m is as shown in the following table.

Table 4.2-1 Alternative Plans with Water Delivery Level of EL.90m

Canal Route	Construction Cost (million LE)	Annual O/M Cost (million LE)	Present Value (million LE)	(Ratio)
A	2,119	57.3	2,125	(1.38)
B	1,741	55.5	1,799	(1.17)
A-C	1,659	53.9	1,721	(1.12)
B-C	1,449	53.3	1,541	(1.00)

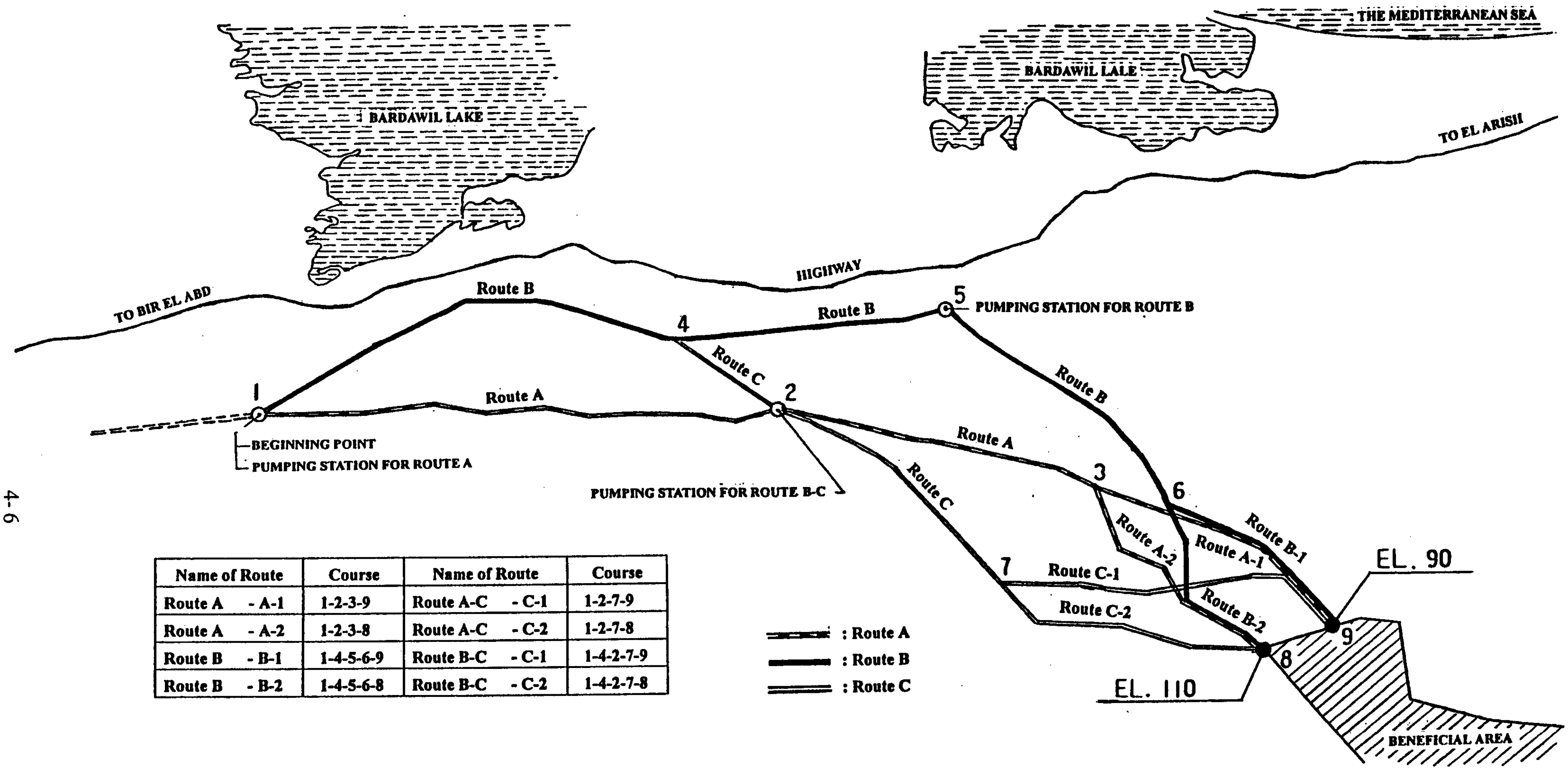
Note: The present value of costs (Construction Cost and O/M Cost) in this table are calculated on the condition with the project life of 50 years, the useful life of pump equipment of 25 years and an annual interest rate of 12 per cent.

(2) Determination of Conveyance Canal Route

(a) Canal Route Survey

The route B-C-C-1 has been selected as the most economical route by using the topographic maps with a sale of 1/25,000 that are not enough for selecting the detailed canal route for the construction work. Therefore, the topographic maps of a scale of 1/10,000 are prepared after the completion of F/S.

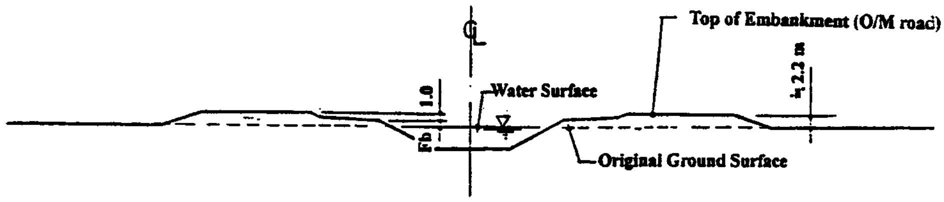
In this detailed design stage, the route of the conveyance canal for the canal route survey was selected by using the topographic maps with a scale of 1/10,000 with an eye on the route B-C-C-1 selected roughly on the maps of a scale of 1/25,000. In selecting the canal route, special attentions are given to the following items.



Name of Route	Course	Name of Route	Course
Route A - A-1	1-2-3-9	Route A-C - C-1	1-2-7-9
Route A - A-2	1-2-3-8	Route A-C - C-2	1-2-7-8
Route B - B-1	1-4-5-6-9	Route B-C - C-1	1-4-2-7-9
Route B - B-2	1-4-5-6-8	Route B-C - C-2	1-4-2-7-8

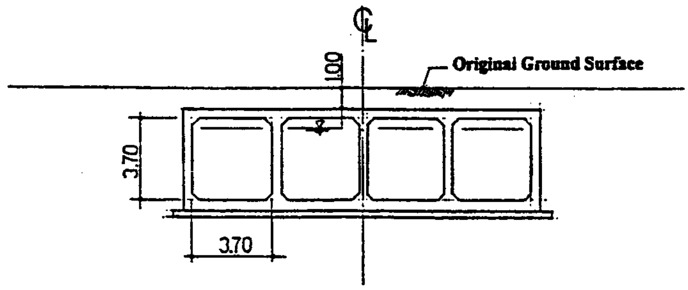
Figure 4.2-1 Route Map of Conveyance Canal for Comparative Study

(i) The route of the open canal should be selected so that the top of canal embankment is in principle about two meters higher than the original ground surface in order to prevent intrusion of drifting sand into the canal. Accordingly the designed water surface in the canal will be nearly same as the original ground surface at the location of the canal.



Typical Cross Section of Open Canal

(ii)The route of the box culvert should be selected in principle on the location that top of the box culvert can be embedded about one meter deep from the original ground surface.



Typical Cross Section of Box Culvert

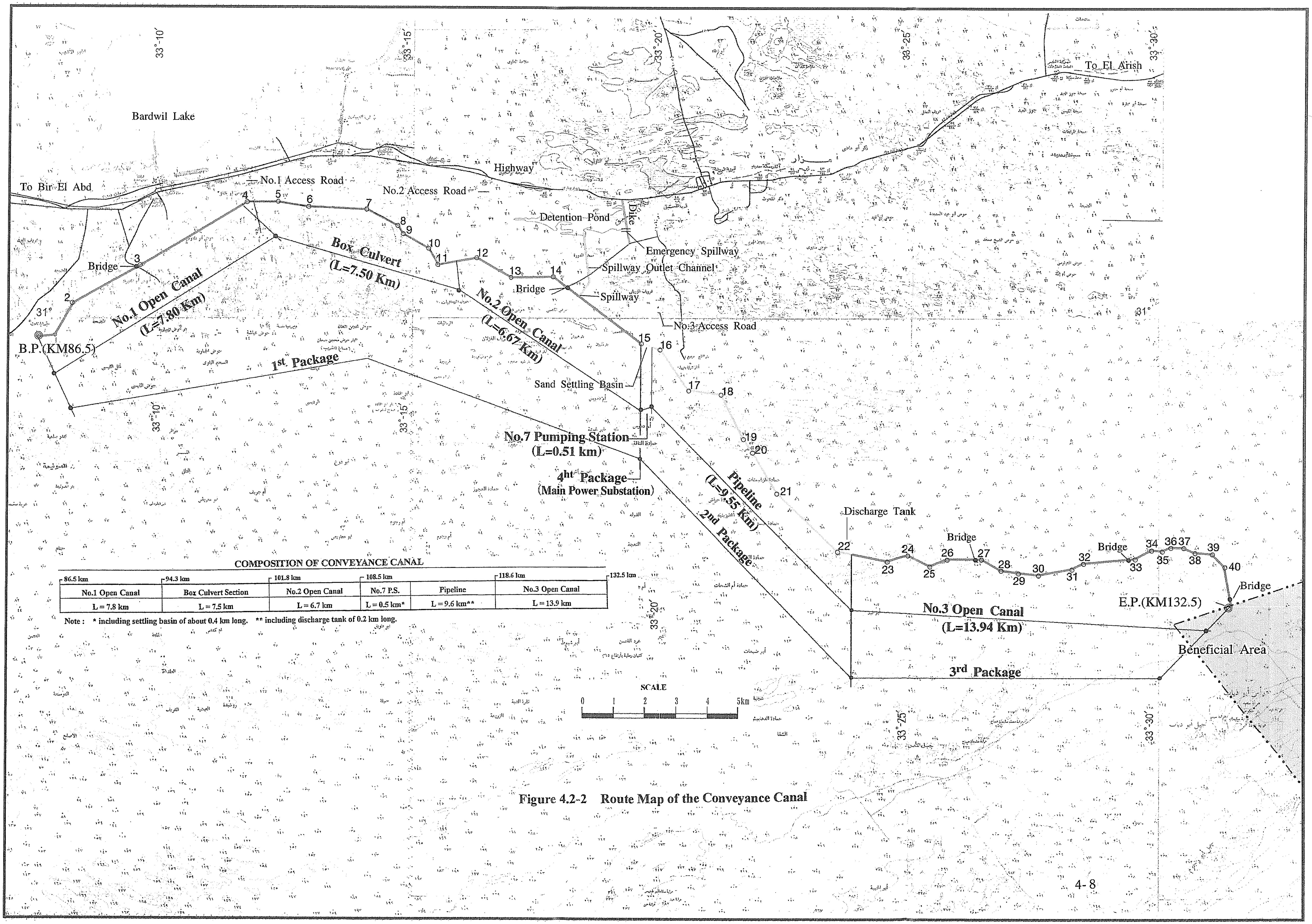
(iii) The route of the pipeline was selected based on the following considerations:

- The pipeline will require a high unit cost of more than 10 times as compared with that of the open canal. Therefore, the route of the pipeline should be selected to the direction near due south from No.7 pumping station in order to shorten the length of the pipeline section as much as possible.
- The route of the pipeline should be selected to the area other than drifting sand dune as much as possible.

The topographic survey was carried out based on the canal route maps of 1/10,000 scale. Necessary modifications of the canal route are made in the site and the final result is shown in Figure 4.2-2 and Tables 4.2-2 and 4.2-3.

(b) Routes of Open Canals and Box Culvert Section

Except the downstream end portion of No.2 Open Canal shown in Figure 4.2-3, the routes of three open canal sections and box culvert section are the same as the canal routes surveyed as shown in Figure 4.2-2 and Tables 4.2-2 and 4.2-3. The route of the canal at the downstream end portion of No.2 Open Canal is decided by considering the selected location of No.7 Pumping Station as shown in Figure 4.2-3.



COMPOSITION OF CONVEYANCE CANAL

86.5 km	94.3 km	101.8 km	108.5 km		118.6 km – 132.5 km
No.1 Open Canal	Box Culvert Section	No.2 Open Canal	No.7 P.S.	Pipeline	No.3 Open Canal
L = 7.8 km	L = 7.5 km	L = 6.7 km	L = 0.5 km*	L = 9.6 km**	L = 13.9 km

Note : * including settling basin of about 0.4 km long. ** including discharge tank of 0.2 km long.

Figure 4.2-2 Route Map of the Conveyance Canal

Table 4.2-2 **Results of Topographic Survey and Data of Curves to be set up**

Location	Distance (m)	Acc. Distance (m)	IA (°)	Radius (m)	TL (m)	CL (m)	SL (m)
BP	0.00	0.00	0.00	0	0.00	0.00	0.00
IP. 1	500.00	500.00	52.47972	500	246.46	457.98	57.44
IP. 2	1,195.95	1,695.95	29.57833	500	132.00	258.12	17.13
IP. 3	2,544.61	4,240.56	0.50333	0	0.00	0.00	0.00
IP. 4	3,896.31	8,136.87	28.26278	500	125.88	246.64	15.60
IP. 5	806.35	8,943.22	14.53083	500	63.74	126.80	4.05
IP. 6	1,101.22	10,044.44	10.85333	500	47.50	94.72	2.25
IP. 7	1,913.23	11,957.67	29.84944	500	133.27	260.48	17.46
IP. 8	1,152.76	13,110.43	34.30333	450	138.88	269.42	20.94
IP. 9	321.48	13,431.91	37.69722	500	170.69	328.98	28.33
IP. 10	783.64	14,215.55	34.02917	500	153.00	296.96	22.89
IP. 11	586.84	14,802.39	71.78417	500	361.83	626.44	117.19
IP. 12	1,227.17	16,029.56	39.56806	500	179.85	345.30	31.36
IP. 13	1,295.43	17,324.99	31.38417	500	140.47	273.88	19.36
IP. 14	1,451.66	18,776.65	38.80917	500	176.12	338.68	30.11
IP. 15	3,544.08	22,320.73	17.45472	500	76.76	152.32	5.86
IP. 16	635.70	22,956.43	34.83333	0	0.00	0.00	0.00
IP. 17	1,550.01	24,506.44	43.65556	0	0.00	0.00	0.00
IP. 18	1,100.08	25,606.52	52.83333	0	0.00	0.00	0.00
IP. 19	1,489.98	27,096.50	12.16667	0	0.00	0.00	0.00
IP. 20	580.01	27,676.51	9.66667	0	0.00	0.00	0.00
IP. 21	1,510.05	29,186.56	20.00000	0	0.00	0.00	0.00
IP. 22	2,792.38	31,978.94	30.00000	0	0.00	0.00	0.00
IP. 23	1,569.70	33,548.64	25.50000	500	113.14	222.52	12.64
IP. 24	685.02	34,233.66	45.50000	500	209.67	397.06	42.18
IP. 25	700.00	34,933.66	51.96528	500	243.68	453.48	56.22
IP. 26	733.42	35,667.08	20.00000	500	88.16	174.54	7.71
IP. 27	1,068.50	36,735.58	28.50000	500	126.98	248.70	15.87
IP. 28	720.03	37,455.61	27.00000	500	120.04	235.62	14.21
IP. 29	503.00	37,958.61	13.32444	500	58.40	116.28	3.40
IP. 30	680.62	38,639.23	27.82444	500	123.85	242.82	15.11
IP. 31	1,104.99	39,744.22	10.44528	500	45.70	91.16	2.08
IP. 32	410.74	40,154.96	19.44861	500	85.68	169.72	7.29
IP. 33	1,659.96	41,814.92	22.00000	500	97.19	191.98	9.36
IP. 34	629.98	42,444.90	29.73333	500	132.73	259.48	17.32
IP. 35	411.14	42,856.04	24.50000	500	108.56	213.80	11.65
IP. 36	290.01	43,146.05	21.00000	500	92.67	183.26	8.52
IP. 37	390.18	43,536.23	25.96000	500	115.25	226.54	13.11
IP. 38	367.57	43,903.80	21.53306	500	95.08	187.92	8.96
IP. 39	588.93	44,492.73	41.34444	500	188.66	360.80	34.41
IP. 40	572.94	45,065.67	32.85667	500	147.43	286.73	21.28
EP	1,273.84	46,339.51	0.00000	0	0.00	0.00	0.00
Total	46,339.51				4,339.32	8,339.13	

Note ; IA : Internal angle
TL : Tangent length
CL : Curve length
SL : Cosecant length

Table 4.2-3 Length of the Conveyance Canal Route

Location	Distance (m)	Acc. Distance (m)	Location	Distance (m)	Acc. Distance (m)
BP.	0	0	BC23	1,456.56	33,219.24
BC1	253.54	253.54	EC23	CL=222.52	33,441.76
EC1	CL=457.98	711.52	BC24	362.23	33,803.99
BC2	817.47	1,528.99	EC24	CL=397.06	34,201.05
EC2	CL=258.12	1,787.11	BC25	246.65	34,447.70
IP-3	2,412.61	4,199.72	EC25	CL=453.48	34,901.18
BC4	3,770.42	7,970.14	BC26	401.58	35,302.76
EC4	CL=246.64	8,216.78	EC26	CL=174.54	35,477.30
BC5	616.72	8,833.50	BC27	853.35	36,330.65
EC5	CL=126.80	8,960.30	EC27	CL=248.70	36,579.35
BC6	989.98	9,950.28	BC28	473.01	37,052.36
EC6	CL=94.72	10,045.00	EC28	CL=235.62	37,287.98
BC7	1,732.46	11,777.46	BC29	324.56	37,612.54
EC7	CL=260.48	12,037.94	EC29	CL=116.28	37,728.82
BC8	880.61	12,918.55	BC30	498.37	38,227.19
EC8	CL=269.42	13,187.97	EC30	CL=242.82	38,470.01
BC9	11.91	13,199.88	BC31	935.44	39,405.45
EC9	CL=328.96	13,528.84	EC31	CL=91.16	39,496.61
BC10	459.96	13,988.80	BC32	279.34	39,775.95
EC10	CL=296.96	14,285.76	EC32	CL=169.72	39,945.67
BC11	72.00	14,357.76	BC33	1,477.08	41,422.75
EC11	CL=626.44	14,984.20	EC33	CL=191.98	41,614.73
BC12	685.48	15,669.68	BC34	400.07	42,014.80
EC12	CL=345.30	16,014.98	EC34	CL=259.48	42,274.28
BC13	975.10	16,990.08	BC35	169.84	42,444.12
EC13	CL=273.88	17,263.96	EC35	CL=213.80	42,657.92
BC14	1,135.07	18,399.03	BC36	88.78	42,746.70
EC14	CL=338.68	18,737.71	EC36	CL=183.26	42,929.96
BC15	3,291.19	22,028.90	BC37	182.26	43,112.22
EC15	CL=152.32	22,181.22	EC37	CL=226.54	43,338.76
IP-16	558.95	22,740.17	BC38	157.24	43,496.00
IP-17	1,550.01	24,290.18	EC38	CL=187.92	43,683.92
IP-18	1,100.08	25,390.26	BC39	305.20	43,989.12
IP-19	1,489.98	26,880.24	EC39	CL=360.80	44,349.92
IP-20	580.01	27,460.25	BC40	236.85	44,586.77
IP-21	1,510.05	28,970.30	EC40	CL=286.72	44,873.49
IP-22	2,792.38	31,762.68	EP.	1,126.51	46,000.00

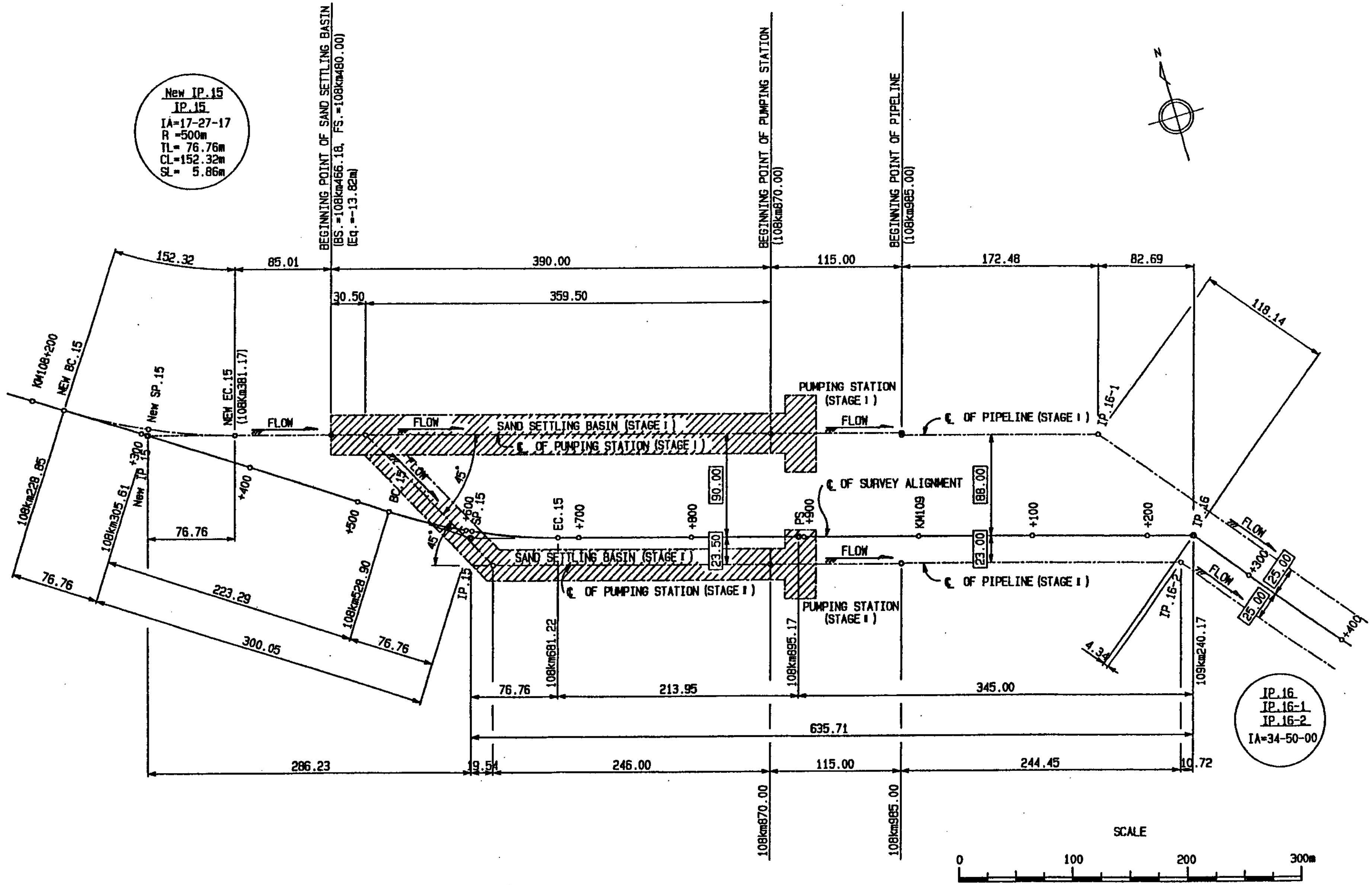


Figure 4.2-3 Canal Route at Downstream End Portion of No.2 Open Canal

(c) Route of Pipeline

The route of the pipeline was selected at the location 25 m far from the surveyed route as shown in Figure 4.2-4 and Figure 4.3-4 considering the provision of O/M road and the pipeline to be constructed in Stage II construction work.

(3) Antiquity and Ancient Monuments on Canal Route

In response to the requests of NSDO, Kantara office of the Authority for Antiquity and Ancient Monuments for North Sinai, Ministry of Culture has informed NSDO that there is no antiquity and ancient monuments on the route of conveyance canal. In case that antiquity or ancient monuments are found in the site during the period of construction works, NSDO should inform it to Kantara office of Authority mentioned above for inspection.

4.2.2 Profile and Water Level of the Canal

The profile of the conveyance canal shall be decided in due consideration of the following items;

1) The invert slope of the open canal shall ensue the velocity to avoid sand deposition in the canal bottom.
2) The velocity of the culvert box shall be more than 1.2 times of the velocity of the open canal to provide the economic conveyance canal system and to make more sure the sand transport capacity.
3) The profile of the conveyance canal shall cope with the topographic profile so as to minimize the construction cost

(1) Invert Slope of the Open Canal

In order to prevent sand deposition in the open canal, the hydraulic gradient should be decided in consideration of the minimum velocity to ensure the transport capacity. The minimum discharge is given at 8.09 m^3/sec in Stage I as described in '3.3.1 Design Discharges'.

The hydraulic gradient of 8 cm / km=1 / 12,500, which is applied in the upstream canal under construction now, could reasonably be applied in the design of the open canal section of the conveyance canal. A rectangular shaped hydraulic cross section with bottom width of 12 m and side slope of 1 : 2 gives following hydraulic dimensions for the minimum discharge.

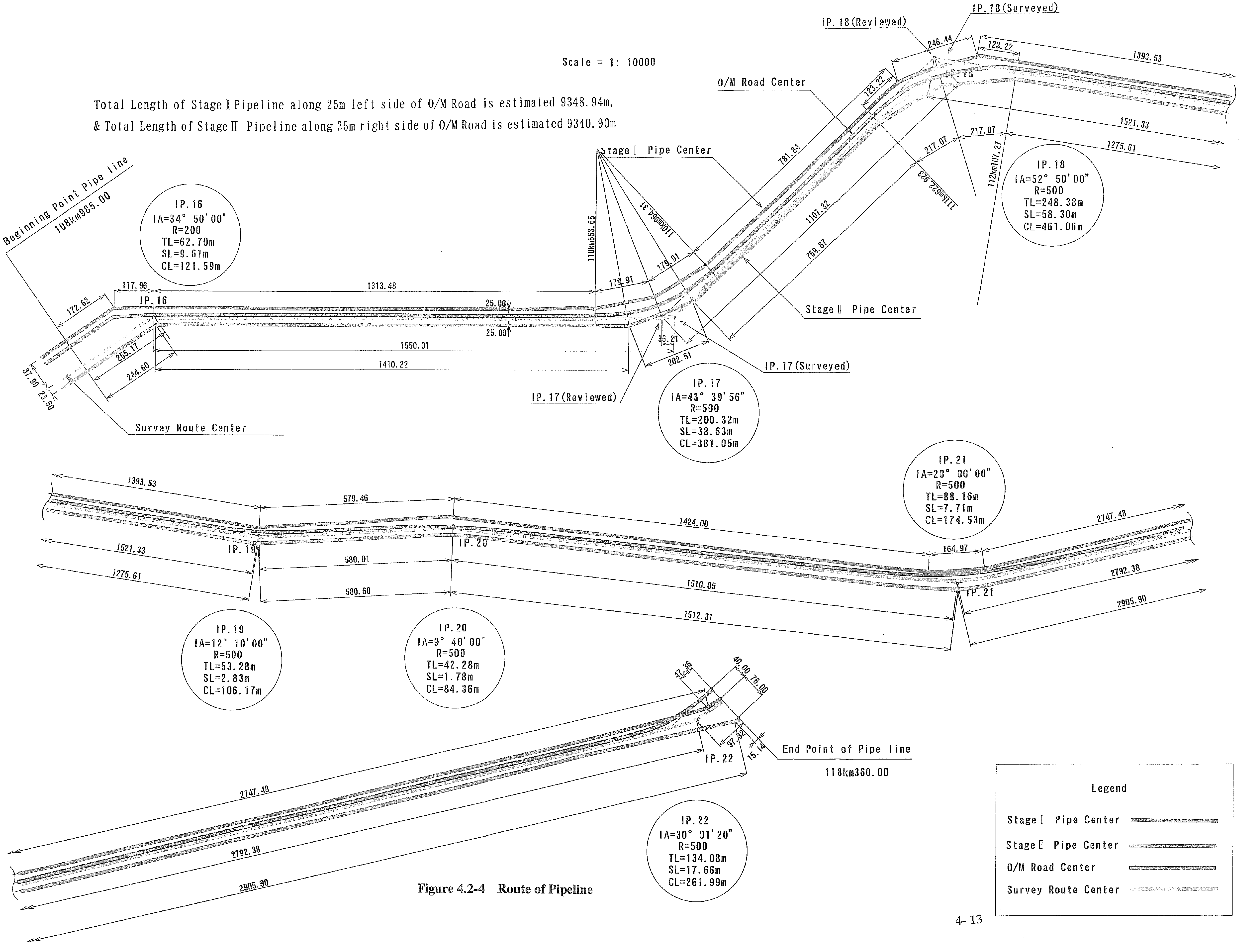


Figure 4.2-4 Route of Pipeline

	for Stage I	for Stage II
Minimum Discharge	$Q=8.09\ m^3/sec$	$13.93\ m^3/sec$
Hydraulic Gradient	I=0.00008	0.00008
Roughness Coefficient	n=1/55	1/55
Water Depth	d=1.17 m	1.60 m
Flow Area	$A=16.78\ m^2$	$24.32\ m^2$
Wetted Perimeter	P=17.23 m	19.16 m
Hydraulic Radius	R=0.974 m	1.269 m
Velocity	V=0.483 m/sec	0.577 m/sec

The minimum transport capacity of the canal at Stage I development is expressed by the friction velocity and is given by the following formula.

$$U_{c1}=(g\ R\ I)^{1/2}$$
$$=(9.8x0.974x0.00008)^{1/2}$$
$$=0.0276\ m/sec=2.76\ cm/sec \quad (U_{c1}=3.15\ cm/sec \text{ after Stage II development})$$

According to IWAGAKI, the critical friction velocity to transport the particle size d=1 mm is given by the following formula.

$$U_{c2}=(55\ d)^{1/2}$$
$$=(55x0.1)^{1/2}=2.35cm/sec$$

The transport capacity U_{c1} is 1.2 times larger than the critical friction velocity U_{c2} and the open canal has sufficient transport capacity for the anticipated maximum particle size of 1 mm in diameter.

(2) Invert Slope of the Box Culvert

In order to make sure that the sand transported from the upstream open canal shall not be deposited in the section of box culvert, but shall be transported to the downstream, the design velocity of the box culvert shall be decided at more than 1.2 times of that of the open canal. The ratio of the velocity in the box culvert to that of the open canal decreases with the increase of the discharge. Therefor, the design velocity of the box culvert shall decided based on the velocity of the open canal at the maximum design discharge (V=0.86 m/sec at $Q=52.66\ m^3/sec$). The design velocity of box culvert shall be more than 1.03 m/sec (1.2x0.86 m/sec) and decided 1.07 m/sec in a safe side setting the designed invert slope at 20 cm/km=1/5,000.

(3) Profile of the Conveyance Canal

The profile of the conveyance canal is roughly shown in Figures 4.2-5, 4-2-6 and 4.2-7 based on the given hydraulic requirements, designed invert slope, topographic features on the canal route, etc.

(4) Water Level in the Canal

The water levels in No.1 Open Canal, box culvert and No.2 Open Canal are shown in Figure 4.2-5 and Table 4.2-4, and the water levels in No.3 Open Canal are shown in Figure 4.2-7 and Table 4.2-5.

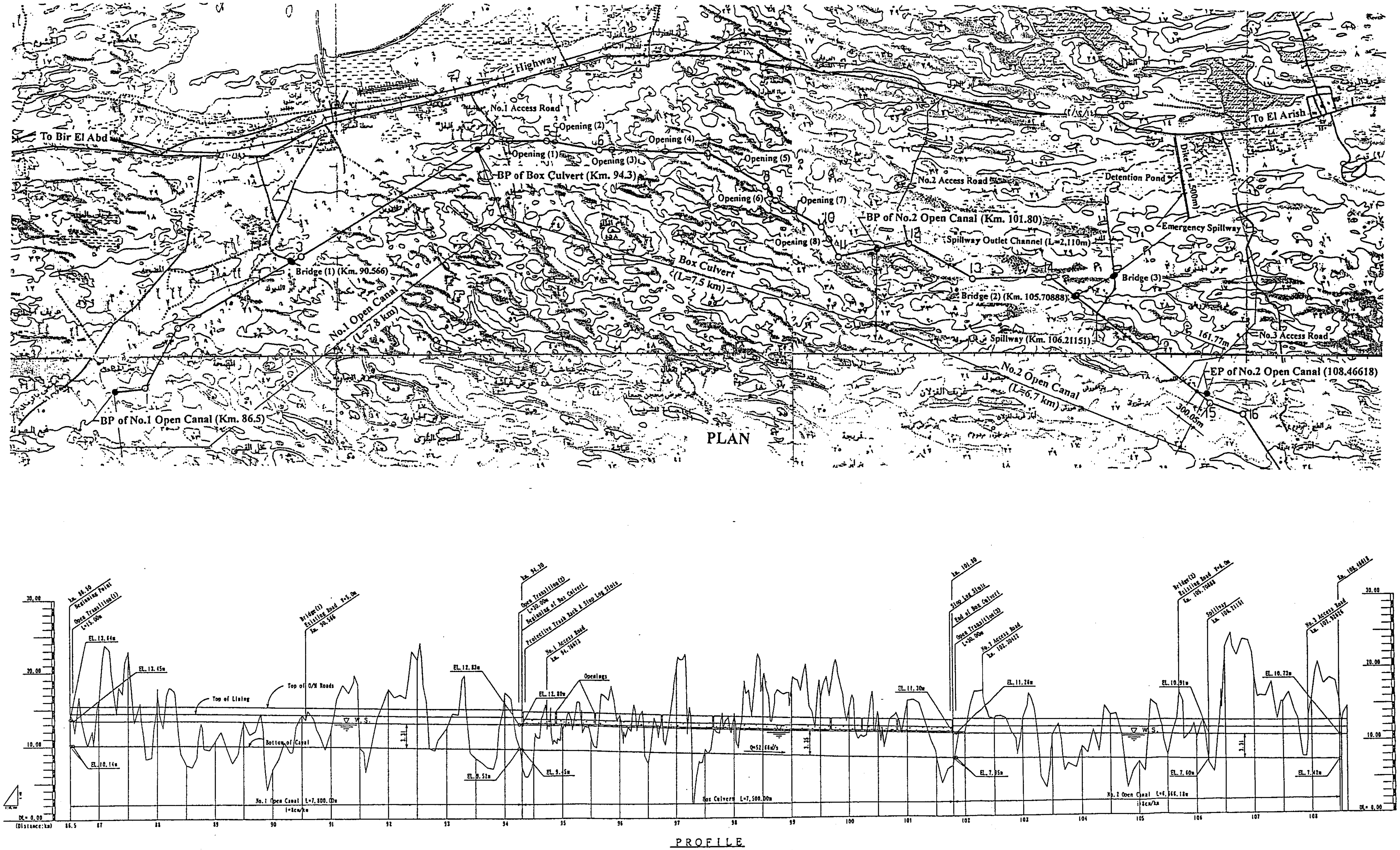
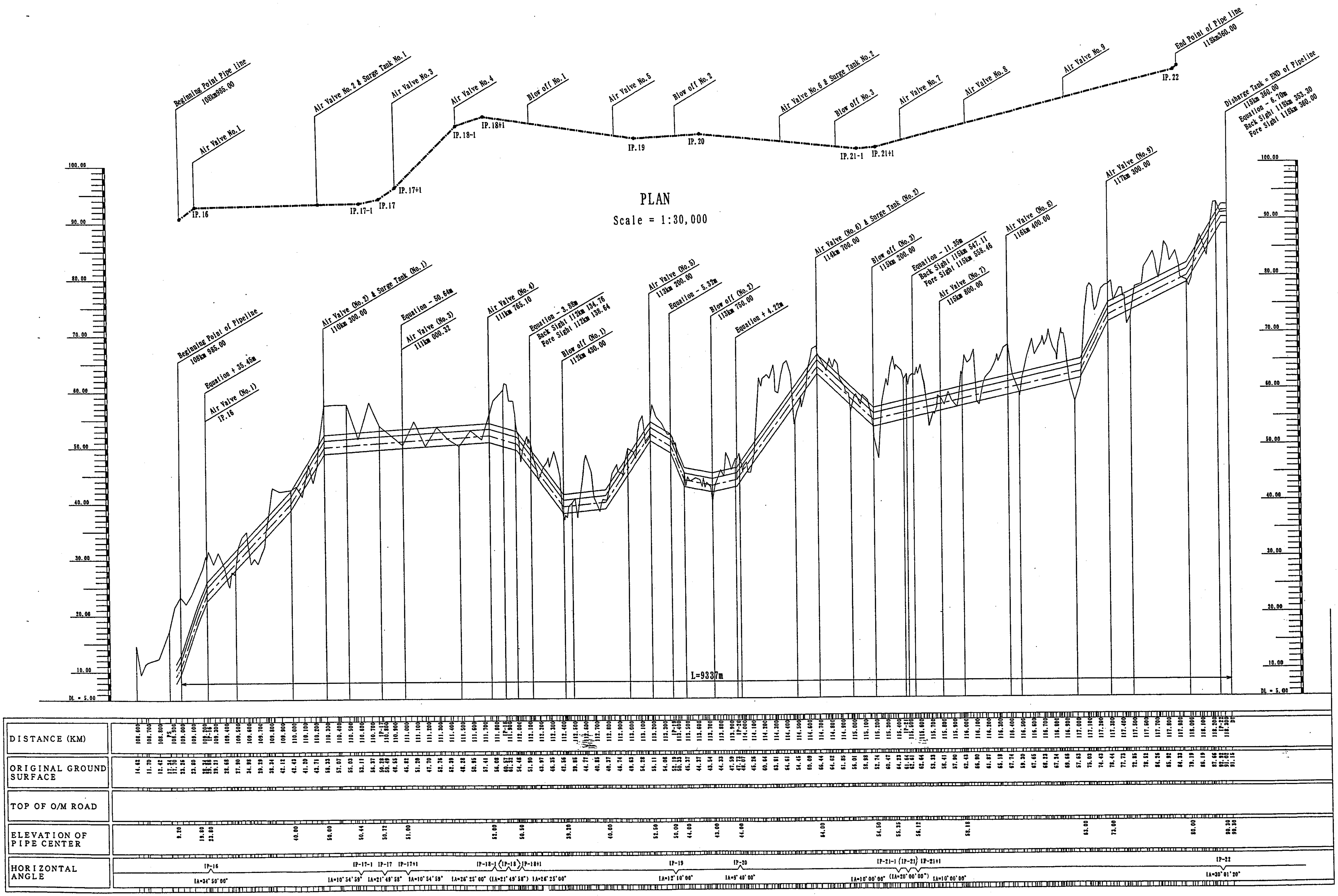


Figure 4.2-5 Plan and Profile of No.1 Open Canal, Box Culvert and No.2 Open Canal



PROFILE Scale = 1:30,000

Figure 4.2-6 Plan and Profile of Pipeline

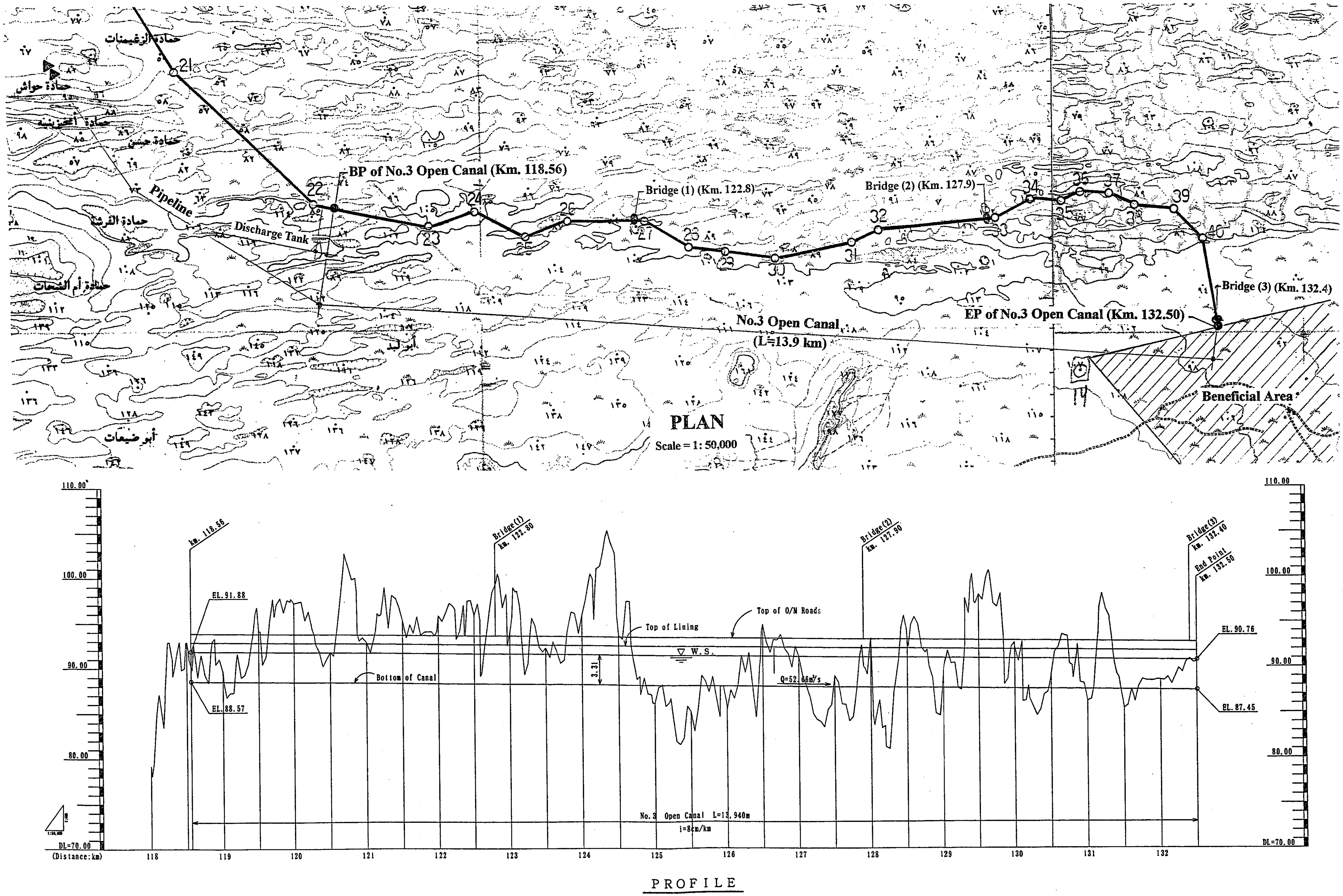


Figure 4.2-7 Plan and Profile of No.3 Open Canal

Table 4.2-4 Water Level in Conveyance Canal Between Km. 86.5 and Km. 108.44618 (No.1 Open Canal, Box Culvert & No.2 Open Canal)

(at the time of design discharge Q = 52.66 m^3/sec)

Location	Distance (m)	Acc. Distance (m)	Canal Bottom (EL. m)	Water Level (EL. m)
1) No.1 Open Canal (B=12m, Side Slope = 1 : 2, I = 8cm/km, n = 1/55)				
BP of No.1 Canal & OT_1	-	86,500.00 m	EL. 10.14 m	EL. 13.64 m
EP of OT_1	15.00	86,515.00	10.14	13.45
BC1	238.54	86,753.54	10.12	13.43
EC1	457.98	87,211.52	10.08	13.39
BC2	817.47	88,028.99	10.02	13.33
EC2	258.12	88,287.11	10.00	13.31
Existing Road (Bridge (1))	2,278.89	90,566.00	9.82	13.13
IP3	133.72	90,699.72	9.81	13.12
BP of OT2	3,570.28	94,270.00	9.52	12.83
EP of No.1 Canal & OT2	30.00	94,300.00	9.45	12.80
2) Box Culvert Section (4-cell Box Culvert (3.7m x 3.7m x 4), I = 20cm/km, n = 1/67)				
BP of Box Culvert Section	-	94,300.00	9.45	12.80
BC4	170.14	94,470.14	9.42	12.77
EC4	246.64	94,716.78	9.37	12.72
No.1 Access Road	49.95	94,766.73	9.36	12.71
Opening (1)	130.05	94,896.78	9.33	12.68
BC5	436.72	95,333.50	9.24	12.59
EC5	126.80	95,460.30	9.22	12.57
Opening (2)	120.00	95,580.30	9.19	12.54
BC6	869.98	96,450.28	9.02	12.37
EC6	94.72	96,545.00	9.00	12.35
Opening (3)	204.00	96,749.00	8.96	12.31
Opening (4)	900.00	97,649.00	8.78	12.13
BC7	628.46	98,277.46	8.65	12.00
EC7	260.48	98,537.94	8.60	11.95
Opening (5)	456.00	98,993.94	8.51	11.86
BC8	424.61	99,418.55	8.43	11.78
EC8	269.42	99,687.97	8.37	11.72
Opening (6)	0.0	99,687.97	8.37	11.72
BC9	11.91	99,699.88	8.37	11.72
EC9	328.96	100,028.84	8.30	11.65
Opening (7)	204.00	100,232.84	8.26	11.61
BC10	255.96	100,488.80	8.21	11.56
EC10	296.96	100,785.76	8.15	11.50
Opening (8)	48.00	100,833.76	8.14	11.49
BC11	24.00	100,857.76	8.14	11.49
EC11	626.44	101,484.20	8.01	11.36
EP of Box Culvert Section	315.80	101,800.00	7.95	11.30
3) No.2 Open Canal (B=12m, Side Slope = 1 : 2, I = 8cm/km, n = 1/55)				
BP of No.3 Canal & OT3	-	101,800.00	7.95	11.30
EP of OT3	30.00	101,830.00	7.95	11.26
BC12	339.68	102,169.68	7.92	11.23
No.2 Access Road	134.54	102,304.22	7.91	11.22
EC12	210.76	102,514.98	7.90	11.21
BC13	975.10	103,490.08	7.82	11.13
EC13	273.88	103,763.96	7.80	11.11
BC14	1,135.07	104,899.03	7.70	11.01
EC14	338.68	105,237.71	7.68	10.99
Existing Road (Bridge (2))	471.17	105,708.88	7.64	10.95
Spillway	502.63	106,211.51	7.60	10.91
No.3 Access Road	1,714.75	107,926.26	7.46	10.77
End Point	539.92	108,466.18	7.42	10.73

Note : OT = Open Transition, BC = Beginning of Curvature, EC = End of Curvature

Table 4.2-5 Water Level in Conveyance Canal Between Km. 118.56 and Km. 132.50 (No.3 Open Canal)

(at the time of design discharge Q = 52.66 m^3/sec)

Location	Distance	Acc. Distance	Canal Bottom	Water Level
No.3 Open Canal (B=12m, Side Slope = 1 : 2, I = 8cm/km, n = 1/55)				
BP of No.3 Open Canal	-	118,560.00 m	EL. 88.57 m	EL. 91.88 m
BC23	1,159.24	119,719.24	88.48	91.79
EC23	222.52	119,941.76	88.46	91.77
BC24	362.23	120,303.99	88.43	91.74
EC24	397.06	120,701.05	88.40	91.71
BC25	246.65	120,947.70	88.38	91.69
EC25	453.48	121,401.18	88.34	91.65
BC26	401.58	121,802.76	88.31	91.62
EC26	174.54	121,977.30	88.30	91.61
Bridge (1)	822.70	122,800.00	88.23	91.54
BC27	30.65	122,830.65	88.23	91.54
EC27	248.70	123,079.35	88.21	91.52
BC28	473.01	123,552.36	88.17	91.48
EC28	235.62	123,787.98	88.15	91.46
BC29	324.56	124,112.54	88.13	91.44
EC29	116.28	124,228.82	88.12	91.43
BC30	498.37	124,727.19	88.08	91.39
EC30	242.82	124,970.01	88.06	91.37
BC31	935.44	125,905.45	87.98	91.29
EC31	91.16	125,996.61	87.98	91.29
BC32	279.34	126,275.95	87.95	91.26
EC32	169.72	126,445.67	87.94	91.25
Bridge (2)	1,454.33	127,900.00	87.82	91.13
BC33	22.75	127,922.75	87.82	91.13
EC33	191.98	128,114.73	87.81	91.12
BC34	400.07	128,514.80	87.77	91.08
EC34	259.48	128,774.28	87.75	91.06
BC35	169.84	128,944.12	87.74	91.05
EC35	213.80	129,157.92	87.72	91.03
BC36	88.78	129,246.70	87.72	91.03
EC36	183.26	129,429.96	87.70	91.01
BC37	182.26	129,612.22	87.69	91.00
EC37	226.54	129,838.76	87.67	90.98
BC38	157.24	129,996.00	87.66	90.97
EC38	187.92	130,183.92	87.64	90.95
BC39	305.20	130,489.12	87.62	90.93
EC39	360.80	130,849.92	87.59	90.90
BC40	236.85	131,086.77	87.57	90.88
EC40	286.72	131,373.49	87.54	90.85
Bridge (3)	1,026.51	132,400.00	87.46	90.77
End Point	100.00	132,500.00	87.45	90.76

Note : BC = Beginning of Curvature, EC = End of Curvature

4.3 Cross Section of the Canals

4.3.1 Typical Cross Section of Open Canal

The concrete lined canal section, that is constructed in Stage I, has a 12 m base with 1 to 2 side slopes and a height of 4.5m. Thickness of lining for the side slope is planned to be 0.25m. The berm having a net wide of 9m and a total wide 10.65 m is provided along the open canal. The berm will be used for remving the sediment deposited in the canal and to stock temporarily the dredged materials on it(refer to Figure 4.3-1). The hydraulic properties of the concrete lined section is as follows (For detailed hydraulic properties, see Table 4.3-1) :

Hydraulic Properties of Open Canal

D	A	V	Q	Remarks
3.31 m	61.63 m^2	0.857 m/sec	52.82 m^3/sec>52.66*	Flow in Stage II
2.55 m	43.61 m^2	0.745 m/sec	32.49 m^3/sec>32.48*	Flow in Stage I

Note : * = required discharge at each of Stage I and II., 1/n = 55, I = 1/12,500 (8cm/km)

Typical cross section of the open canal is shown in Figure 4.3-1 and the results of structural design are shown in Table 4.3-2.

4.3.2 Typical Cross Section of Box Culvert

The 4-cell box culvert section (3.7 m x 3.7 m x 4), that is constructed in Stage I, has been planned in the section 7.8 km – 15.3 km from the beginning point where drift sand dunes are prevailing. The hydraulic properties of the box culvert section is as follows (For detailed hydraulic properties, see Table 4.3-3.) :

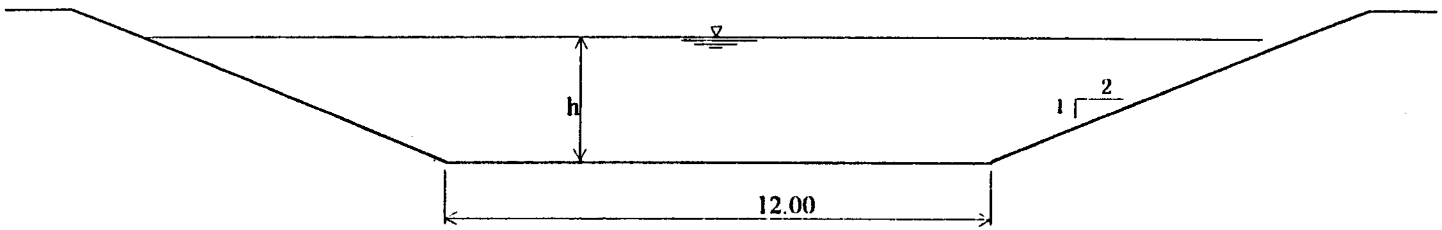
Hydraulic Properties of 4-cell Box Culvert

D	A	V	Q	Remarks
3.35 m	12.395x4 m^2	1.065 m/sec	52.80 m^3/sec>52.66*	Flow in Stage II
2.29 m	8.473x4 m^2	0.962 m/sec	32.60 m^3/sec>32.48*	Flow in Stage I

Note : * = required discharge at each of Stage I and II., 1/n = 67, I = 1/5,000 (20cm/km)

The structural design of the box culvert was carried out based on the results of structural analysis of the 4-cell box culvert covered with drifting sand of 5 m deep. Typical cross section of the box culvert, structures of inlet and outlet portions, etc. are shown in Figures 4.3-2 and 4.3-3.

Table 4.3-1 Detailed Hydraulic Properties of Open Canal



	Symbol	unit	Stage I			Stage II		
			Min. Discharge	Ave. Discharge	Max. Discharge	Min. Discharge	Ave.. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	8.09	16.98	32.48	13.93	28.05	52.66
Hydraulic Gradient	I		0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Roughness Coefficient	1/n		55	55	55	55	55	55
Assumed Water Depth	h'	m	1.17	1.79	2.55	1.60	2.36	3.31
Flow Area	A	m^2	16.78	27.83	43.61	24.32	39.51	61.63
Wetted Perimeter	P	m	17.23	19.99	23.40	19.16	22.56	26.80
Hydraulic Radius	R	m	0.974	1.392	1.864	1.269	1.751	2.300
	$R^{2/3}$		0.983	1.247	1.515	1.172	1.453	1.742
Velocity	V	m/s	0.483	0.613	0.745	0.577	0.715	0.857
Estimated Discharge	Q'	m^3/s	8.10	17.06	32.49	14.03	28.25	52.82
Friction Velocity	U_*	cm/s	2.76	3.30	3.82	3.15	3.71	4.25
Critical Tractive Particle Size	d_{max}	mm	1.0	1.4	1.8	1.3	1.7	2.3
Design Water Depth	h	m	1.17	1.79	2.55	1.60	2.36	3.31

Manning' Formula $Q = A \times 1/n \times R^{2/3} \times I^{1/2}$

Friction Velocity $U_* = (980 \times R \times 100 \times I)^{0.5}$

Iwagaki' Formula $dmax = (U^*/1.2)^2 \times 10/55.0$

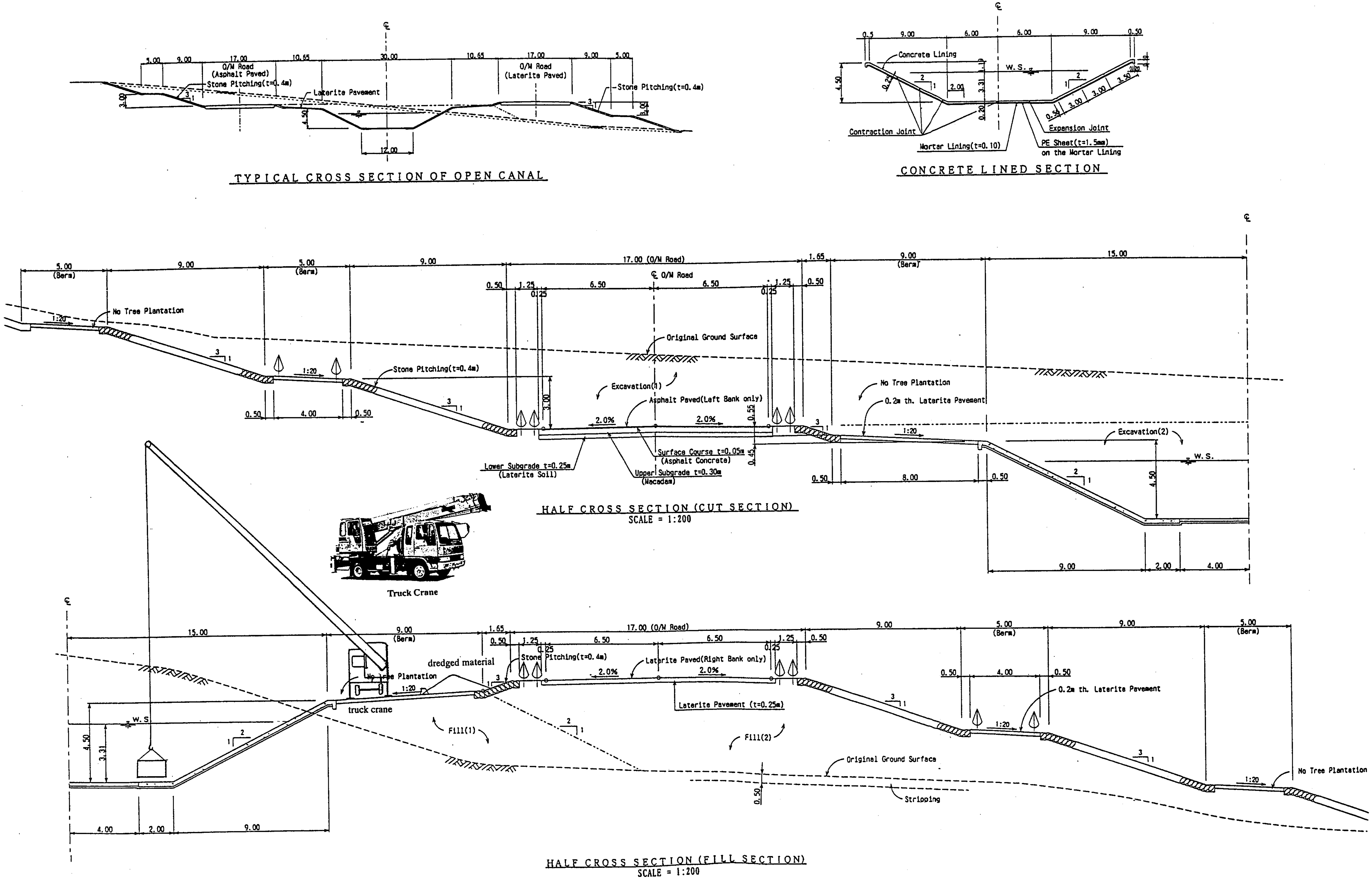


Figure 4.3-1 Typical Cross Section of Open Canal

Table 4.3-2 Structural Design of the Conveyance Canal

1) Concrete Lining of Open Canal

i) Thickness of Canal Concrete Lining

- Canal Sides	25 cm
- Canal Bottom (cut section)	15 cm
- Canal Bottom (fill section)	20 cm

ii) Location of Expansion Joints and Grooves

- Expansion Joints	30 m interval on longitudinal section
- Grooves	3 m (for each of transverse and longitudinal grooves)

iii) Seepage Control

- Both Fill & Cut Sections	Placing a polyethylene sheet of 1 mm thick on mortar lining of 10 cm thick

2) Earth Works for the Conveyance Canal

i) Protection of Ground Surface excavated or embanked

- Side Slopes	30 cm thick wet stone pitching (wet-rock paving)
- Berms	40 cm thick gravel paving

ii) Typical Section of Asphalt Paved O/M Road

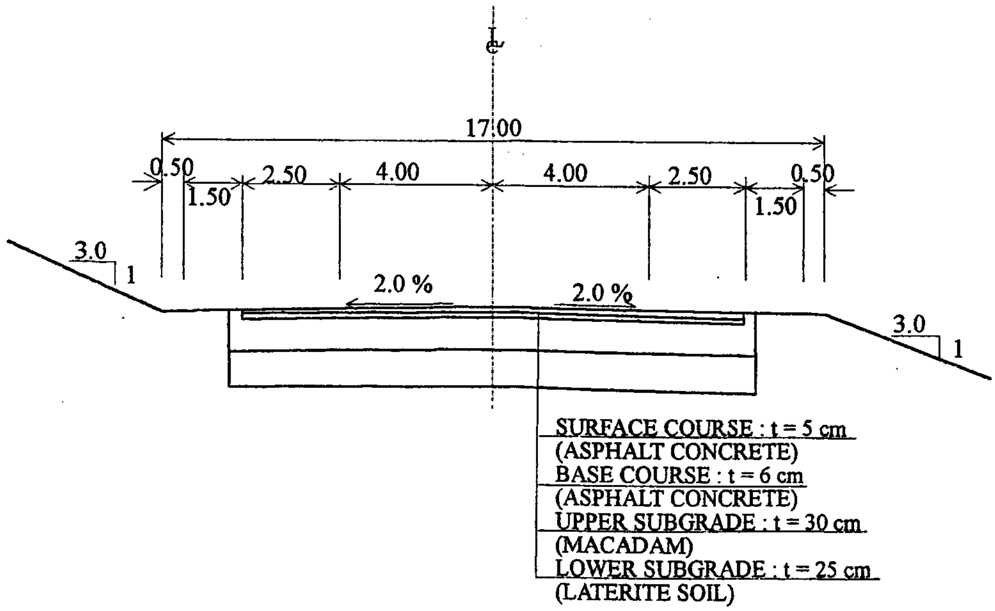
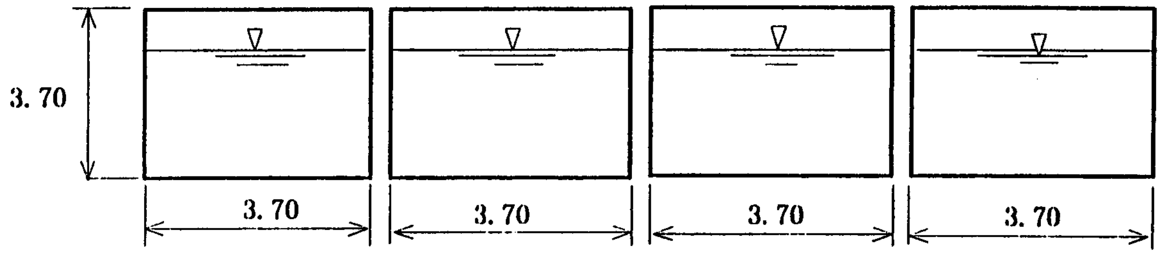


Table 4.3-3 Detailed Hydraulic Properties of 4-cell Box Culvert

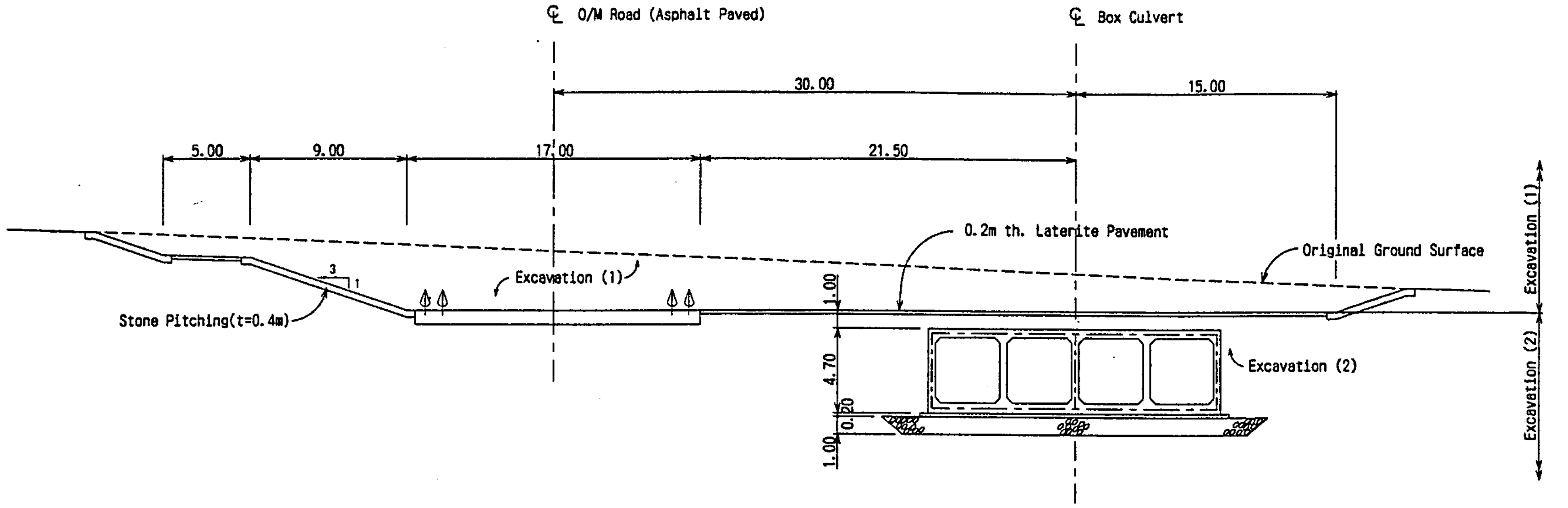


	Symbol	unit	Stage I			Stage II		
			Min. Discharge	Ave. Discharge	Max. Discharge	Min. Discharge	Ave. Discharge	Max. Discharge
Design Discharge	Q	m^3/s	8.09	16.98	32.48	13.93	28.05	52.66
Hydraulic Gradient	I		0.00020	0.00020	0.00020	0.00020	0.00020	0.00020
Roughness Coefficient	1/n		67	67	67	67	67	67
Assumed Water Depth	h'	m	0.82	1.38	2.29	1.19	1.98	3.35
Flow Area	A	m^2	12.14	20.42	33.89	17.61	29.37	49.58
Wetted Perimeter	P	m	21.36	25.84	33.12	24.32	30.67	41.60
Hydraulic Radius	R	m	0.568	0.790	1.023	0.724	0.958	1.192
	$R^{2/3}$		0.686	0.855	1.015	0.806	0.972	1.124
Velocity	V	m/s	0.650	0.810	0.962	0.764	0.921	1.065
Estimated Discharge	Q'	m^3/s	7.89	16.54	32.60	13.45	27.05	52.80
Friction Velocity	U_*	cm/s	3.34	3.93	4.48	3.77	4.33	4.83
Critical Tractive Particl	d_{max}	mm	1.4	2.0	2.5	1.8	2.4	2.9
Design Water Depth	h	m	0.82	1.38	2.29	1.19	1.98	3.35

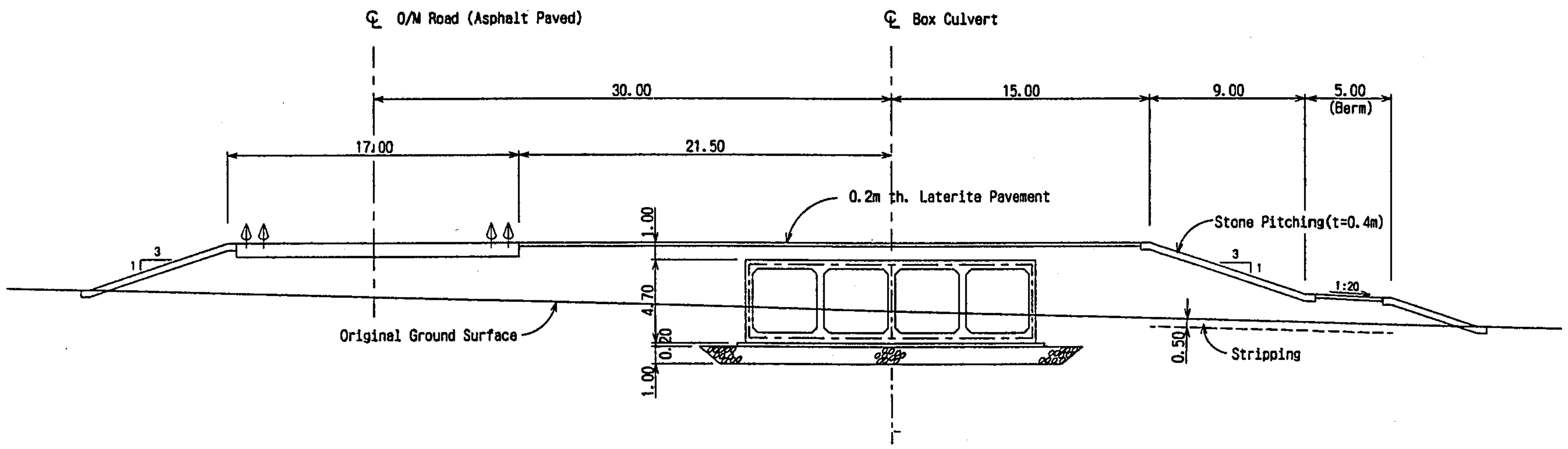
Manning' Formula $Q = A \times 1/n \times R^{2/3} \times I^{1/2}$

Friction Velocity $U_* = (980 \times R \times 100 \times I)^{0.5}$

Iwagaki' Formula $dmax = (U^*/1.2)^2 \times 10/55.0$



TYPICAL CROSS SECTION OF BOX CULVERT (CUT SECTION)
SCALE = 1:400



TYPICAL CROSS SECTION OF BOX CULVERT (FILL SECTION)
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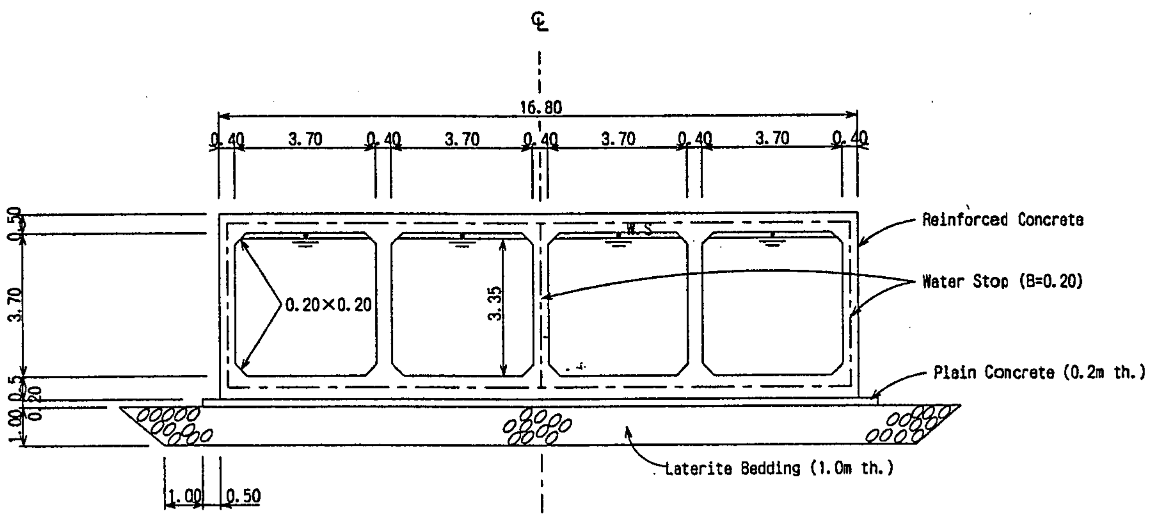
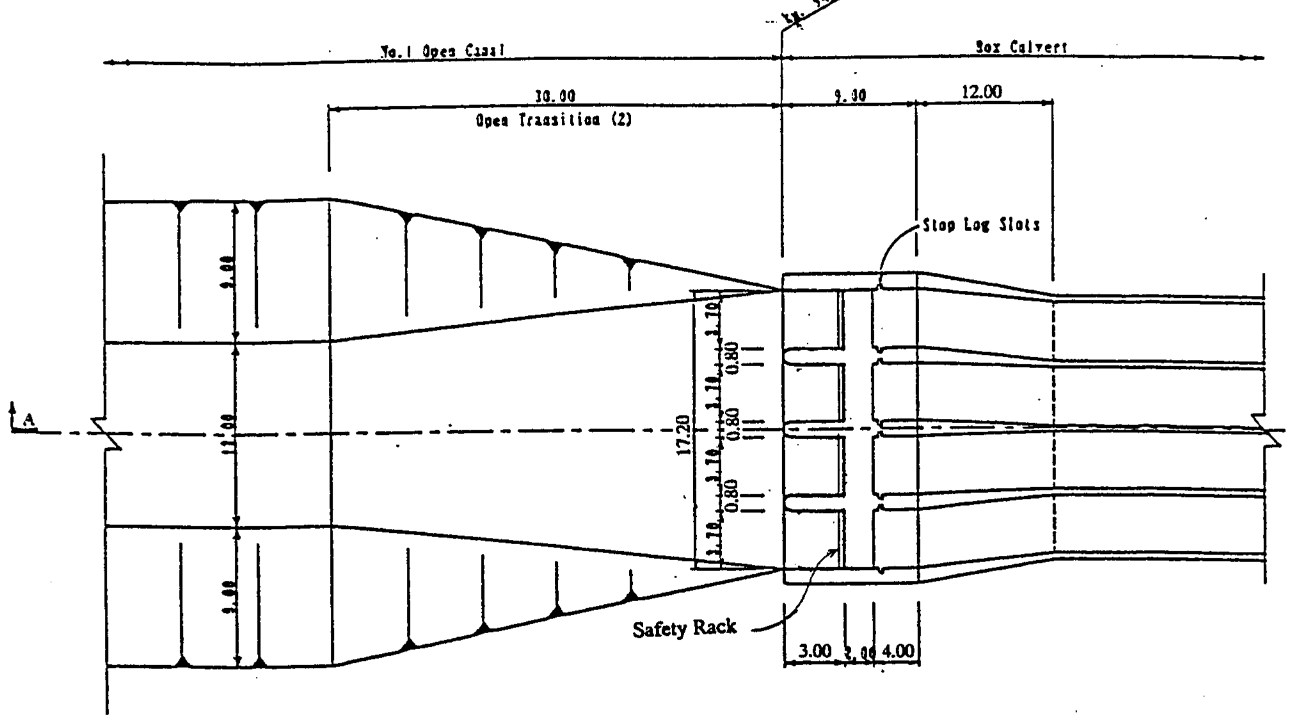
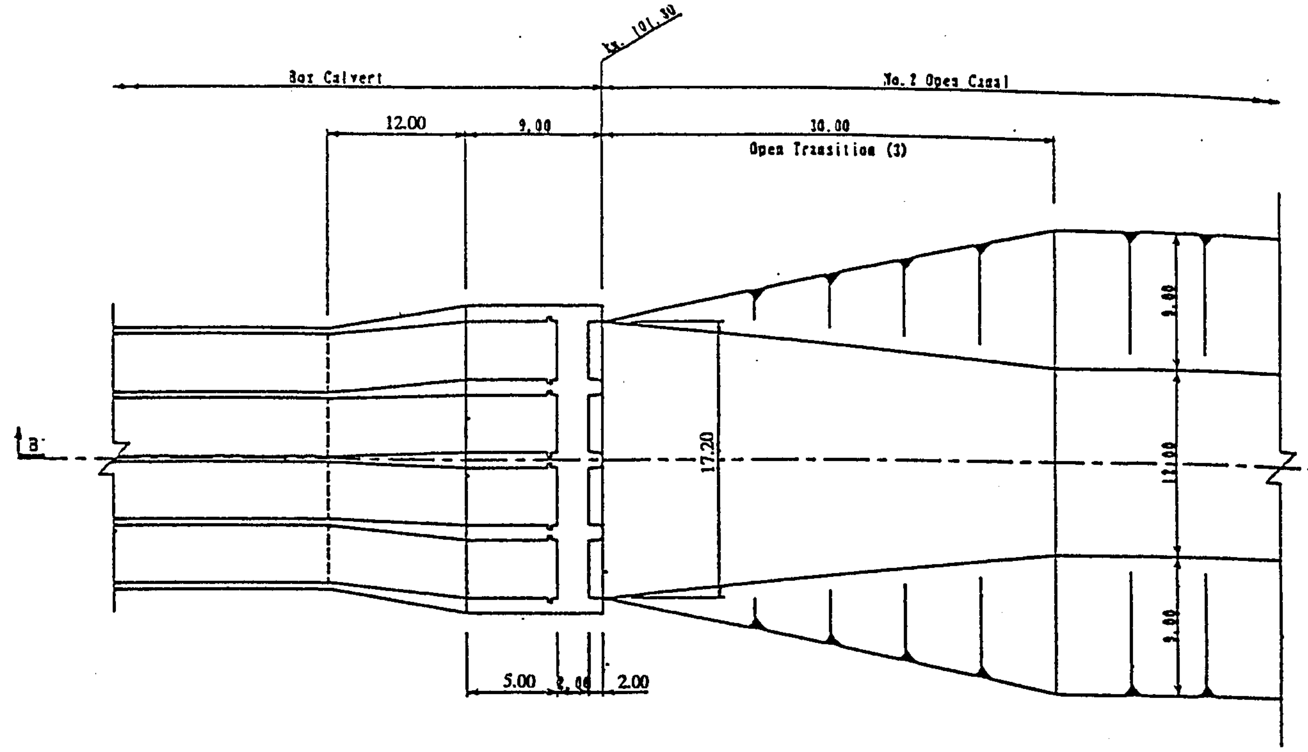


FOUR-CELL BOX
SCALE = 1:200

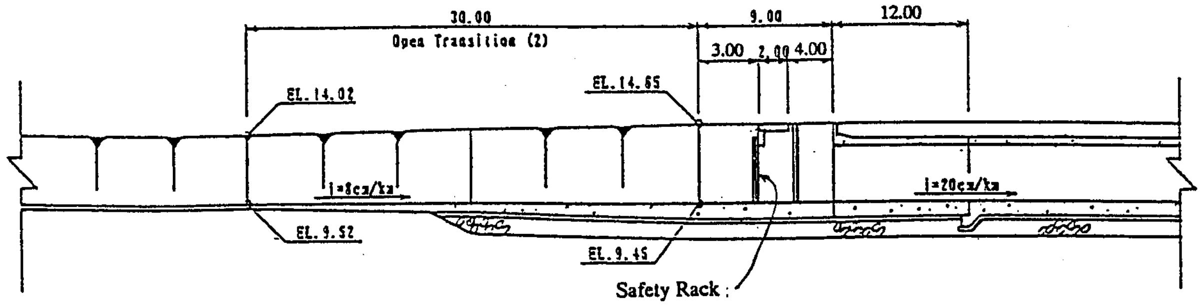
Figure 4.3-2 Typical Cross Section of Box Culvert



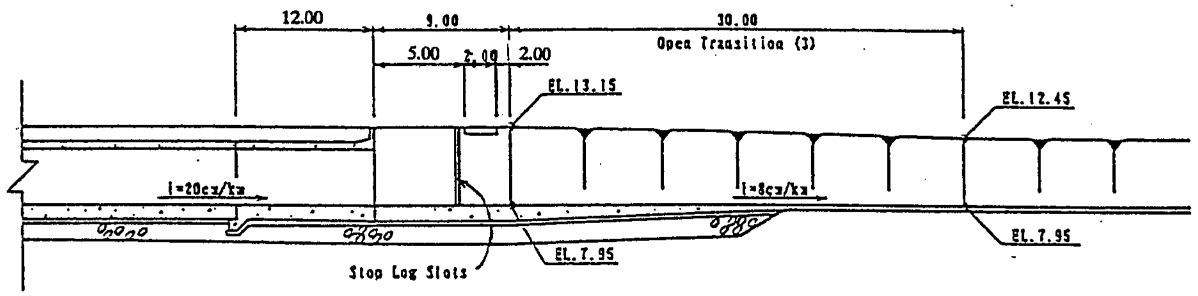
PLAN OF INLET



PLAN OF OUTLET



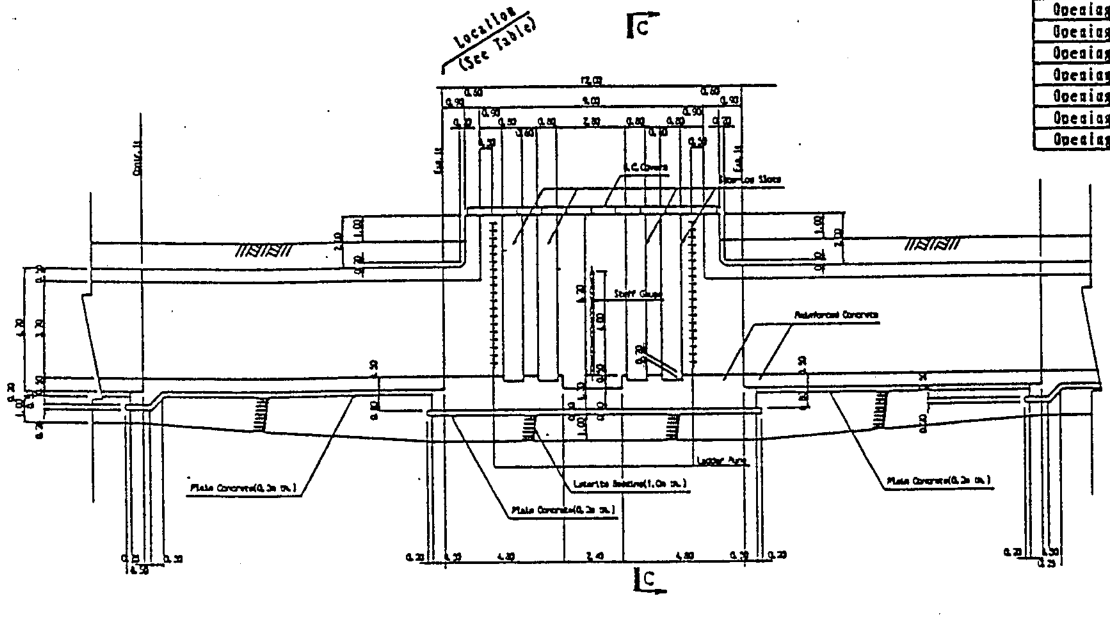
SECTION A–A



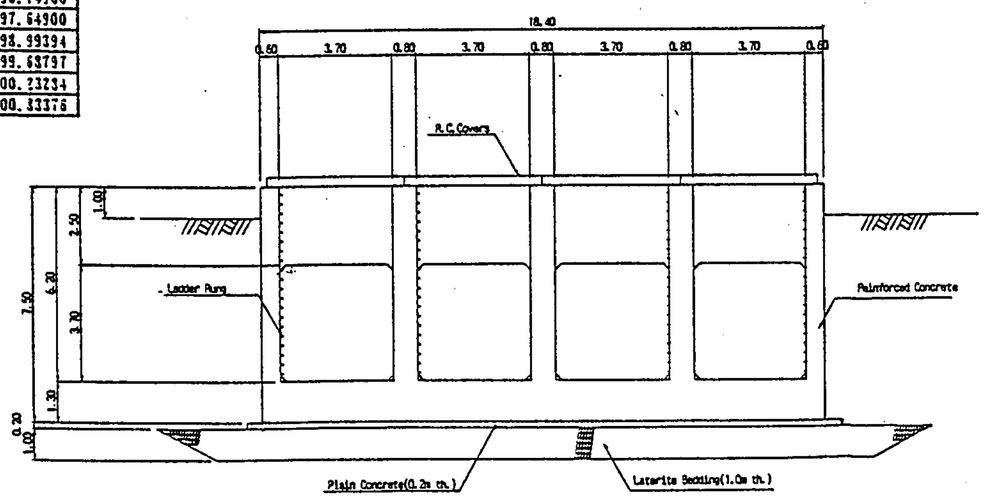
SECTION B–B

LOCATION OF OPENING

No.of Opening	Location
Opening (1)	km. 94.39673
Opening (2)	km. 95.58030
Opening (3)	km. 96.74900
Opening (4)	km. 97.64900
Opening (5)	km. 98.99394
Opening (6)	km. 99.63797
Opening (7)	km. 100.23234
Opening (8)	km. 100.33376



LONGITUDINAL SECTION OF OPENING



SECTION C–C

Figure 4.3-3 Inlet, Outlet and Openings of Box Culvert

4.3.3 Typical Cross Section of Delivery Pressured Pipelines

The alternative studies on the pipe material and the diameter and the number of rows are discussed in detail in Chapter "5.7 Delivery Pressure Pipeline". The pipeline of steel pipe for this project has been planned as follows:

Pipeline Construction

	Stage I Development	Stage II Development	Full Development
Diameter (mm)	2,400	2,400	2,400
Number of Row	3	2	5

The items to be considered for deciding the typical cross section of the pipeline will be as follow;

- Preceding construction of O&M road for using it as a construction road.
- Construction of necessary construction road in addition to the preceding construction of O/M road, if necessary.
- Selection of side slope of cut and fill sections for both temporary and permanent works and of necessary slope protection work.
- Selection of backfill materials and its compaction method by machinery.
- Location of spoil bank.
- Suitable materials for pipe bed.

The compacted laterite layer of 50 cm thick is planned as a bed of the pipe. The slope of the permanent earth work is planned at 1 : 3 for both cut and fill sections, whereas the slope of the temporary excavation is planned at 1 : 1.5. The asphalt paved O/M road with a width of 17 m and the compacted laterite layer on excavated trench bed will be used for installation work of the pipes. The backfill is planned up to a height of 1 m on the top of the pipe.

The design earth cover on the top of pipe for determination of pipe wall thickness shall be of 5 m in consideration of drifting sand deposit. The maintenance works to remove sand deposited on the pipe shall be carried out periodically for safety of the pipeline.

The typical cross section of the pipeline is shown in Figure 4.3-4.

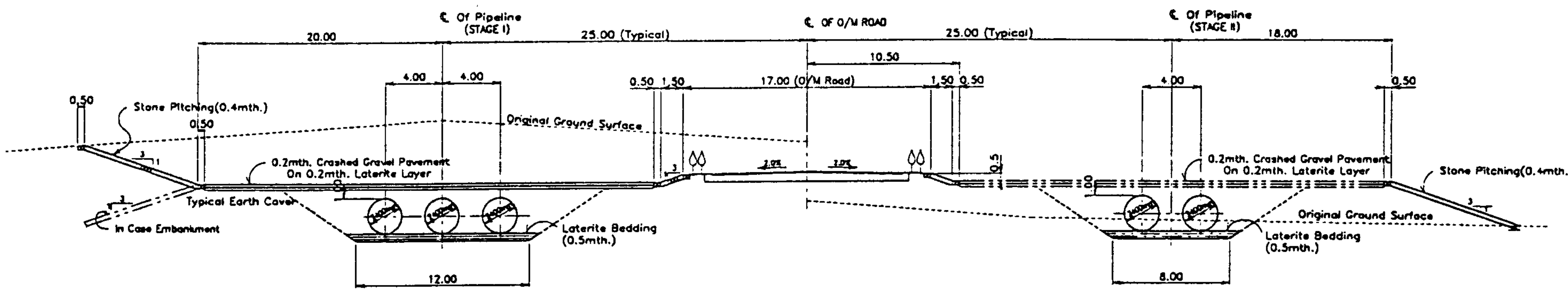


Figure 4.3-4 Typical Cross Section of pipeline

4.4 Basic Design of Appurtenant Structures

4.4.1 Spillway System

(1) Necessity of Spillway

The purpose of this conveyance canal is to convey 52.66 m^3/sec of irrigation and industrial water from the location at 86.5 km on the Shikh Gaber El Sabah Canal to the beneficial area so called the El Sir and El Kawareer zone having a gross irrigation area of 135,000 feddan. This conveyance canal has a length of 46 km and No. 7 pumping station is planned to be constructed at the location about 22.36 km downstream from the beginning point of the conveyance canal. No. 6 pumping station is under construction at the location 40 km upstream from the beginning point of the conveyance canal, but no spillway is planned on this canal route. At the time of flowing the design discharges, water amount stored in the canal with a length of about 62.36 km between No. 6 pumping station and No. 7 pumping station is estimated at about 4.59 MCM (refer to Figure 4.4-1). Because possible storage capacity of the canal below the top of canal embankment at No. 7 pumping station is estimated at 2.38 MCM, overtopping of flow will occur from the canal section near No. 7 pumping station at the time of a power failure and pump shutdown. Therefore, the construction of spillway will be indispensable to prevent collapse of canal bank caused by overtopping of flow and to keep safety of life of people lived or stayed near the conveyance canal and of social infrastructure such as highways, houses, etc.

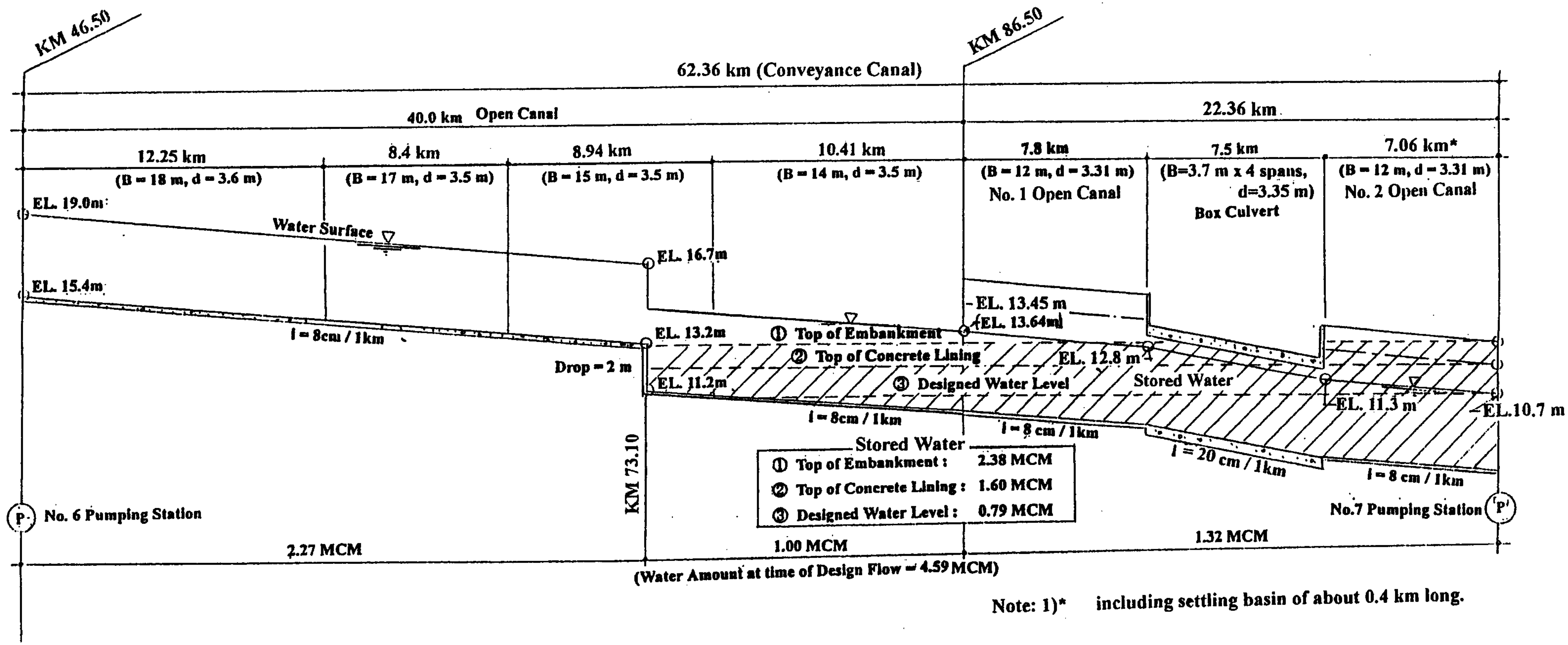
(2) Composition of Spillway System

There is no river around the site of the conveyance canal, and Bardawil lake and Mediterranean sea are far from No. 7 pumping station. Under such conditions, the lowland so called Sabkhet El Mustablq expanded both side of the highway located at 4.8 km north from No.7 pumping station will be only disposal point for the spillway of the conveyance canal. Released water from the spillway will overtop the highway embankment with a height of 0.5 to 1.0 m. There are two countermeasures to prevent such overtopping as shown below (refer to Figure 4.4-2):

Alternative 1 : To improve highway (rise of embankment) of 4.2 km long.
Alternative 2 : To provide a detention pond to store excess water released from the spillway by constructing a dike of about 1.5 km long from western edge of highway within the lowland to southern direction.

The length of highway to be improved in Alternative 1 is estimated at about 4.2 km that is 2.8 times longer than the length of a dike to be constructed in Alternative 2.

Alternative 2, which requires cheaper cost, is recommendable because construction cost will



Note: 1)* including settling basin of about 0.4 km long.

Figure 4.4-1 Profile of Conveyance Canal between No.6 and No.7 Pumping Stations

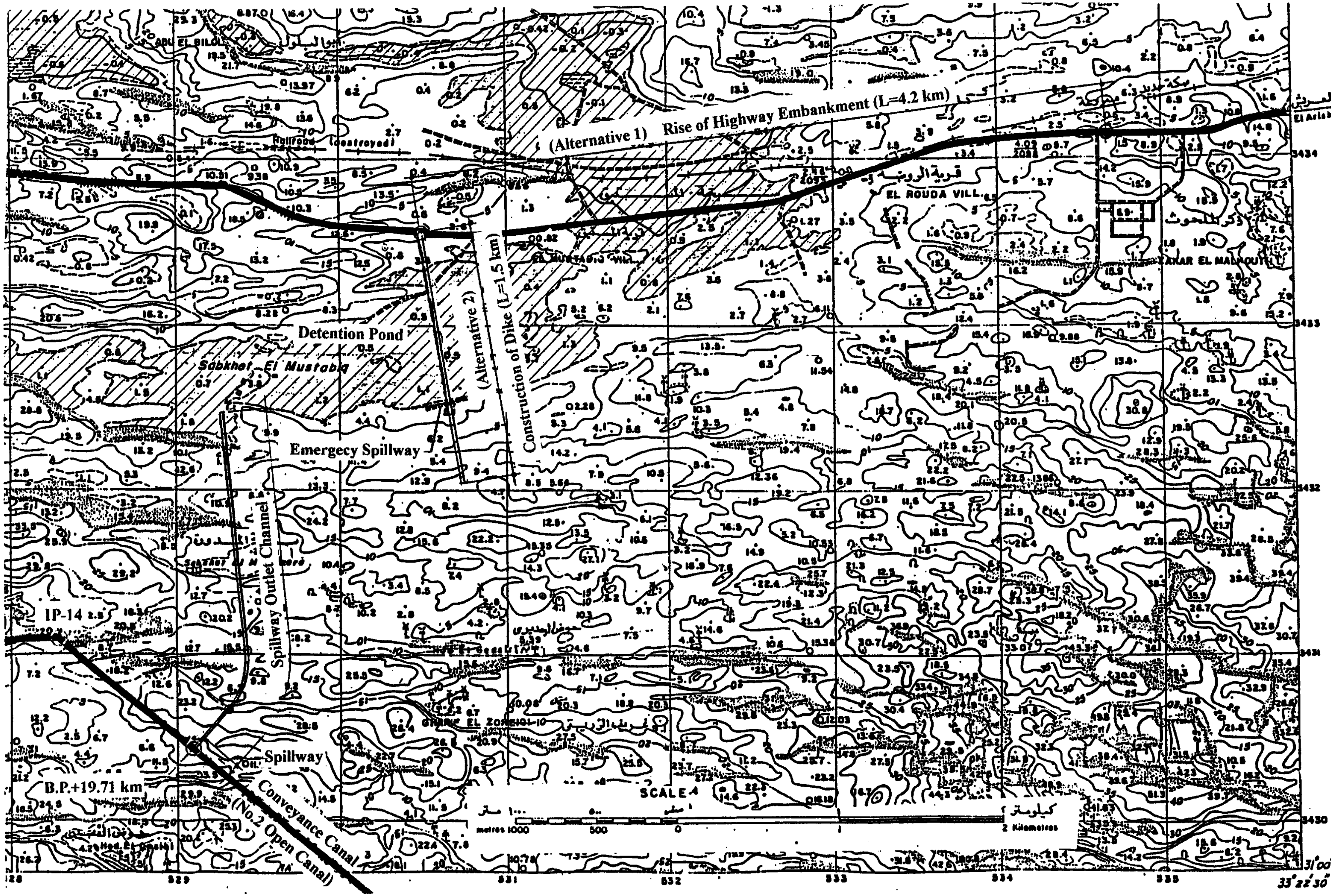


Figure 4.4-2 Alternatives of Spillway System

be in proportion to the length of highway to be improved and dike to be constructed. However, in the case of Alternative 2, the pond can not store all of released water from spillway on the conveyance canal if pump shutdown of No. 7 pumping station occurs again before the pond become empty by evaporation and seepage of stored water , although it is possible to predict the overtopping on highway embankment and to take necessary safety measures

The spillway system consists of the following structures (For the spillway system, see Figure 4.4-3) :

(1) Overflow type Spillway in combination with two gated sections in order to empty the canal for inspection, maintenance and emergency such as a canal bank failure.
(2) Spillway Outlet Channel of approx. 2.1 km long.
(3) Dike with emergency spillway to create the detention pond.

(3) Design of Spillway System

The spillway system will be designed under the condition that the conveyance canal flows designed discharges after completion of Stages I and II construction works. In the case that operation of No. 6 pumping station is stopped after three hours from the time of pump shutdown of No. 7 pumping station, water amount to be released from spillway can be calculated as shown below;

Water Amount to be Released from Spillway

(i) Inflow from No. 6 Pumping Station during 3 hours:	
52.66 cu.m/sec x 3 hr x 60 min x 60 sec =	0.57 MCM
(ii) Stored Water in Canal between No.6 and No.7 Pumping Station	4.59 MCM
(iii) Diverted Water through Turnouts: 3.27 MCM x 38.02 / 90.68 (m^3/sec) =	- 1.37 MCM
(iv) Stored Water below Spillway Crest:	- 0.79 MCM
Total	3.00 MCM

(a) Spillway

The spillway with the overflow crest of 38 m long (9.5m x 4 spans) is planned, in combination with two gated sections for emptying the canal. The water depth on the crest will be 0.84 m for draining the design discharge of 52.66 m^3/sec ($d= (Q/CB)^{2/3}=(52.66/1.8 \times 38)^{2/3}=0.84$ m). The preliminary design of the spillway is shown in Figure 4.4-4.

(b)Spillway Outlet Channel

The spillway outlet channel of approx. 2.1 km long are planned to release the excess water from the spillway to the detention pond. The design discharge of the spillway outlet channel is 52.66 m^3/sec and the preliminary design is shown in Figure 4.4-5.

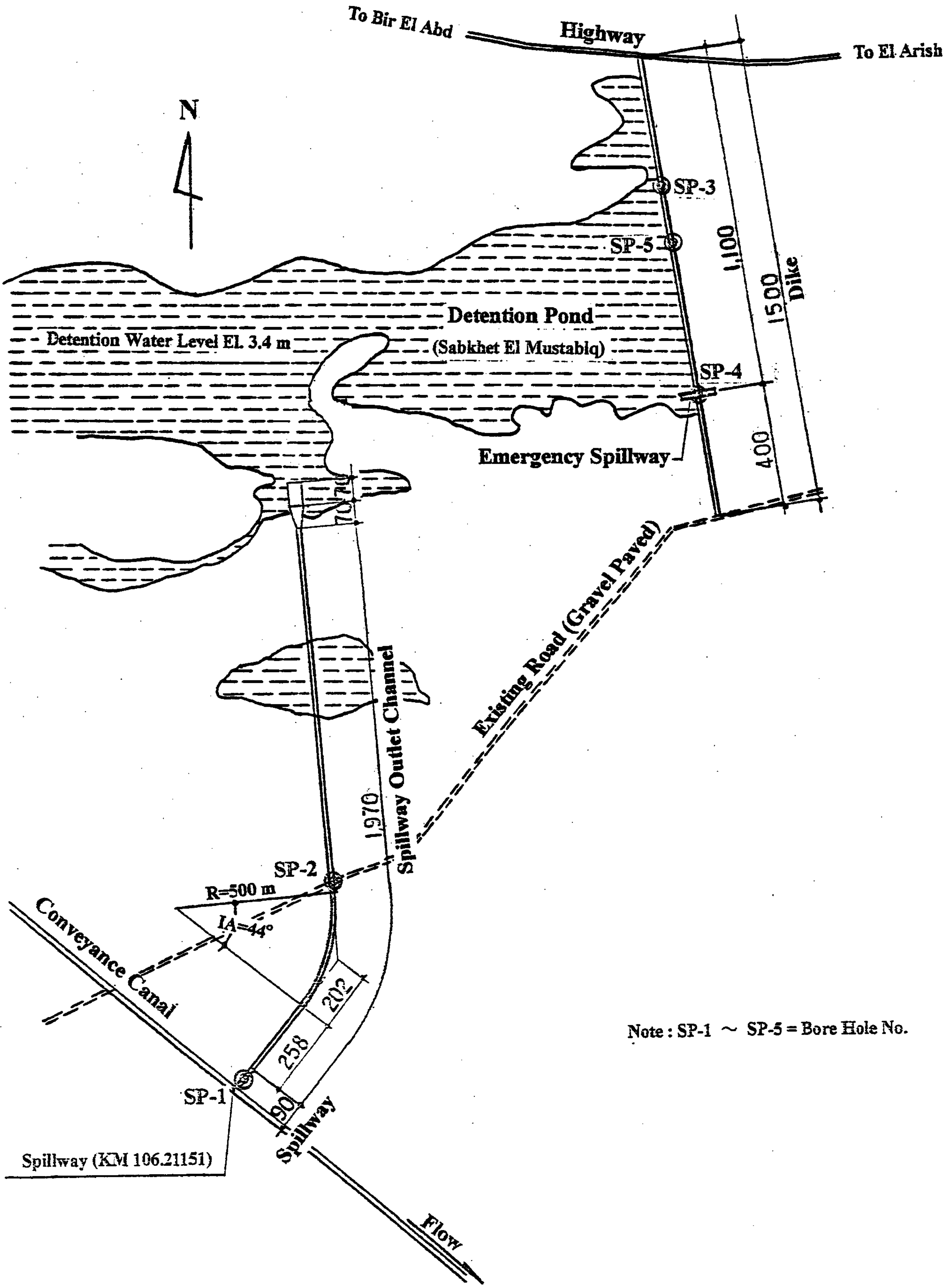
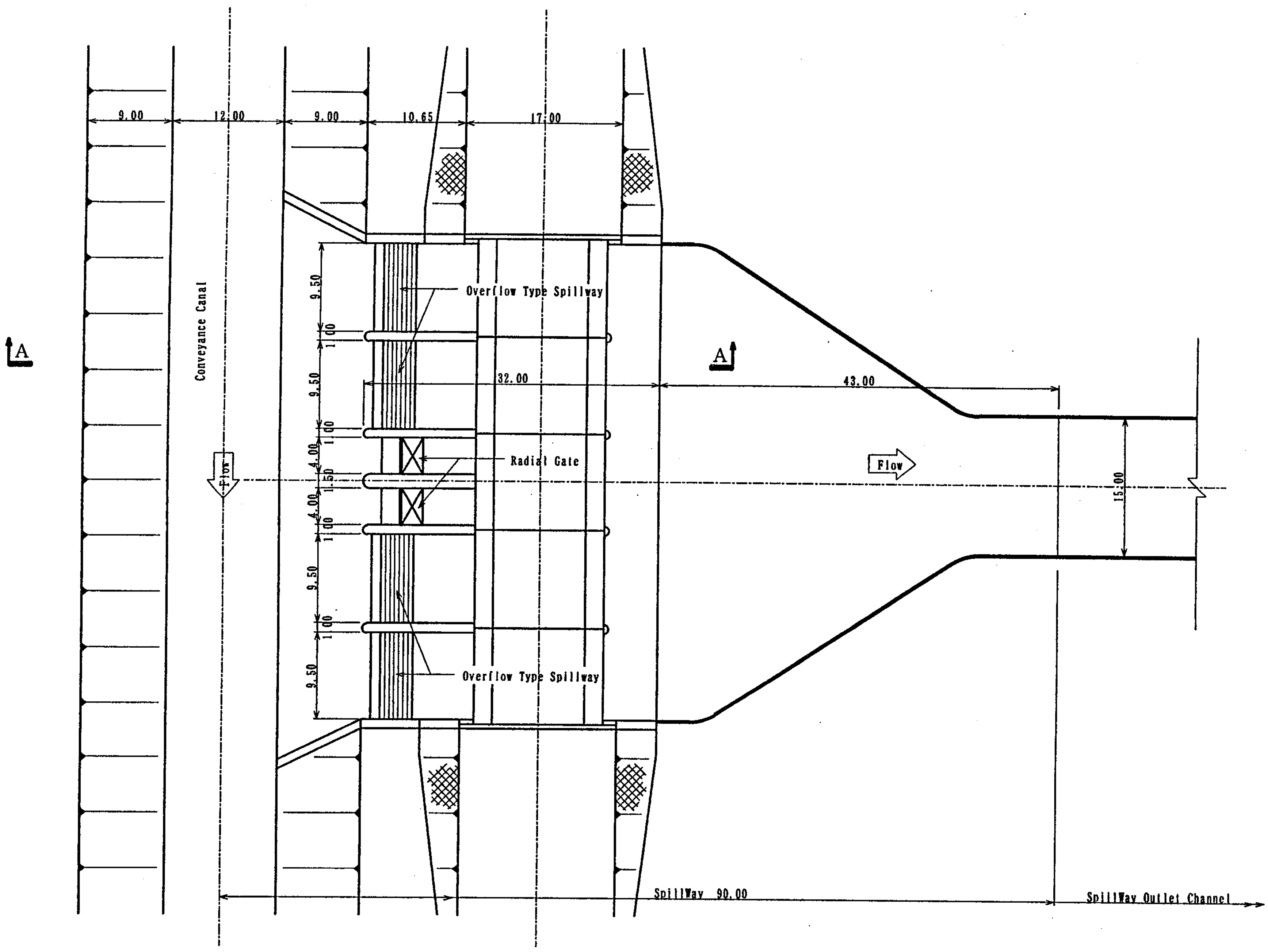
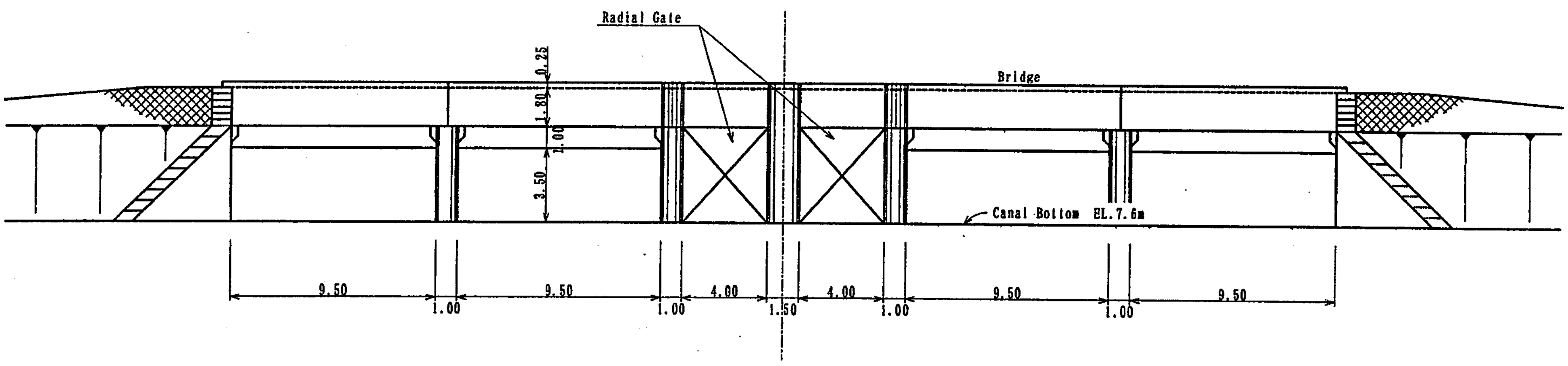


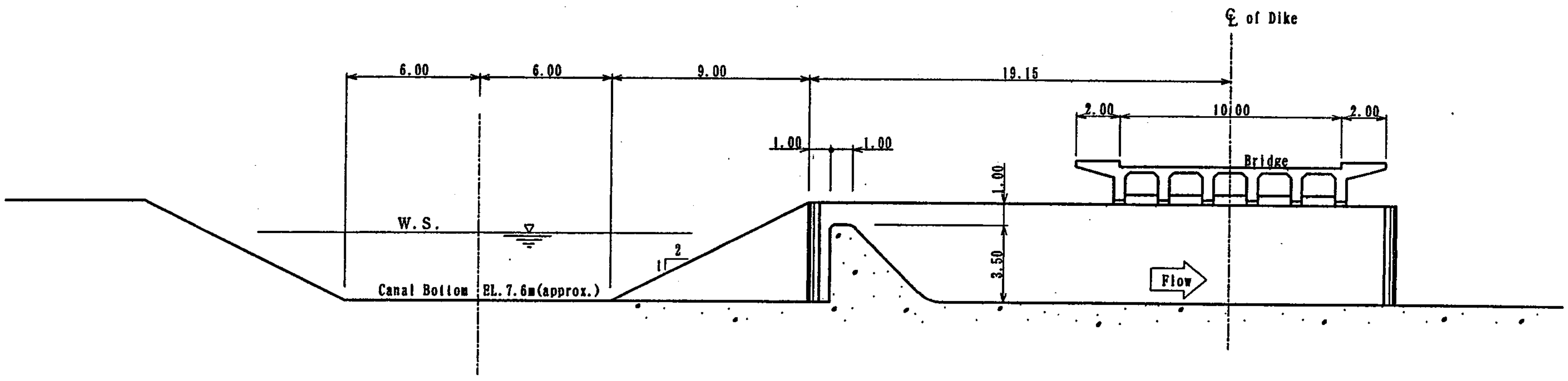
Figure 4.4-3 Layout Plan of Spillway System



PLAN OF SPILLWAY

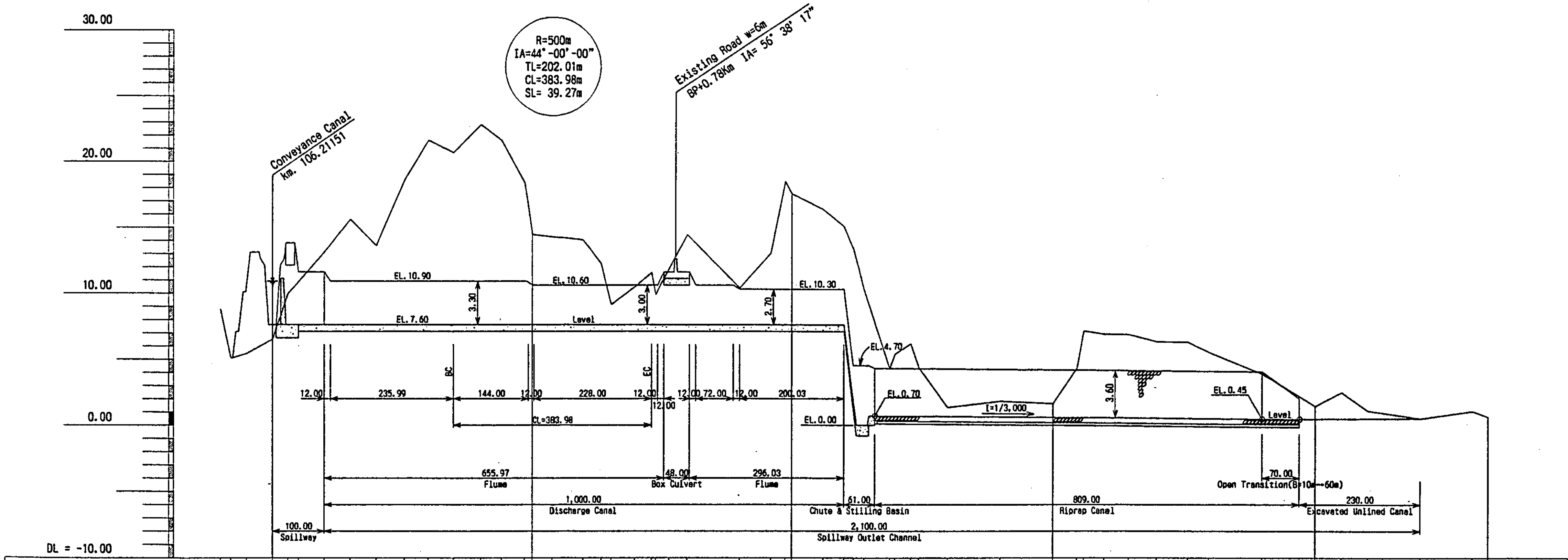


ELEVATION OF SPILLWAY



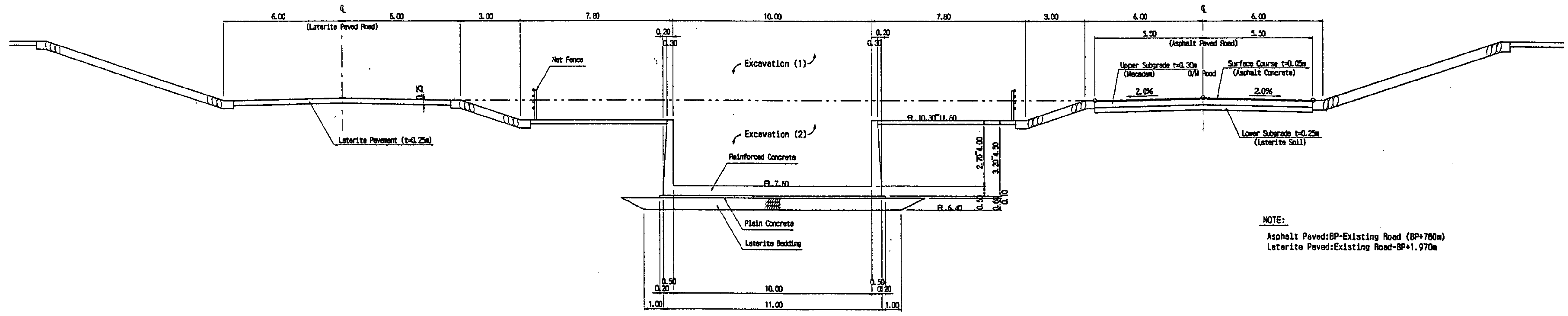
SECTION A-A

Figure 4.4-4 Plan, Elevation and Section of Spillway



DISTANCE (KM)	ORIGINAL GROUND LEVEL
-0.100	8.79
-0.080	5.06
-0.050	5.41
BP	7.23
0.030	9.96
0.050	10.86
0.100	13.10
0.150	15.58
0.200	13.58
0.254	18.55
0.300	21.57
BC-1	20.64
0.400	22.77
0.440	21.57
0.485	18.36
0.500	14.44
SP-1	14.25
0.600	14.04
0.635	12.23
0.655	9.13
0.700	10.46
EC-1	11.54
0.740	9.87
0.765	11.86
0.800	14.42
0.900	10.38
0.960	13.03
0.987	18.49
1.000	17.54
1.060	16.36
1.100	15.07
1.120	13.34
1.140	10.28
1.190	4.29
1.200	5.36
1.230	6.17
1.245	4.37
1.300	1.34
1.400	1.81
1.500	1.62
1.547	4.32
1.560	7.13
1.600	6.89
1.646	6.86
1.700	6.32
1.760	6.28
1.800	5.52
1.900	3.88
2.000	1.44
2.050	2.49
2.100	1.09
2.200	0.51
2.300	1.07
2.330	0.63

PROFILE



NOTE:
Asphalt Paved:BP-Existing Road (BP+780m)
Laterite Paved:Existing Road-BP+1.970m

TYPICAL SECTION OF DISCHARGE CANAL

Figure 4.4-5 Profile and Section of Spillway Outlet Channel

(c) Dike and Emergency Spillway

The dike construction is necessary to create a detention pond with a storage capacity of 3 million m^3, and an emergency spillway having a design head of 1.1 m ($d=(Q/CB)^{2/3}=(52.66/1.8 \times 9.5x3)^{2/3}=1.02=1.1$ m) should be also provided for keeping the safety of the dike.

The preliminary design of the dike and emergency spillway is shown in Figure 4.4-7.

4.4.2 Bridge

The bridges with 10 m roadway and sidewalks, as shown in Figure 4.4-8, are planned at the locations shown below and in Figure 4.4-9, which have been agreed upon and decided between NSDO and the Study Team.

Location of Bridges

(1) On the existing roads :

(a) Location No.1: on No.1 Open Canal Section	Km. 90.566
(b) Location N0.2: on Box Culvert Section	Km. 94.76673
(No bridge construction. The existing road is restored on the box culvert section.)	
(c) Location No.3: on No.2 Open Canal Section	Km. 105.70888
(d) Location No.4: on Spillway Outlet Channel	780 m downstream from the beginning point of the spillway. (refer to Figure 4.4-5)

(2) Newly Planned :

(a) Location No.5: on No.3 Open Canal	Km. 122.8
(b) Location No.6: on No.3 Open Canal	Km. 127.9
(c) Location No.7: on No.3 Open Canal	Km. 132.4

In addition to the locations above, the bridges will be planned at the locations of the spillway, emergency spillway, etc.

4.4.3 Safety and Maintenance Devices

The following devices will be provided on the open canal for the protection of the public, easy maintenance of the facilities, etc.

(1) Stairway... ... ...about 500 m interval on open canal sections

(2) Trash Rack... ... ... upstream end of box culvert section, and immediate upstream of No. 7 pumping station

(3) Stop-log Gates... ... ...upstream and downstream ends of box culvert section, and upstream end of settling basin

(4) Entrance to Box Culvert... ... about 1 km interval on box culvert section

(5) Staff Gauges ... ...at the places of beginning point, upstream and downstream end of box culvert section, spillway, upstream end of settling basin, and upstream end, middle point and downstream end of No. 3 open canal

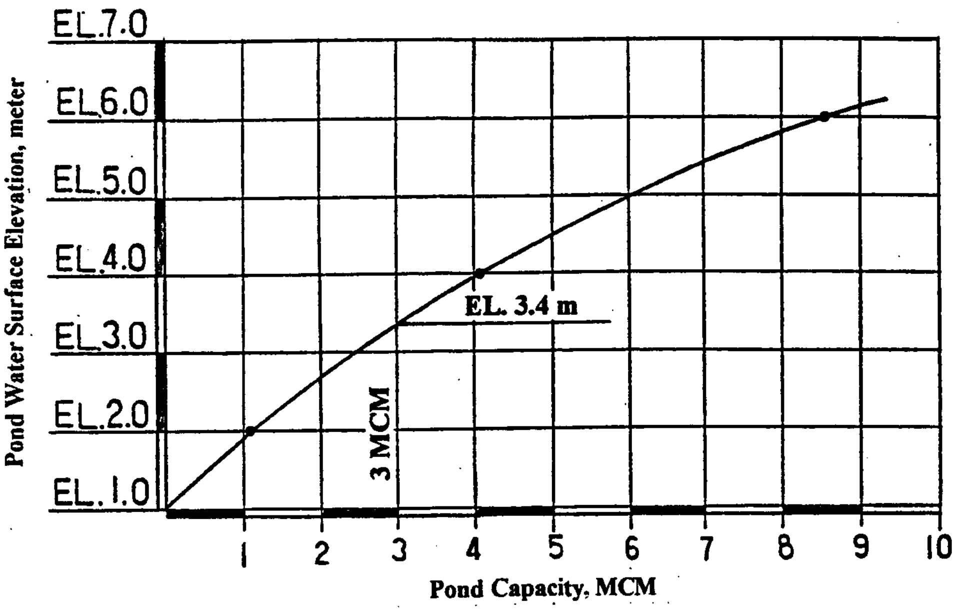
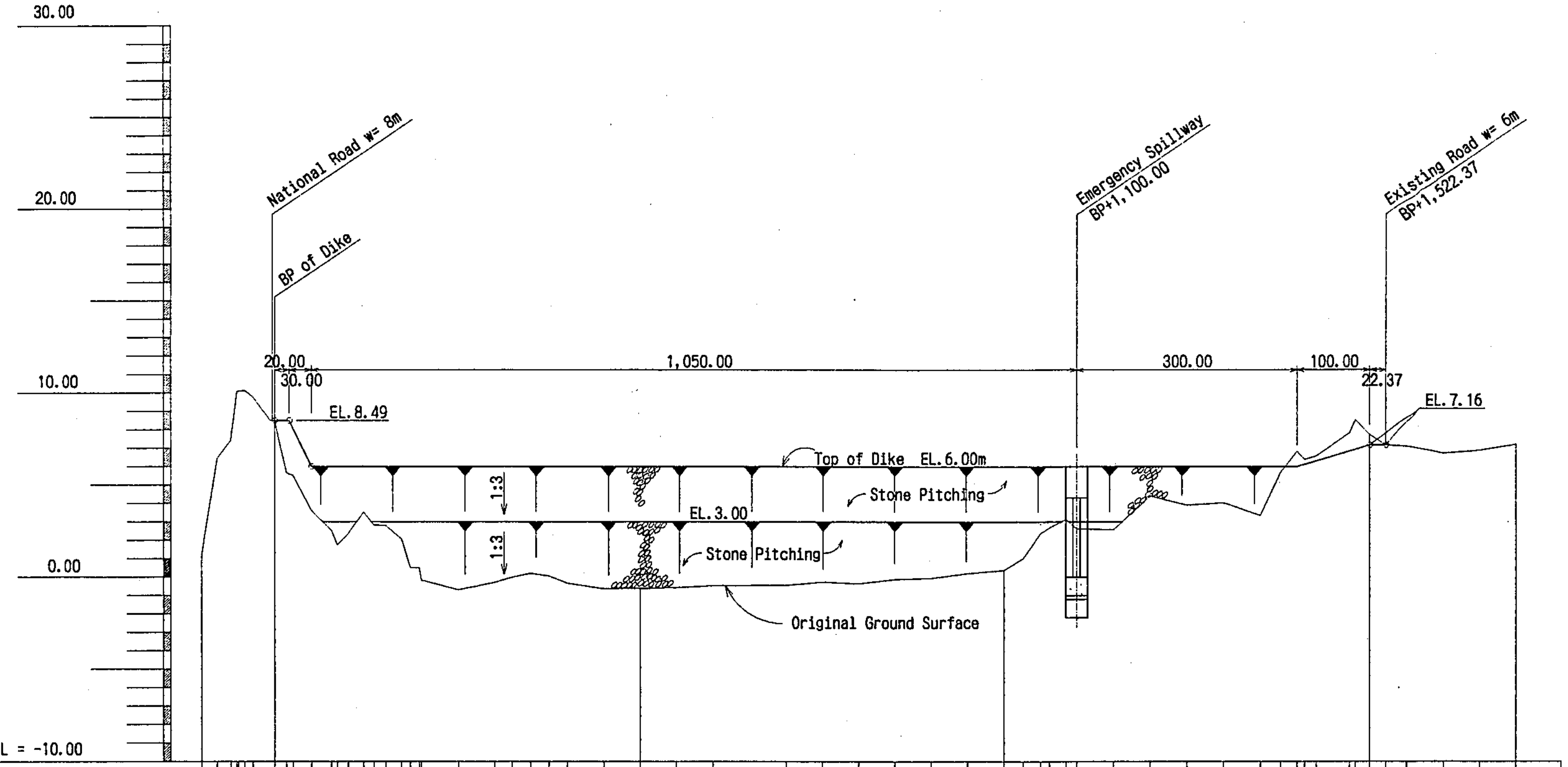


Figure 4.4-6 Detention Pond Capacity Curve

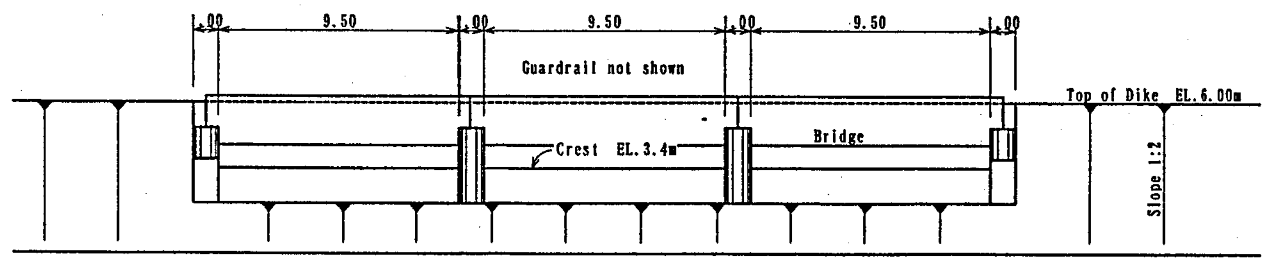
Table 4.4-1 Detention Pond Capacity

Pond Water Surface		Pond Capacity (1,000 m^3)
Elevation (EL. m)	Area (1,000m^2)	
EL. 1.0	938	0
EL. 2.0	1,209	1,073.5
EL. 4.0	1,783	4,065.5
EL. 6.0	2,675	8,523.5

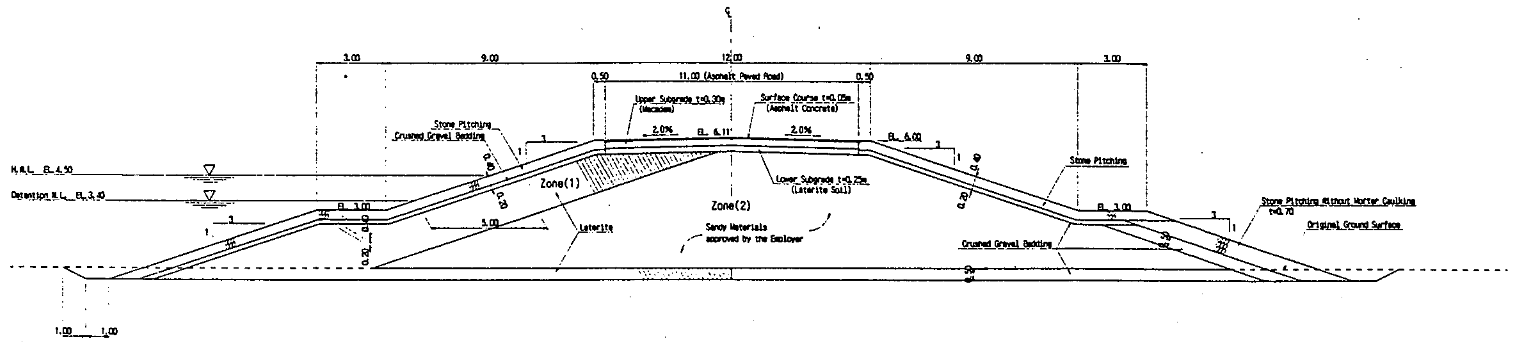


DISTANCE (KM)	ORIGINAL GROUND SURFACE
-0.100	1.21
-0.079	6.43
-0.060	7.40
-0.052	10.02
-0.050	10.10
-0.041	10.12
-0.030	9.79
BP	8.49
0.016	5.65
0.025	5.52
0.050	3.59
0.077	2.54
0.085	1.75
0.100	2.36
0.121	3.53
0.135	3.83
0.151	2.79
0.173	2.06
0.187	[illegible]
0.197	0.49
0.200	-0.16
0.250	-0.70
0.300	-0.28
0.324	-0.02
0.350	0.25
0.375	0.06
0.400	-0.33
0.450	-0.64
0.500	-0.63
0.550	-0.58
0.600	-0.48
0.700	-0.44
0.750	-0.27
0.800	-0.36
0.850	-0.11
0.900	-0.05
0.950	0.20
1.000	0.37
1.026	1.02
1.050	2.37
1.062	2.68
1.085	3.14
ES	2.63
1.150	2.57
1.200	4.38
1.250	3.90
1.300	4.03
1.350	3.34
1.378	5.70
1.400	6.83
1.410	6.39
1.426	6.58
1.472	7.82
1.480	8.54
1.500	7.73
IP-1	7.16
1.550	7.09
1.600	6.71
1.650	6.88
1.700	7.20

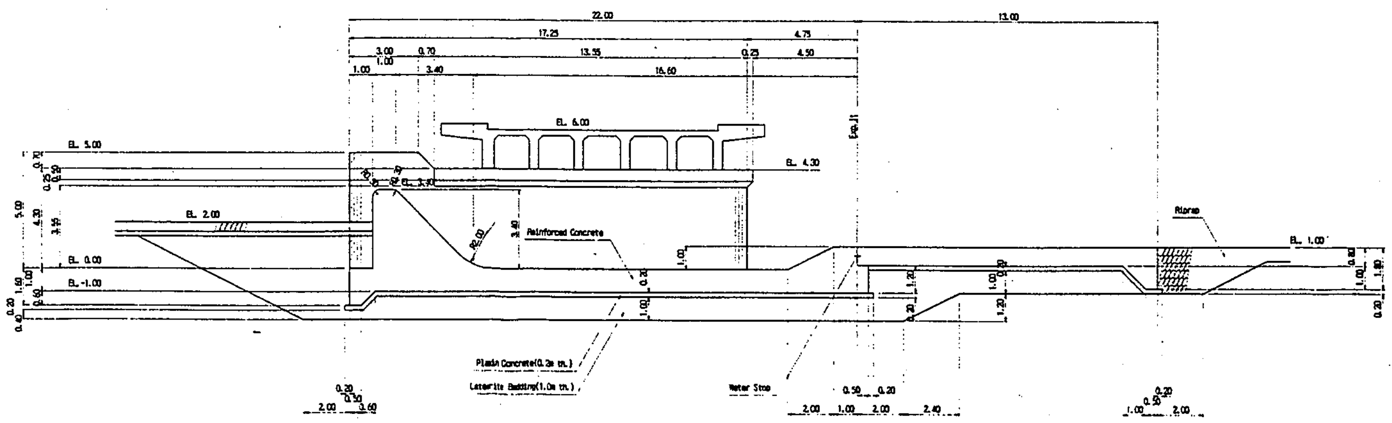
PROFILE



ELEVATION OF EMERGENCY SPILLWAY
NO SCALE

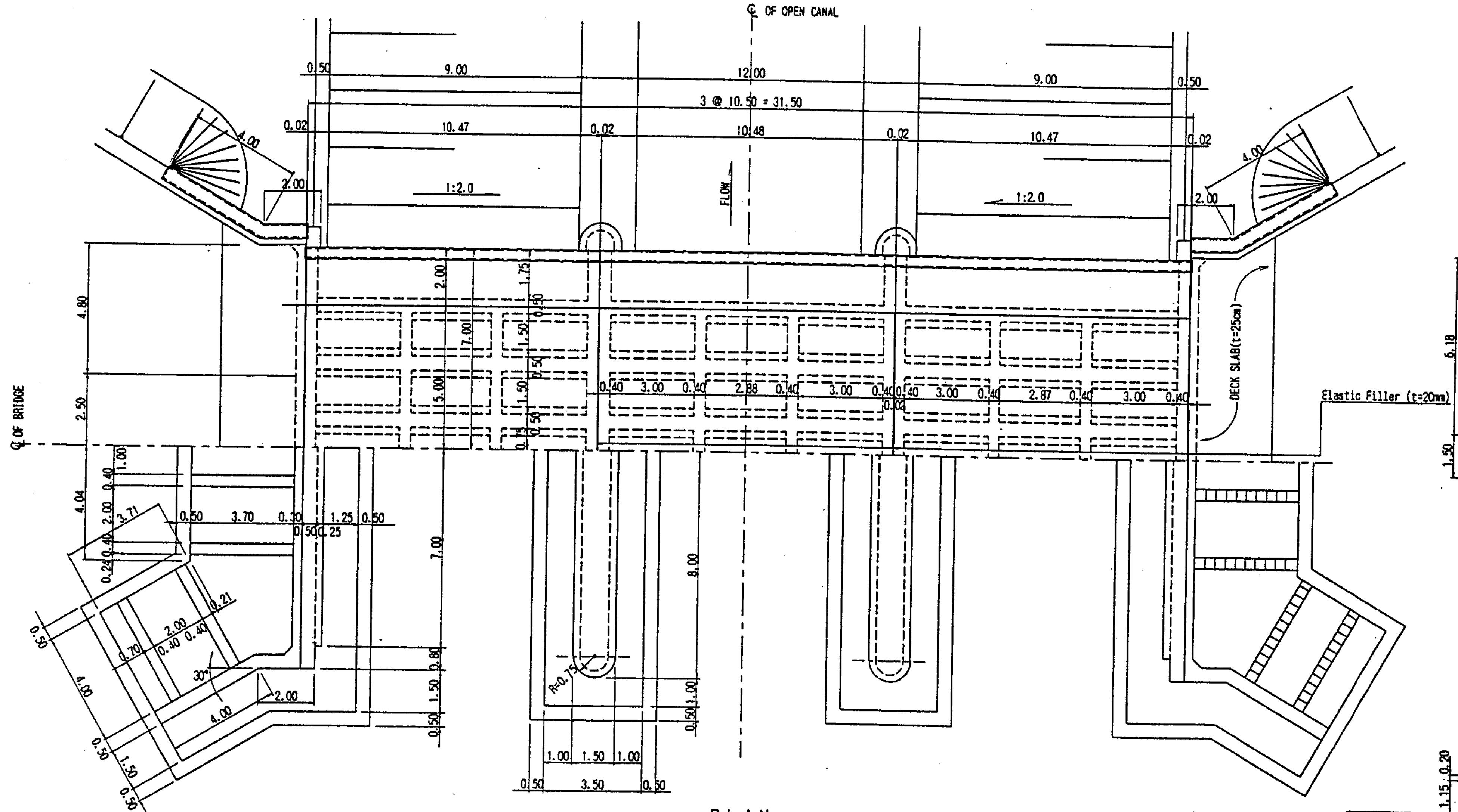


TYPICAL CROSS SECTION OF DIKE
NO SCALE

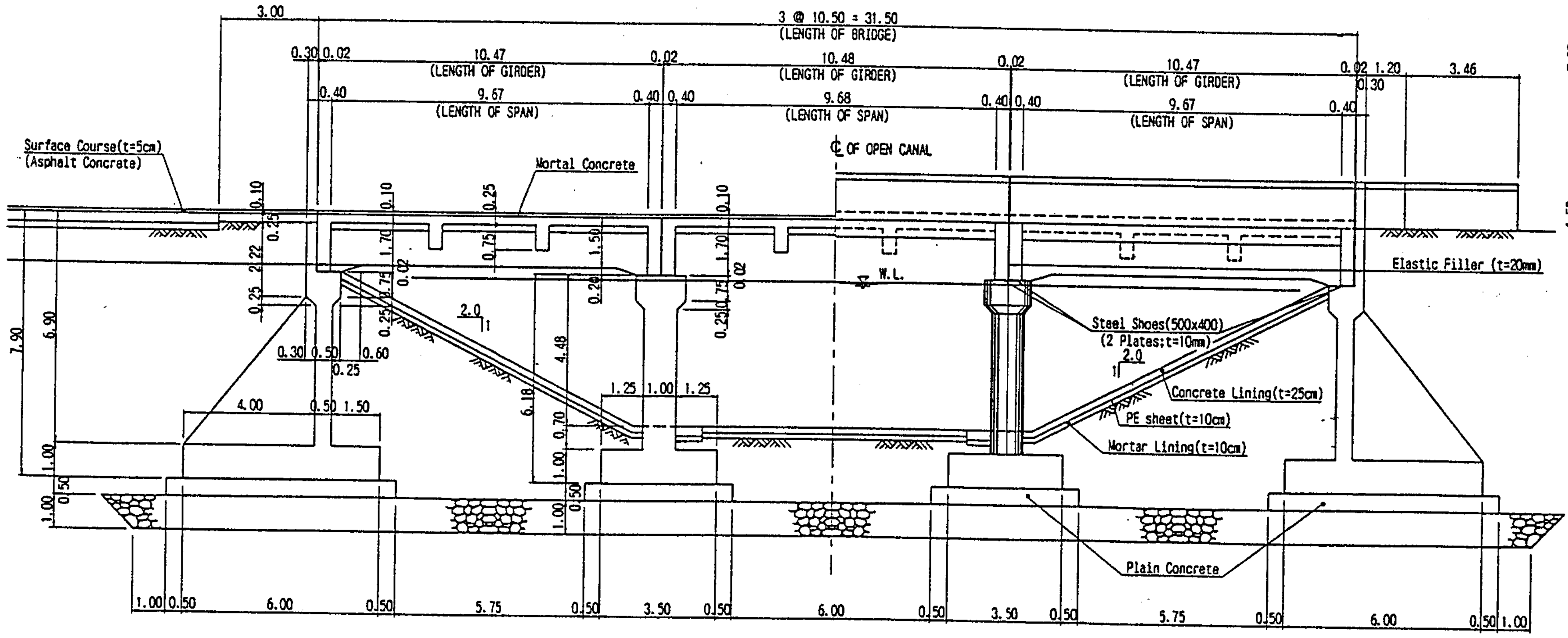


LONGITUDINAL SECTION OF EMERGENCY SPILLWAY
NO SCALE

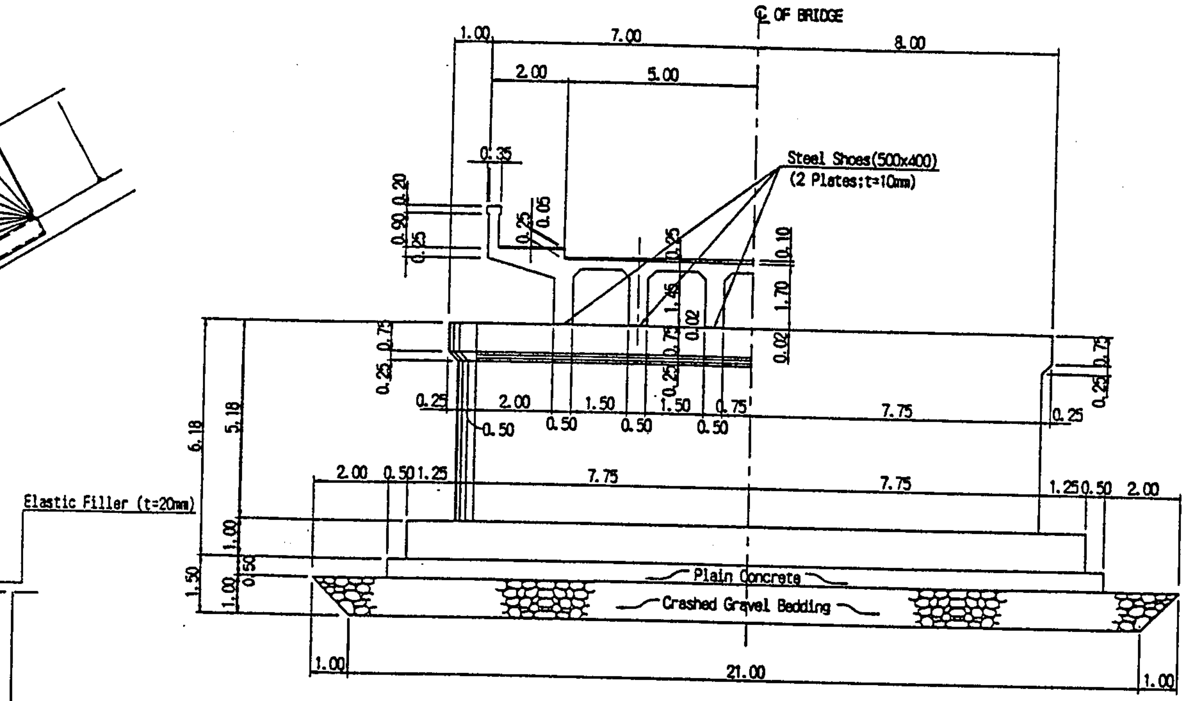
Figure 4.4-7 Profile and Section of Dike, Longitudinal Section and Elevation of Emergency Spillway



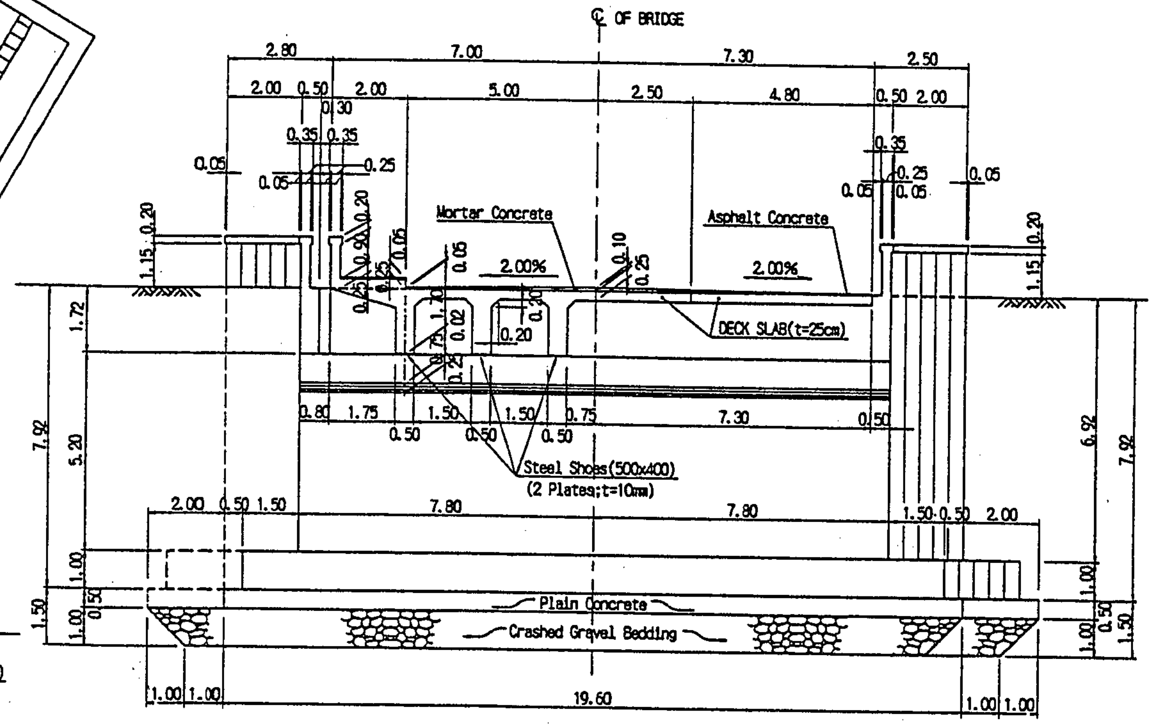
PLAN
SCALE 1:200



ELEVATION
SCALE 1:200

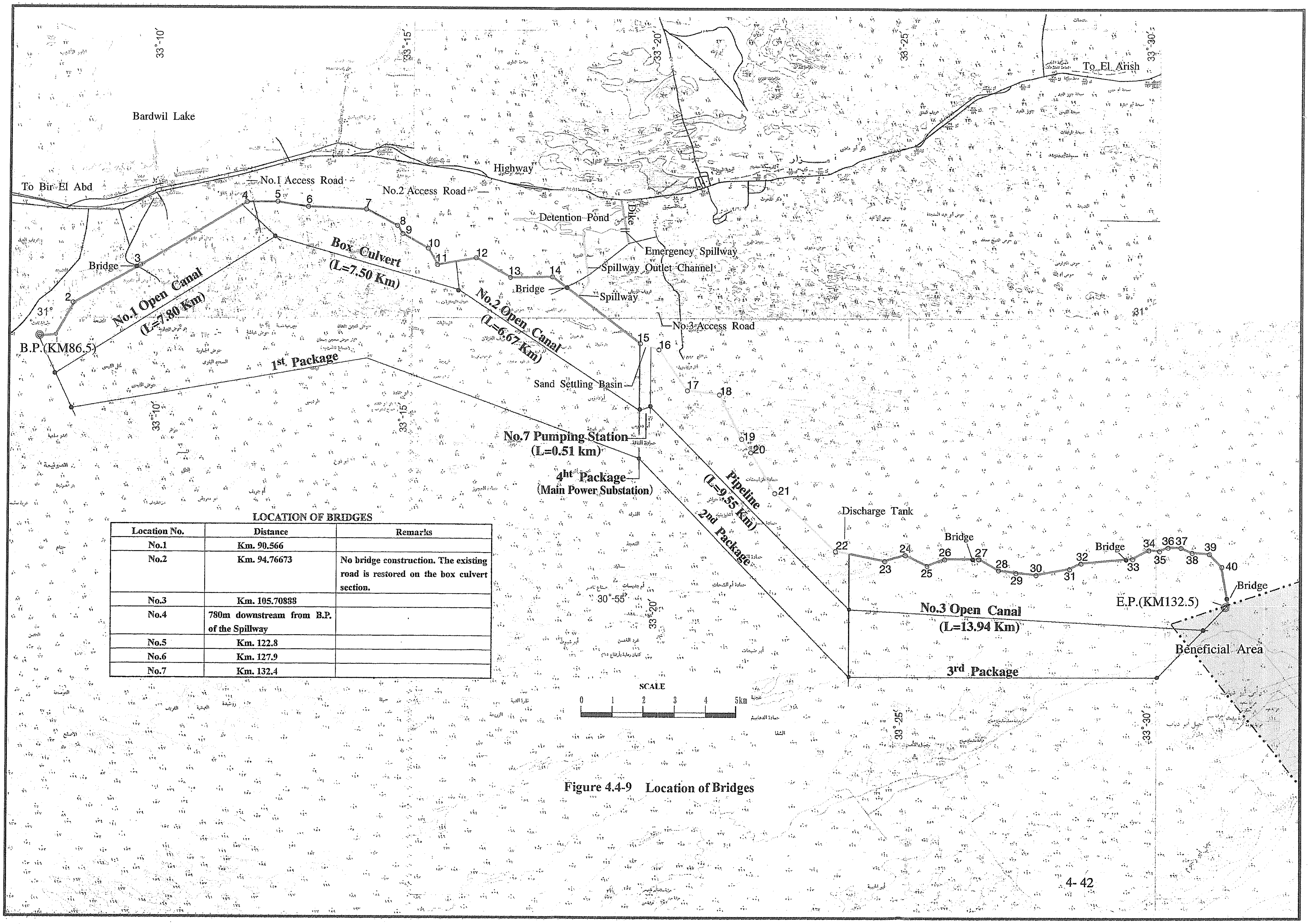


ELEVATION OF PIER
SCALE 1:200



ELEVATION OF ABUTMENT
SCALE 1:200

Figure 4.4-8 Elevation and Section of Bridge



LOCATION OF BRIDGES

Location No.	Distance	Remarks
No.1	Km. 90.566	
No.2	Km. 94.76673	No bridge construction. The existing road is restored on the box culvert section.
No.3	Km. 105.70888	
No.4	780m downstream from B.P. of the Spillway	
No.5	Km. 122.8	
No.6	Km. 127.9	
No.7	Km. 132.4	

Figure 4.4-9 Location of Bridges