5.7 Delivery Pressured Pipeline

Procedure of basic design pipeline will be carried out as shown Figure 5.7-1.

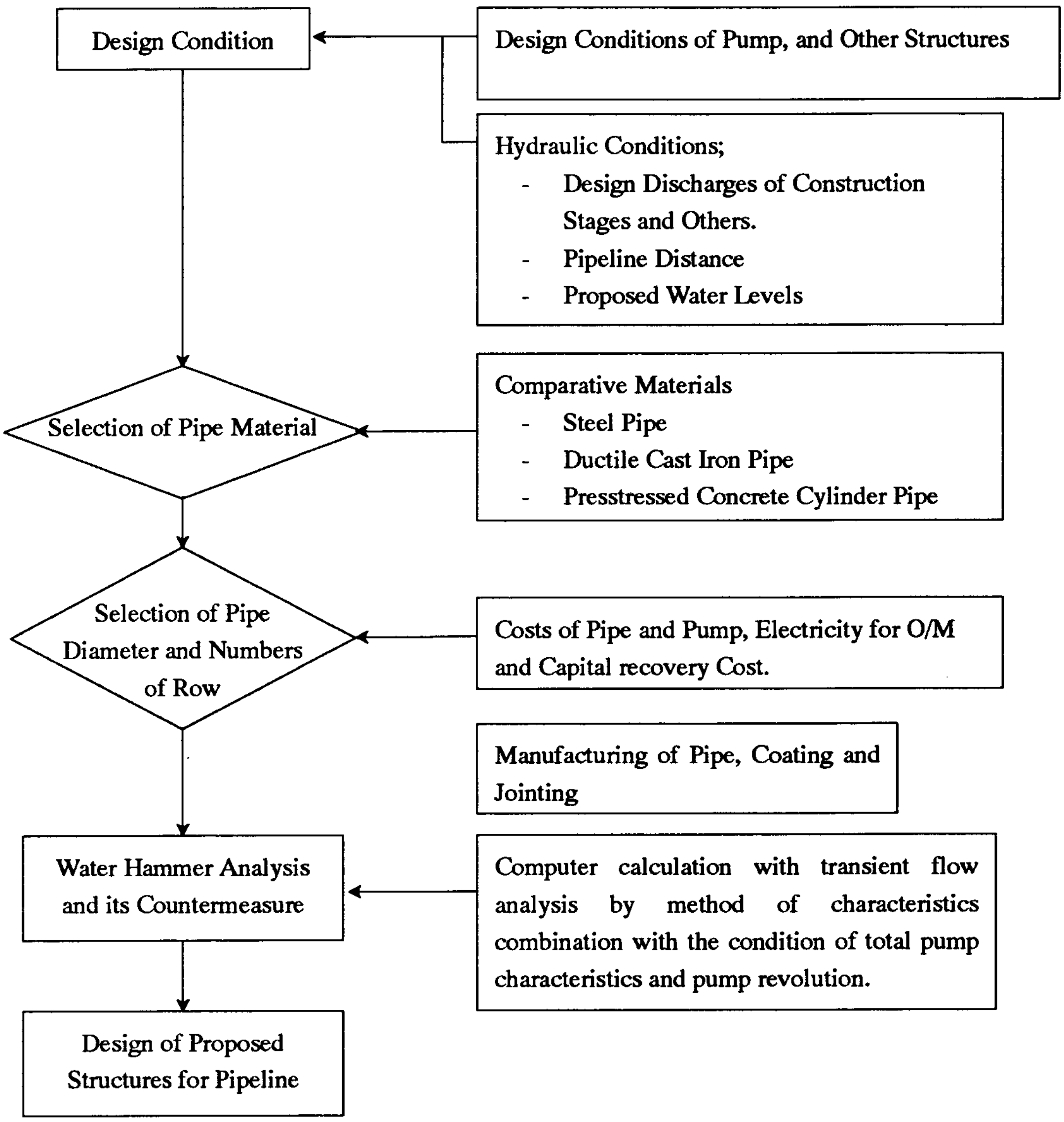


Figure 5.7-1 Flow Chart for Basic Design of Pipeline

5.7.1 Hydraulic Conditions of the Pipeline

Hydraulic conditions of delivery pressured pipeline are summarized as follows;

(1) Design Discharge

Design discharges of each construction stage are as follows;

Stage I ; Q = 32.48 m^3/s including 2.96 m^3 /s of industial water requirement

Stage II; Q = 20.18 m^3 /s including 2.82 m^3 /s of industial water requirement

Design discharge of the pipeline are determined in accordance with the pump operation unit. The following tables are shown pipeline discharges of one row at each stages. Three rows of pipe for Stage I and 2 rows of pipe for Stage II were proposed through series of disscussion with NSDO officail concerned as indicated in Section 6.9.3 of the Progress Report (2).

Design Discharge of pipeline at Stage I m^3 /s

Pump operation unit	Total pump discharge	Discharge of the pipeline
3 units operation	32.481	10.827
2 units operation	21.654	7.218
1 units operation	10.827	3.609

Design Discharge of pipeline at Stage II m^3 /s

Pump operation unit	Total pump discharge	Discharge of the pipeline
2 units operation	21.654	10.827
1 units operation	10.827	5.414

(2) Design Water Level and Surging Pressure

(a) Proposed water level

- Water level at Suction Sump

WL1	Stage I	Stage II
HWL (m)	10.70	10.70
NWL (m)	9.90	-
LWL (m)	8.80	8.80

- Water level at Discharge Tank

WL2	Stage I		Stage II	
	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)	Water level (m)
HWL	10.827	92.90	10.827	92.90
NWL	7.218	92.68	-	-
LWL	3.609	92.43	5.414	92.56

Over flow depth on the discharge tank crest is 90 cm as discussed in Secter 5.8.2. in the case of HWL, and in the other cases, each depth is calculated by the formula in the same Sector.

(b) Head lose of pipeline

Head losses of pipeline with diameter of 2,400 mm at each discharges are estimated as follows;

Stage	Pump operation unit	Discharge (m^3 /s)	Head loss of Pipelene(m)
Stage I	3	10.827	14.78
	2	7.218	6.96
	1	3.609	1.92
Stage II	2	10.827	14.78
	1	5.414	4.08

(3) Optimum Design Velocity

Optimum design of pipe diameter shall be determined in the consideration that mean velocity of pipe will affect energy cost, cost of pumping plants and pressured pipes. Therefore, the ranges of optimum design velocity of pipe are to be 1.50~2.50 m/sec.

(4) Water Hammer Pressure

The water hammer pressure of the pump deliverly pipeline will be estimated up and down surge pressures in case of pump sudden stop. In general, both empirical estimation and elastic theory-based unsteady flow analysis by computer will be applied.

(a) Empirical estimation

- Dynamic head = 92.90 (water level of discharge tank) + 14.80 (head loss of pipeline) - 9.20(pipe center elevation) = 98.5 m, say 9.9 kg/cm^2
- Up surging : 60% of total head = 9.9 × 0.6 = 5.9 kg/cm^2
- Water pressure of up surging is 9.9 + 5.9 = 15.8 kg/cm^2

(b) Water hammer calculation by unsteady flow analysis

Up surging elevation is about 175 m without countermeasure of down surge. Then, up surge pressure at pump is about 16.6 kg/cm^2 and down surge pressure is about 5.8 kg/cm^2 as shown Figure 5.7-3.

5.7.2 Selection of Pipe Materials and Production Technology

(1) General

Suitable pipe materials to be used for the project are “steel pipe”, “cast iron” and “PCCP (Pre-stressed Concrete Cylinder Pipe)”. Selection of pipe materials shall be considered following key factors, such as technical reliability of main body of the pipe as well as joint mechanism, hauling and installation method, construction workability, production capacity and cost economy, etc.

(2) Structural Reliability of Pipes

The key factors related to structural reliability of pipes will be as follows;

- Structural safety of pipe body and pipe joint mechanism
- Water tightness of pipe installed
- Countermeasures for pipe corrosion
- Pipe production technology at factory
- Workability of the pipe hauling and installation (This factor will be judged based on the pipe weight, allowable deflection angle for pipe installation)
- Production and supply capacity of the pipe
- Experience of large size pipe installation
- Adaptability to undulating sand dune area

The results of comparative studies for structural reliability of pipes are tabulated in Table 5.7-1 and 5.7-2. As shown in these tables, acceptable pipe materials for the project are steel pipe and cast iron pipe judging from the required Test Water Pressure of approx. $2\times(11.9\sim 7.8) = (23.8\sim 15.6)$ kg/cm^2. (Refer to Figure 5.7-6, 11.9 kg/cm^2 at beginning point of pipeline and 7.8 km/cm^2 at km 1.40)

Table 5.7-1 Comparative Study for Structural Reliability of Pipes

Key Factor	Steel Pipe	Cast Iron Pipe	PCCP
1.Safety of main body of the pipe	Satisfactory	Satisfactory	Satisfactory
2.Joint mechanism of the pipe	Perfect	Perfect (K-type)	Limitation
3.Water tightness of the pipe	Satisfactory	Satisfactory	Satisfactory
4.Allowable deflection angle	None	1.5 degrees	1.0 degree
5.Countermeasures for corrosion	Possible	Possible	Possible
6.Pipe production technology	Low bending and welding tech.	Perfect	Perfect
7.Workability of hauling and installation	Light weight but, need high welding technology	Heavy weight but easy connection of joint	Heavy weight but, accuracy of installation
8.Production and supply capacity	To be cooperated	100 % imported for large diameter	Only two factories
9.Experiences of large size production in Egypt (More than 2,000 mm)	A few xperiences	No experiences because of all imported	A few experiences
10. Adaptability of undulated sand dune area	Adaptable because longitudinally reliable strength	Adaptable because longitudinally reliable strength	Needs careful considerations due to no longitudinal reliable strength
11. Overall evaluation	*Advantage* - Tight for water pressure at joint - Light weight *2.Disadvantage* -Needs technology of bending and welding process *3.Acceptable*	*Advantage* -Tight for water pressure at joint for K-type - Heavy weight *2.Disadvantage* - All imported for large scale diameter 3. *Acceptable*	*Advantage* - Perfect of main body *2Disadvantage* - Heavy weight - Limited deflection angle for installation 3. *Not suitable*

Table 5.7-2 Characteristics of Joint Structures of Pipe

Type	Structures	Specification	Design water pressure (kg/cm^2)
1.Fixed Joint	Flange joint	-Connection of flange end pipes with rubber packing and bolts for SP, CI -PC pipe for PCCP option	
2. Joint	Welding joint	-Connection of pipes end by welding for SP only, -Cylinder core welding with steel collar for PC for PCCP option	Depending on welding efficiency
3.Flexible Joint	Rolling joint	-Normal joint with rubber ring for PC -Similar joint PC for PCCP option	6.0 (N. A.)
4.Flexible Joint	Back up joint	-Connection of pipes with rubber gasket and stopper bolts for PC -Similar joint of bell bolt type harness for PCCP option	9.0 (N.A.)
5.Flexible Joint	Double spigot joint	-Connection of pipes with steel collar and double rubber ring for PC pipe	12.0
6.Flexible Joint	Mechanical joint K type	-Connection of pipes with push on rubber ring and push ring for CI	38.5

Source : MOAFFJ's standard (Pipeline)

Note : SP=Steel Pipe, CI=Cast Iron Pipe, PC=Pre-stressed Concrete Pipe

In general, Test Water Pressures (Hsc) of the flexible pipe joint shall be equivalent and or more two(2) times of the design water pressures (H). Such as,

$$HSC \geqq S \cdot H$$

Where : HSC : Test water pressure (kg/cm^2)

H : Design water pressure (kg/cm^2)

S : Safety factor (normally 2.0)

Acceptable joint structures of the pipes against the Test Water Pressures 23.8 ~ 10.0 kg/cm2 are applied only steel pipe (SP) and cast iron (CI). The said test water pressures shall be two times of actual acting pressures as indicated in the Figure 5.7-6 as an example. Therefore, the pipe to be used for the project will be selected through economical comparison among steel pipe and cast iron pipe.

(3) Cost comparison

Pipe costs consists of expences for supply of pipe materials, welding, coating, X-ray and water pressure testing, hauling and or freight charges, and installation etc. Summary of cost comparison of the 2,400 mm diameter is tabulated as follow:

Table 5.7-3 Cost Comparison per Linear Meter

Cost Item	Steel pipe	Cast iron pipe
1.Pipe dimension -Diameter (mm) -Thickness (mm) -Standard length of unit (m) -Weight per unit (ton/unit)	 2,400 22 9.0 11.80(1.311t/m)	 2,400 36.5 4.0 10.08(2.52t/m)
2.Pipe material cost at factory and or CIF base per one unit	20,200/74,500	43,200
3.Welding cost at factory per unit for thickness 22 mm case	24,800/0	0
4.Coating cost at factory for internal and external	12,600/0	Included into item 2.
5.Hauling cost per unit (100km between factory/site case)	2,600	2,631
6.Site welding and coating per one unit	Included into item 7	0
7.Installation cost per one unit	5,700	250
8.X-ray testing per one unit	1,800	0
9.Sub-total	67,700/84,600	45,856
10.Fitting cost for 2 % weight of main pipe weight	5% of item 9. 3,400/4,230	5% of item 9. 2,293
11. Total cost per one unit	71,100/88,830	48,149
12. Total cost per meter	7,900/9,870	12,037
13. Total cost per ton	6,026/7,528	4,777

Note : For selection of suitable size of steel pipe, refer to section 5.7-3
Cost by domestic product/Cost by import in case Steel pipe

(4) Production Technology

As results of inspection and discussion with several steel pipe manufactures in Cairo and the other, the following techical matters shall be taken account with the manufacturing and construction of steel pipeline for comformity of the requirement;

- Quality shall be satisfied on the manufacturing in the factory.
- Material shall also be satisfied as specified quality of material.
- Accuracy of roundness of pipe is the most important technical matter.
- Production capacity shall be the required amount of pipe.
- Method of erection, installation and welding of the pipe shall be the manner of satisfactory to keep well performance.
- Manner of coating and jointing internal and external of pipe shall be the specified quality to privent errosion and corrosion agaist water flow and chemical errosion.

There are two manufacturing methods for big size steel pipe such as more than ϕ2,000mm. One is the spiral welding method and the other is bending roll method among the various pipe welding methods. The pipe manufacturing method of this Project will be applied to bending roll method because of the pipe wall thickness, cost of pipe manufacturing and acuracy of pipe roundness. .

The procedure of pipe manufacturing of the bending roll method is shown in the Figure 5.7-2. And major points to be considered for the high pressured pipeline are the accuracy of roundness and the quality of welding.

The most important point of the pipe manufacturing in the factory is the minimize of its circular deflection due to the welding of pipe each other in the field with required quality of welding. The value of deflection of pipe each other shall be less than 4 mm.

Furthermore, the automatic welding may be acceptable in the factory welding and the quality of the welding result shall be in conformity of required criteria under the super-sonic wave inspection or x-ray test.

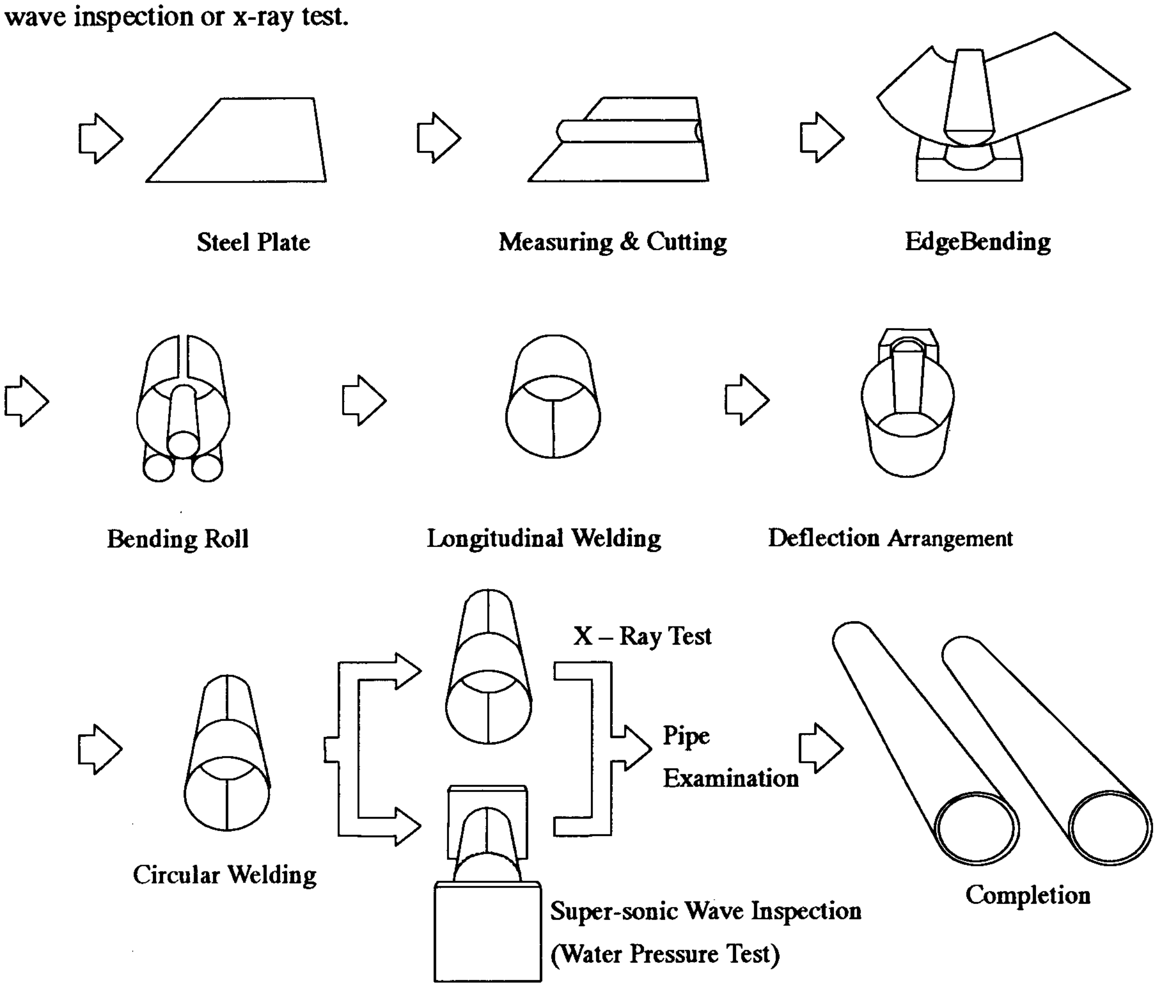


Figure 5.7-2 Progress of Bending Roll Method of Steel Pipe

(5) Design Conditions of Steel Pipe and Conclusion

Basic design conditions of the steel pipes specified by the above study are summarized as follows ;

- Support angle of pipe for construction : 360 degrees

- Design support angle of pipe :90 degrees
- Thickness of pipe and depth of soil covered on the pipe

Covered soil (m)	Pipe thickness (mm)
5	22
4	18
3	15

Recommendable material for delivery pressured pipelines is to be steel pipe from the view points of pipe safety and economy. Environmental conditions of steel pipe production in the country, however, are not sufficient compared with required high technology and accuracy of large size steel pipes. So, particular considerations shall be paid for grading up the technology of roll bending and welding of steel pipe.

5.7.3 Suitable Size and Numbers of Pipe Installation

The cost comparison for selecting suitable size and it's number of row of steel pipe will be made against the costs combined with capital recovery cost of the pump plants, pipelines and annual energy cost of the pump. Annual capital recovery cost can be estimated by multiplying each construction cost of the pumping station and pipeline by capital recovery factor (CRF).

Equation of capital recovery factor is as follows ;

$C.R.F. = i(1+i)^n / \{(1+i)^n - 1\}$

Where, i: Annual interest rate is assumed 6 %

n: Durable life of facilities for pipeline : 50 years and pumping plants : 25 years

Therefore, C.R.F values of the facilities are estimated as follows ;

- Pipeline: 0.06344
- Pump plants: 0.07823

Hydroulic features of alternatives of pipeline are shown as following table.

Table 5.7-4 Hydroulic Features of Alternatives

Option	Discharge of pipeline (m^3/s)	Velocity of pipeline (m/s)	Pipeline length (m)	Head loss of pipeline	Total head of pump
2,000- 7	7.523	2.40	9,400	18.16	103.0
2,200- 6	8.777	2.31	9,400	15.24	100.1
2,400- 6	8.777	1.94	9,400	10.01	94.8
2,400- 5	**10.827**	**2.39**	**9,400**	**14.78**	**99.6**
2,600-5	10.827	2.04	9,400	10.04	94.9
2,600-4	**13.165**	**2.48**	**9,400**	**14.44**	**99.3**
2,800- 4	**13.165**	**2.14**	**9,400**	**10.10**	**94.9**
3,000- 4	13.165	1.86	9,400	7.24	92.1

Cost comparison of steel pipe is tabulated as shown below.

Table 5.7-5 Comparison of Annual Cost

(unit : million LE)

Option	Pump cost (PU) (1)	Pipeline cost (PL) (2)	Annual cost (PU) (3)=(1) x 0.07823	Annual cost (PL) (4)=(2) x 0.06344	Energy cost (5)	Total ann. Cost (6)= (3)+(4)+ (5)	Order
2,000- 7	185.68	355.65	14.53	22.56	56.78	93.87	8(104.3)
2,200- 6	184.54	362.14	14.44	22.97	55.20	92.61	5(102.9)
2,400- 6	182.56	424.24	14.28	26.91	52.28	93.47	7(103.8)
2,400- 5	**184.26**	**353.53**	**14.41**	**22.43**	**54.53**	**91.37**	**3(101.5)**
2,600- 5	182.56	409.61	14.28	25.99	52.06	92.33	4(102.6)
2,600- 4	**184.26**	**327.68**	**14.41**	**20.79**	**54.81**	**90.01**	**1(100.0)**
2,800- 4	**182.85**	**375.85**	**14.30**	**23.84**	**52.40**	**90.54**	**2(100.6)**
3,000- 4	181.71	440.15	14.22	27.92	50.82	92.96	6(103.3)

Note : 1) For pump plants cost, refer to Table 5.7-6.
2) For pipeline cost, refer to Table 5.7-7.

Judging from economic viewpoints, the following three pipe sizes will be suitable for the pipeline of the project.

1) 2,400 mm dia. x 5 rows
2) 2,600 mm dia. x 4 rows
3) 2,800 mm dia. x 4 rows

In conclusion, the pipeline having 5 rows of 2,400 mm diameter steel pipe is selected for the project by the following reasons with referring Table 5.7-6 and 5.7-7

1)Manufacturing of 2,400 mm steel pipe is more easy compared with manufacturing of 2,600 mm and 2,800mm steel pipes.
2)Balance of number of rows of the pipeline for stage I (about 62% of total design discharge) and stage II (about 38% of the total) is better in case of 2,400 mm dia. x 5 rows as shown below.

Option	Stage I	Stage II
2,400 mm x 5 rows	3 rows (60 %)	2 rows (40%)
2,600 mm x 4 rows	3 rows (75 %)	1 row (25%)
2,800 mm x 4 rows	3 rows (75 %)	1 row (25%)

Table 5.7-6 Cost of Pumping Plants

(unit : million L.E)

Item	2000-7	2200-6	2400-6	2400-5	2600-5	2600-4	2800-4	3000-4
Motor output (kw)	13,500x7 = 94,500	13,100x7 = 91,700	12,400x7 = 86,800	13,000x7 = 91,000	12,400x7 = 86,800	13,000x7 = 91,000	12,500x7 = 87,500	12,100x7 = 84,700
Cost of Pump	130.10	130.10	130.10	130.10	130.10	130.10	130.10	130.10
Cost of Others	55.58	54.44	52.46	54.16	52.46	54.16	52.75	51.61
Total Cost	185.68	184.54	182.56	184.26	182,56	184.26	182.85	181.71

Note: Cost of others consists of main motor (404.4LE/kw), switch gear (16.00 million L.E) and cables (1.36 million LE)

Table 5.7-7 Cost of Pipeline

Diameter and No. of Row	Total Pipe Length (km)	Unit Pipe Cost per m.	Amount (million LE)	Energy Cost (M.LE/ yr)	Remarks
2000-7	9.4 x 7 = 65.8	5,405	355.65	56.78	0.894 ton/m
2200-6	9.4 x 6 = 56.4	6,421	362.14	55.20	1.093 ton/m
2400-6	56.4	7,522	424.24	52.28	1.311 ton/m
2400-5	9.4 x 5 = 47.0	7,522	353.53	54.53	
2600-5	47.0	8,715	409.61	52.06	1.549 ton/m
2600-4	9.4 x 4 = 37.6	8,715	327.68	54.81	
2800-4	37.6	9,996	375.85	52.40	1.807 ton/m
3000-4	37.6	11,706	440.15	50.82	2.159 ton/m

Note : Design conditions of pipe : earth cover of 5 m thick, and 22mm of pipe thickness.
; up-surge pressure with 12 kg/cm^2
;.unit pipe cost estimated as domestic production
; unit pipe cost includes earth works & taxes

5.7.4 Calculation of Steel Pipe Thickness

Calculation of steel pipe thickness will be shown in case 1 m to 5 m earth cover as an example based on Japan Water Steel Pipe Association.

(a) Design condition

steel pipe dimension	Diameter	D = 2400 mm
		Dc = 2438.4 mm
		t = 22 mm
Design Inner Pressure		P = 12 kgf/cm^2
Earth cover from the top of pipe to the surface of backfill or embankment		H = 1.0 ~ 5.0 m
Vertical Load (Truck load)		T - 70
Unit Volume Weight of Wet Earth		γ = 1.8 tf/m^3
Angle of Shear Resistance		ϕ = 30°
Design Support Angle		θ = 90°
Reaction Modulus of Foundation Material		E' = 40 kgf/cm^2 (source : MOAFF's standard (pipeline))
Excavation Method		non sheet pile method
Excavation Width		B = 21.0/3 = 6.90 m
Material of Steel Pipe		STW41
Allowable Stress		σa = 1400 kgf/cm^2
Design Deflection Ratio(%)		3%

(b) Tensile Stress by Inner Pressure of Pipe

$\sigma t = PD/2t$

where, σt : Tensile Stress by Inner Pressure of pipe (kgf/cm^2)
P : Inner Pressure (12 kgf/cm^2)

D : Inner Diameter of pipe (Dc – 2t = 243.8 – 2 x 2.2 = 239 cm)

t : Pipe thickness (t = 2.2cm)

$\sigma t = 12 \times 239 / (2 \times 2.2) = 871$ kgf/cm^2 < $\sigma a = 1400$ kgf/cm^2 O.K.

(c) Vertical Earth Pressure

Vertical earth pressure shall be calculated by following equations;

$$\begin{cases} H \leqq 2.0m & Wv = \gamma \cdot H \quad \text{(Vertical Earth Press.F.)} \\ H > 2.0m & Wv = Cd \cdot \gamma \cdot B \quad \text{(Marston's F.)} \end{cases}$$

H≦2.0m $Wv = \gamma \cdot H$

H = 1.0 m Wv = 0.18

H = 2.0 m Wv = 0.36

H>2.0m $Wv = Cd \cdot \gamma \cdot B$

$Cd = (1 - e - 2K \cdot \mu' \cdot H / B) / 2K\mu'$

$K = (1 - \sin\phi) / (1 + \sin\phi) = (1 - \sin 30^\circ) / (1 + \sin 30^\circ)$

$\therefore K = 0.33$

ϕ' : Friction Angle (generally $\phi = \phi'$) $\therefore \phi' = 30^\circ$

μ : Friction coefficient $= \tan \phi'$ $\therefore \mu = 0.58$

H	K	μ'	B(cm)	$-2K \cdot \mu \cdot H/B$	$e^{-2K \cdot \mu \cdot H/B}$	Cd	γ	Wv
3.0 m				-0.1657	0.847	0.401		**0.498**
4.0 m	0.33	0.58	690	-0.2209	0.802	0.520	0.0018	**0.646**
5.0 m				-0.2761	0.759	0.633		**0.786**

(d) Wheel Load

$$Wv = \frac{P \cdot \beta}{W} = \frac{P \cdot \beta}{20 + 2H} \qquad P = \frac{2 \times [\text{Back Wheel Load}]}{[\text{Vehicle Occupation Width}]} \times (1 + i)$$

where, Ww : vertical load by wheel load (kgf/cm^2)

P : back wheel load per unit length (kgf/cm)

β : Decreasing Coefficient of sectional force

W : distribute width (cm)

H : Earth Cover from the top of the pipe to the surface of backfill earth (cm)

i : Impact Coefficient

Wheel Load and Vehicle occupation Width

Load	Weight (tf)	Front wheel load (kgf)	Back Wheel load (kgf)	Vehicle Occupation Width(cm)
T-70	**70**	**11650**	**11700**	**350**
T-25	25	2,500	10,000	275
T-20	20	2,000	8,000	275
T-14	14	1,400	5,600	275
T-10	10	1,000	4,000	275

Decreasing Coefficient of Sectional Force

Load	β
More than T-25	**0.9**
Smaller than T-20	1.0

Standard Value of i

Road Condition	H < 1.5m	1.5m≦H<2.5m	2.5 m ≦ H
Non-Pavement	**0.4**	**0.3**	**0.2**
Asphalt or Concrete Pavement	0.3	0.2	0.1

Vertical Pressure by Wheel Load

H(m)	Back Wheel Loads (kgf)	Vehicle Occupation width (cm)	i	P (kgf/cm)	β	**Wt (kgf/cm^2)**
1.0	11700	350	0.4	94	0.9	**0.383**
2.0			0.3	87		**0.186**
3.0			0.2	80		**0.116**
4.0			0.2	80		**0.088**
5.0			0.2	80		**0.071**

(e) Calculation of Deflection

$$\Delta X = \frac{2Kx \cdot (Wv + Wt) \cdot R^4}{EI + 0.061E' \cdot R^3}$$

Coefficient by Support Angle of Foundation

Support Angle	Kb	Kx	0.061Kb - 0.083Kx
60°	0.189	0.103	0.00307
90°	**0.157**	**0.096**	**0.00171**
120°	0.138	0.089	0.00107
150°	0.128	0.085	0.00082

R : Mean Radius of the Pipe R = (243.8 - 2.2) / 2 = 120.8 cm

E : Modulus of Elasticity of the Pipe E = 2100000 kgf/cm^2

I : moment of inertia per unit length of cross-sefction of the pipe wall

$t^3 / 12 = 2.2^3 / 12 = 0.887\ cm^4$

E' : Reaction Modulus of Foundation Material E' = 40 kgf/cm^2

Calculation of Deflection

H(m)	Wv	Wt	ΔX	Design Deflection Ratio ΔX/D×100 (%)			Judge
1.0	0.180	0.383	3.733	**1.5%**	<	3%	O.K.
2.0	0.360	0.186	3.623	**1.5%**	<	3%	O.K.
3.0	0.498	0.116	4.073	**1.7%**	<	3%	O.K.
4.0	0.646	0.088	4.869	**2.0%**	<	3%	O.K.
5.0	0.786	0.071	5.685	**2.4%**	<	3%	O.K.

(f) Flexural Stress

$$\sigma_b = \frac{2(Wv+Wt)}{f \cdot Z} \times \frac{Kb \cdot R^2 \cdot EI + (0.061Kb - 0.083Kx) \cdot E' \cdot R^5}{EI + 0.061E' \cdot R^3}$$

σ b : Bending Stress at the bottom of pipe

f : Coefficient by Shape =1.5

Z: Section Modulus $Z = t^2 / 6 = 2.2^2 / 6 = 0.81$ (cm^3/cm)

Kb : Coefficient for Bending Moment at the Bottom of Pipe Kb = 0.157

Calculation of Flexural Stress

H(m)	Wv	Wt	σ b		σ a	Judge
1.0	0.180	0.383	**906**	<	1400	O.K.
2.0	0.360	0.186	**879**	<	1400	O.K.
3.0	0.498	0.116	**989**	<	1400	O.K.
4.0	0.646	0.088	**1182**	<	1400	O.K.
5.0	0.786	0.071	**1380**	<	1400	O.K.

Following table shows in case 1m to 5m earth cover and 14 mm to 22 mm pipe wall thickness based on 70 ton truck load as an example.

D=2400mm　　　　　　　　　　　　　　　　Upper : Deflection Ratio (%)

Dc=2438mm　　　　　　　　　　　　　　　　Lower : Bending Stress (kgf/cm^2)

t / H(m)	14	15	18	22
1.0	**2.0%** **1365 O.K.**	**1.9%** **1261 O.K.**	**1.8%** **1072 O.K.**	**1.5%** **906 O.K.**
2.0	**1.9%** **1325 O.K.**	**1.9%** **1223 O.K.**	**1.7%** **1040 O.K.**	**1.5%** **879 O.K.**
3.0	2.2% 1490 OUT!	**2.1%** **1375 O.K.**	**2.0%** **1169 O.K.**	**1.7%** **989 O.K.**
4.0	2.6% 1781 OUT!	2.5% 1644 OUT!	**2.3%** **1398 O.K.**	**2.0%** **1182 O.K.**
5.0	3.0% 2079 OUT!	3.0% 1920 OUT!	2.7% 1632 OUT!	**2.4%** **1380 O.K.**

B=6.90m

Notes : Hatched thickness is minimum required thickness for each earth cover.

5.7.5 Coating and Jointing Manner

(1) Soil and Water Quality

The pipe internal and external wall surfaces shall be coated by the suitable materials for the following purposes;

- To prevent from chemical erosion or corrosion for internal and external surfaces of pipe
- To resists abrasion of internal surface of pipe
- To keep smooth roughness coefficient

The chemical erosion/corrosion of steel pipe will be caused by electrically chemical reaction with steel to soil relation called micro-sell corrosion and with steel to concrete and to different kind of steel relation called macro-sell corrosion under the existence of oxygen and water.

(a) Electric resistivity test

According to the Figure 3.2-4 in this report, electric resistivity of the soil at the proposed pipeline route ranges as follows;

Resistivity (Ω-cm)	Percent (%)
Below 2,000	10
2,000~3,000	30
3,000~4,000	30
4,000~5,000	30

(b) Result of Chemical Test

According to the information collected from NSDO Kantara office, salinity contents of irrigation water can be summarized as follows;

Sample site	Contents	Sampling month
Upstream of PS. No.2	776	Jul.98
	1,694	Jan.98
Downstream of PS. No.3	1,752	Jul.98
	3,794	Jan.98
Upstream of Suez Syphone	1,351	Mar.99

Note; Contents means TDS (total Dissolved Solid) of Salinity, ppm.

(2) Countermeasure of the steel pipe corrosions

The pipeline is requested to be prolong it's life for permanently, so the protection of pipe against chemical erosion/ corrosion is the most important measures. There are several countermeasures for corrosions of the steel pipe, in general coating and/or painting are commonly used, furthermore electrical protection methods such as cathodic impressed current system for high electric resistivity of soil and galvanic anode system for low electric resistivity of soil will be used.

In case the pipeline will be laid under the ground water level and/ or the high value of electric resistivity (for example, in case the electric resistivity is less than 900 Ω-cm, the corrosion of steel will be easily occurred), the soil condition is high corrosive. And in case pH value is less than 4, the soil condition is also more corrosive. The value of electric resistivity ranged 1,000 to 5,000 Ω-cm, and the value of ph is between 6.0 to 7.2. Judgement for possibility of chemical errosion will be done more to medium corrosive soil referred to Japanese standard (based on the DIN 50929 Part 3) shown below.

(unit; Ω-cm)

Corrosiveness	much more	more	medium	Less	seldom
Electric resistivity	<900	900 to 2,300	2,300 to 5,000	5,000 to 10,000	>10,000

Then the external coating of asphalt vinylon closs and both casodic impressed current system of pipeline will be recommended to avoid completely the chemical errosions. Mortal coating or tar-epoxy coating of internal protection on the other hand, will be also recommended to protect inside of pipe against high density of T.D.S. as mentioned previous clause.

(3) Jointing

The steel pipe joint is commonly and generally used welding joint. Welding joint is the most reliable joint for high pressured steel pipeline. Flanged type is seldom used for steel pipeline because of expensive and another various kinds of joint between steel and different kinds of pipe are used.

On technical viewpoints of welding, semi-automatic welding by submerged arc welding method will be recommended to result required quality of welding joint and shorten of construction period.
Coating of internal and external of pipe at welding joint is also needed and type of coating shall be same as main body of steel pipe section.

The installation of pipe consists of the earth works, hauling in field, laying by crane, connection of pipe with welding, tests and inspections.

The works of pipe jointing in the field will be done the following procedures; ① edge cleaning, ② adjust pipe centerline each other, ③ tack welding, ④ inspection, ⑤inside circomferential welding, ⑥ supersonic wave inspection (5 to 10% of pipe welding length), ⑦ internal and external joint coatings ⑧ final inspection witnessed by specification.

5.7.6 Hydraulic Analysis of Water Hammer Phenomenon

The pumps and pipelines of this project are so large scale in discharge and lifting head. Careful study of the water hammer analysis is necessary. The water hammer analysis was carried out with combination of pump and high pressured pipeline, applying the method of the elastic theory-based unsteady flow analysis.

(1) Countermeasures of Preventing Water Hammer

To prevent or lighten water hammer pressure, adequate countermeasure shall be planned both up surge and down surge pressures.

(a) Major countermeasures for up surging
Only functionable check valve (bi-plane butterfly valve) controling shutt off time is effectively applied to this kind of large scale pump and pipeline system for the Project to prevent or ligthen of up surge pressure.

(b) Major countermeasure for down surge
Countermeasures for the down surge (minus) pressure are most important factor for safety of pipelines. There are many methods of countermeasures to prevent and or lighten of water hammer as mentioned in the Chapter 3 Design Criteria. The following countermeasures, however, are applicable for large scale diameter and long distance pipelines.

- One-way surge tank
- Conventional surge tank

- Air vessel type
- Vacuum breaker type

From the hydraulic condition, topographic profile of proposed pipeline route and scale of pipe diameter, conventional surge tank and air vessel types are not applicable due to theoretically not practicable.

Function of one-way surge tank is that when water pressure in the pipe was draw down due to sudden stop of pump, check valves of outlet of the tank is automatically opened and water in the tank immediately pour into the pipeline to lighten minus pressure. On the other hand, function of vacuum breaker type is also applicable, but comparatively large scale of air valves shall be installed. So, the following discussion is concentrated to the capacity and or sizing of one-way surge tank type at the specified section of pipeline. Vacuum tank type, however, will be discussed as alternative, if the required capacity of one-way surge tank is lather small scale.

(2) Conditions of Estimation

The followings are conditions of unsteady flow analysis.
Specification of pump; 10.83m^3/s x100m x 375rpm x 13,000kw
Inertia effect of rotating mass of pump and motor; 93.7 ton-m^2
Specification of pipeline; Steel pipe ϕ2,400mm, wall thickness, 22mm
Length of pipeline, 9,400m
Suction and delivery water level; Suction 10.70m, Delivery 92.90m

(3) Cases and Result of Estimations

Possible case studies from the non countermeasure case can be applied as follows;
Case-1; non of any countermeasure
Case-2; Rapid closure of discharge check value.
two proposed one-way surge tanks at 1.40km and 5.78km
Case-3; Slow closure of discharge check value
two proposed one-way surge tanks at 1.40km and 5.78km of pipeline
Case-4; Slow closure of discharge check value
one proposed one-way surge tank at 1.40km
Case-5; Slow closure of discharge check value
one proposed one-way surge tank at 5.78km
Case-6; Slow closure of discharge check value
one proposed one-way surge tank at 1.40km and Vacuum braker at 5.78km
Case-7; Slow closure of discharge check value
two proposed one-way surge tanks at 1.40km and 5.78km with double connection pipes.

Table 5.7-8 Results of Estimations

Case	Surge tank		Vacuum braker	Connection pipe diameter (m)	Max.minus pressure (m)	Evaluation
	At 1.4 km No,1	At 5.78km No,2				
Case-1	-	-	-	-	-56	×
Case-2	○	○	- -	ϕ1.5×2 ϕ0.7×2	-9	×
Case-3	○	○	- -	ϕ1.5×1 ϕ1.0×1	-1	△
Case-4	○	-	-	ϕ1.5×1	-13	×
Case-5	-	○	-	ϕ1.0×1	-45	×
Case-6	○	-	○	ϕ1.5×2.	-15	×
Case-7	○	○	- -	ϕ1.5×2 ϕ0.7×2	0	○

Proposed plan of countermeasure for down surge pressure shall be the Case 7. Case 3 is also acceptable,but connection pipe between pipeline and surge tank with check valve will be recommendable to equip with two lines for safety.

The following Figures show the results of each cases indicated the height of pipeline, hydraulic gradient, maximum and minimum. Pressure line, min. pressure and the location of proposed surge tanks for Case 1, 2, 4, and 7.

Table 5.7-9 Specification of Surge Tanks

Specification	Surge tank at 1.4km No,1	Surge tank at 5.78km No,2
Initial water level	56m	68m
Section area	$60m^2$	$5\ m^2$
Diameter and no,of connection pipe	Φ1.5m×2	Φ0.7m×2
Elevation of pipe center	50m	64m

5.7.7 Basic Design of Surge Tanks and Appurtenant Structures

(1) Surge Tanks

As the result of previous section two surge tanks are proposed to be safe the pipeline against minus pressure which shall be less than 5 to 7m of down surge (minus pressure). One way surge tank is the adequate method for large scale pipeline, such as large discharge and high static pressure.

The required capacities of surge tanks obtained from the estimation are as follows;

No.1 Surge Tank; Section area of one way surge tank; $60m^2$
Initial water level; 56 m
Elevation of pipe center; 50 m
Low water level; 52 m
Effective capacity; $240\ m^3$
Design capacity $5.0\times 15.0\times 4.0 = 300\ m^3$
Diameter of connection pipe ϕ 1.5m×2

No.2 Surge Tank; Section area of one way surge tank; $5\ m^2$
Initial water level; 68 m
Elevation of pipe center; 64 m
Low water level; 66 m
Effective capacity; $10\ m^3$
Design capacity $2.8\times 4.0\times 2.0 = 22.4\ m^3$
Diameter of connection pipe ϕ 0.7 m×2

(2) Appurtenant Structures

Appurtenant structures of pipeline are generally consist of air valves, blow off, maintenance valves, manholes, discharge flow meter and others.

(a) Air valve

The purposes of air valve are to discharge the air from pipeline and to introduce the air into the pipeline. The location of air valve shall be determined the adequate places which air will be left untransported or at least each 600 to 700m of pipe longitudinal distance. The adequate diameter of air valve may be of 200mm.

(b) Blow off

The purpose of blow off is to discharge the water from pipeline when is requested to empty the water for inspection of inside of pipeline. Another purpose is to discharge the air when pipeline was started operations by pump. The location of blow off shall be the lowest portion of the pipeline. The adequate diameter of drain pipe of blow off may be the range of 300 to 500mm depend on the drainage time.

(c) Maintenance valve

The purpose of maintenance valve is to empty the water for maintenance the inside of a pipeline when the other pipelines are being operating. The location of maintenance valve may be at beginning of each pipelines.

(d) Manhole

Regarding to (b) and (c), manholes are needed to enter the pipeline.

(e) Discharge flow meter

Examination of discharge rate of pipeline shall be done for the adequate operation of pump. The method of measure of flow rate may be by supersonic flow meter and its location is just downstream of pump.

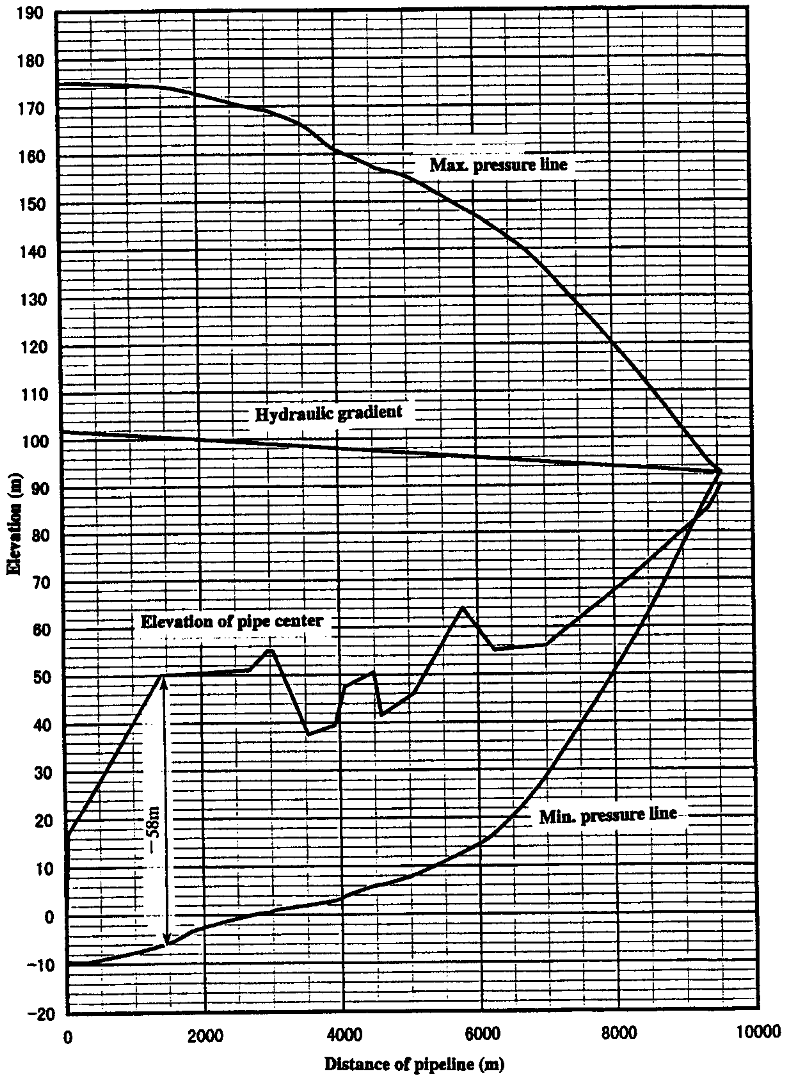


Figure 5.7-3 Water Hammer Analysis : Case – 1

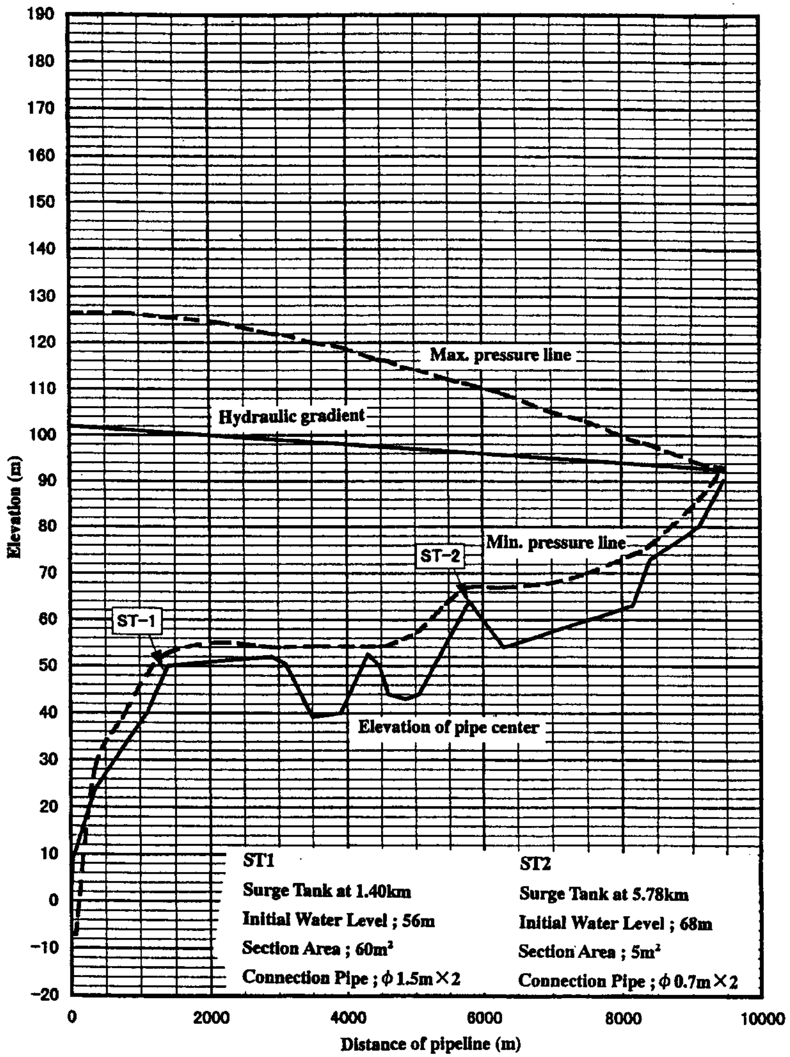


Figure 5.7-4 Water Hammer Analysis : Case – 2

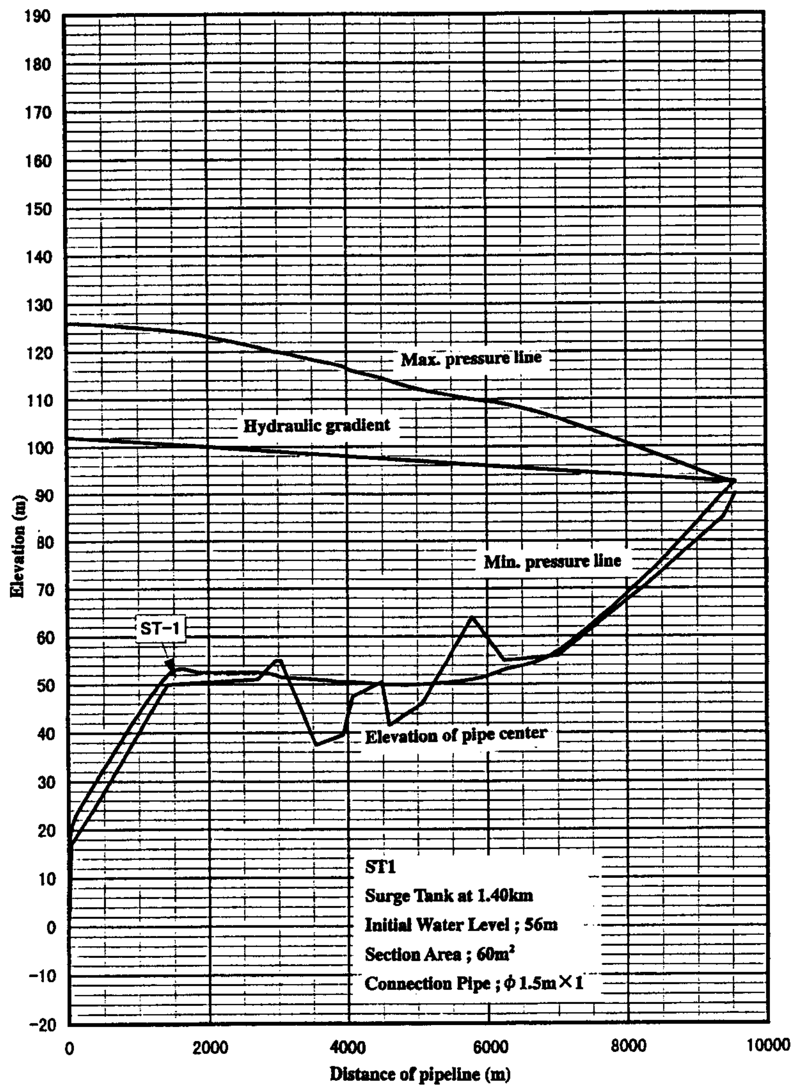


Figure 5.7-5 Water Hammer Analysis : Case – 4

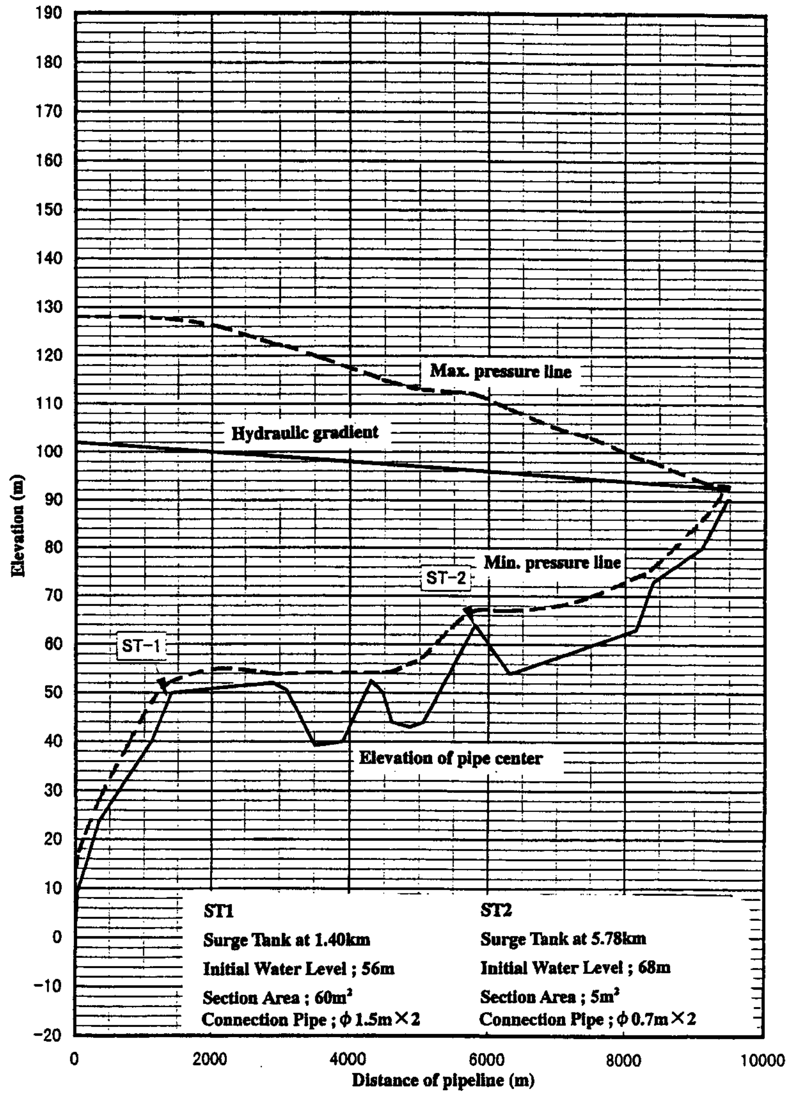


Figure 5.7-6 Water Hammer Analysis : Case – 7

5.8 Discharge Tank

5.8.1 Hydraulic Conditions of the Tank

(1) Hydraulic Conditions of the Discharge Tank

- Design Discharge: (Minimum, Average and Maximum design discharge are the pump capacity of 1, 2 or 3 and 3or 5 units, respectively.)

	Stage I	Stage II (overall)
Max. Discharge	32.48 m^3/sec.	54.14 m^3/sec.
Ave. Discharge	21.65 m^3/sec.	32.48 m^3/sec
Min. Discharge	10.83 m^3/sec	10.83 m^3/sec.

- Designed Elevation of the Canal Bottom at the end of the Discharge Tank : KM 118.560

Elevation of the Canal Bottom: EL. 88.57 m

- Design Water Level at the end of the Discharge Tank : KM 118.560

	Stage I	Stage II
Max. Discharge	HWL. 91.12 m	HWL. 91.94 m
Ave. Discharge	MWL. 90.61 m	MWL. 91.12 m
Min. Discharge	LWL. 89.96 m	LWL. 89.96 m

(2) Selection of the Location

The location of the discharge tank was decided preliminary in consideration with topography on the conveyance canal, designed water surface, economical feasibility and environmental impacts. The main considerations for selection of the discharge tank are shown below:

- To minimize the length of pipeline that require a high construction cost for reducing the project cost.
- To select the place with a comparatively large acreage as the site for the discharge tank.
- To select the place with flat topography, less affection of drifting sand dune, natural vegetation which may indicate stable environmental condition.
- To select the place with suitable ground surface elevation for smooth connection with No.3 open canal.

Based on the considerations mentioned above, a result of field survey/topographic survey , the site of the discharge tank is finally decided as indicated below.

- Station: KM 118.36 (BP + 31.860 km)
- Ground elevation: approximately EL.91 m

(3) Selection of Discharge Tank Type

(a) General

Several types of facilities can be considered to prevent reverse flow from the discharge tank i.e. i) rectangular weir, ii) round weir, iii) siphon, iv) non-return valve. The type of the discharge tank shall be decided in consideration of flow rate of discharge, relation of discharge water level and downstream water level, space of land required, elevation of original ground surface, etc.

(b) Alternatives of Discharge Tank Type

The characteristics of the alternatives of discharge tank are shown in the following table.

Table 5.8-1 Alternatives of Discharge Tank Type

Type	Rectangular Weir type	Round weir type	Siphon type	Non-return valve type
Description	• Straight weir	• Round weir	• Siphon at the downstream end of the discharge pipe	• Non-return valve at the downstream end of the discharge pipe
Hydraulic character	• Head loss equal to the overflow depth occurs. (Head loss:1.0m) • Deviated flow tends to occur.	• Head loss equal to the overflow depth occurs. (Head loss:1.0m) • Deviated flow hardly occurs.	• Head loss is less than weir type. (Head loss:0.5m) • Deviated flow tends to occur.	• Head loss is small. (Head loss:0.4m) • Deviated flow tends to occur. • Discharge tank shall be requested countermeasure for water hammer, when the pumping system has High pumping head and long length pipeline. • Except two one way surge tanks, additional conventional surge tank may be necessary because negative pressure shall be occurred at location behind the flap valve when it closed.
Structural character	• Straight structure ensures easy construction.	• Curved structure result in hard construction	• Curved structure on curved discharge pipe result in hard construction.	• Installation of non-return Valve only makes construction easy.
Past example	• Head loss can be Decreased by Lengthening the weir .Many examples for large discharge and less limitation of land	• Largest head loss. As discharged vertically upward, many examples for medium to small discharge.	• Least head loss. Many examples for large discharge with medium to high pumping head in case initial siphon flow are formed by themselves. • No.6 Pumping station of this project	• Little head loss. Many examples for wide range of discharge with Low pumping head. • No.5 Pumping Station of this Project.
Economic	(1,000 L.E.)			
1.Initial Cost	1,109	1,331	1,370	14,377
2.Annual Cost	70	84	87	226
3.Energy Cost	55,820	55,820	55,540	55,483
4.Overall ann. Cost (2+3)	55,890 (1.005)	55,904 (1.005)	55,627 (1.000)	55,709 (1.001)

From the above comparative table, "Rectangular weir type" of discharge tank was adopted because, there are no technical hazard than other alternatives and no different initial cost and energy costs.

5.8.2 Basic Design of Discharge Tank

(1) Basic Concepts of the Discharge Tank

The considerations for discharge tank design are as follows.

(a) Shape and Size of discharge tank

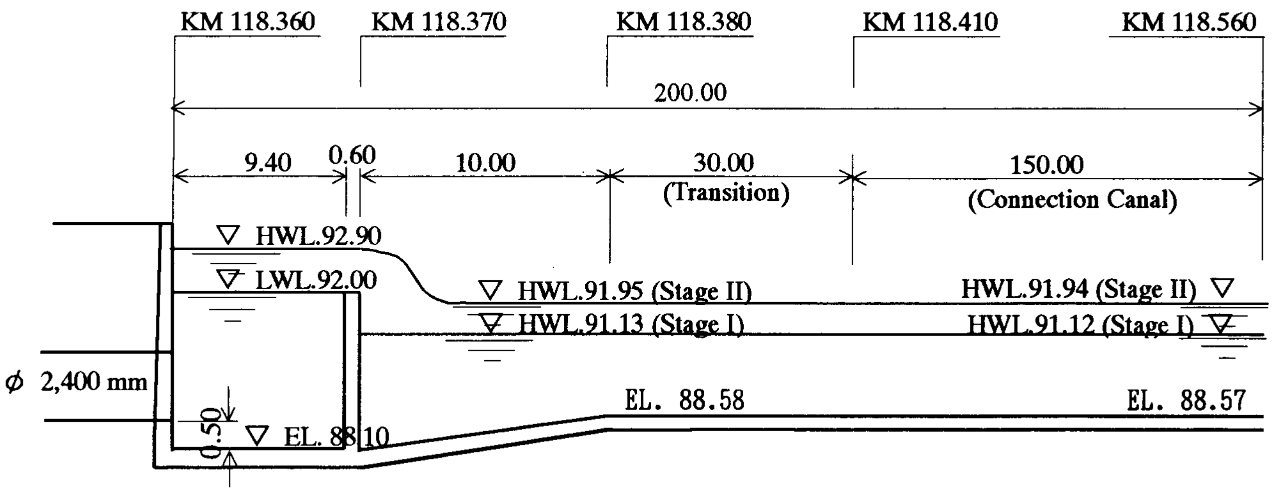
In order to reduce high flow velocity in the discharge tank produced a partial rise in water level and much shape head loss in the tank, such velocity should be reduced in the discharge tank, and then the water flow direction changed so that water is directed to the open canal.

The flow velocity therefor should be below 0.30 to 0.50m/sec in the discharge tank. Insufficient size or improper shape of the discharge tank will produce reflected waves: or step waves on the side wall opposite the discharge pipe. To prevent such waves, a proper distance of the side wall opposite the discharge pipe end should be changed by inclining the wall or by sloping the bottom of the tank. Also, reflected waves produced on the opposite side wall should be prevented from travelling directly to the next pump discharge pipe outlet.

(b) Discharge Tank Sill

The upper end of the discharge pipe should be located at a level 30cm or more below the lowest discharge water level. The discharge tank sill should be about 40 to 60cm below the lower end of the discharge pipe. The width of the discharge tank is often determined on the basis of the relationship between the discharge pipe arrangement and the width of discharge weir.

(2) Basic Design of Discharge Tank



Profile

Dimensions and elevations of discharge tank are as follows.

(a) Discharge Tank Sill

- Upper end of the pipeline : EL. 91.00 m (= LWL. 92.00 m – 1.00 m)
- Discharge Tank Sill : EL.88.10 m (= EL. 91.00 m - 2.40 m - 0.50 m)

(b) Width of Weir

In order to reduce high flow velocity in the discharge tank produced a partial rise in water level and much shape head loss in the tank, such velocity should be reduced in the discharge tank, and then the water flow over the weir so that water is directed to the open canal.

In order to keep the velocity in the discharge tank less than 0.3 m/s - 0.5 m/s, the crest length of the weir shall be about 3 times of the diameter of the pipeline. 7.5 m width of weir per one unit gives the velocity of discharge tank as follows;

The flow velocity in the discharge tank should be given by following formula.

$$V = Q / (W \cdot H)$$

where, V : Flow velocity in the discharge tank (m/s)
Q : Discharge of one row pipeline (m^3/s)
W : Width of upstream discharge tank (m)
H : Water depth in the discharge tank (m)
H = HWL. 92.90 – 88.10 = 4.80 m

$$V = 10.827 / (7.50 \times 4.80) = 0.30 \text{ m/s}$$

(c) Crest Elevation of the Weir

The crest elevation of the weir shall be so planned as not to allow the back-flow from the downstream of the conveyance canal in case of sudden stop of the pump operation. The full water supply level at the immediate downstream of the conveyance canal is EL.91.95 m. Therefor, the crest elevation of the weir is decided at EL.92.00 m, a little higher than the HWL. 91.95 m.

(d) Depth of Over Flow at the Weir and Water Surface Level in the Discharge Tank

$$D = 1.5 \, (q^2 / g)^{1/3}$$

Where, D : Depth of over flow at the weir (m)
q : Discharge per meter (m^3/s)
$q = 10.827 / 7.50 = 1.444 \, m^3/s$
g : Gravitational acceleration (m/s^2)
$g = 9.8 \, m/s^2$

$$D = 1.5 \, (1.444^2 / 9.8)^{1/3} = 0.90 \text{ m}$$

Therefor, the high and low water surface level should be 92.90 m (= EL.92.00m + 0.90m) and 92.00m, respectively.