CHAPTER IV
PROGRAM TESTING

4.1 Gas Network

4.1.1 Data Input

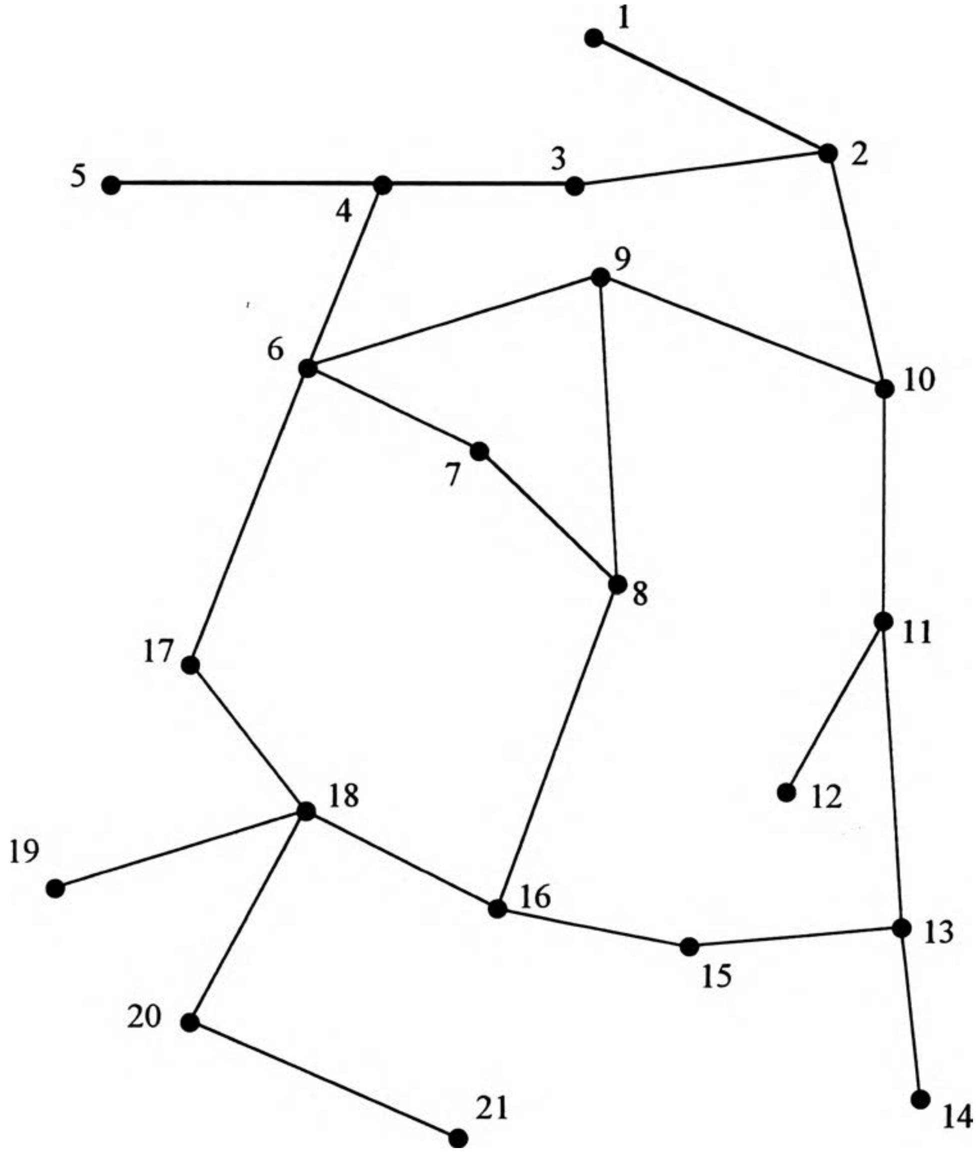

Fig. 4.1 Sketch of topological representation of the gas transmission system.

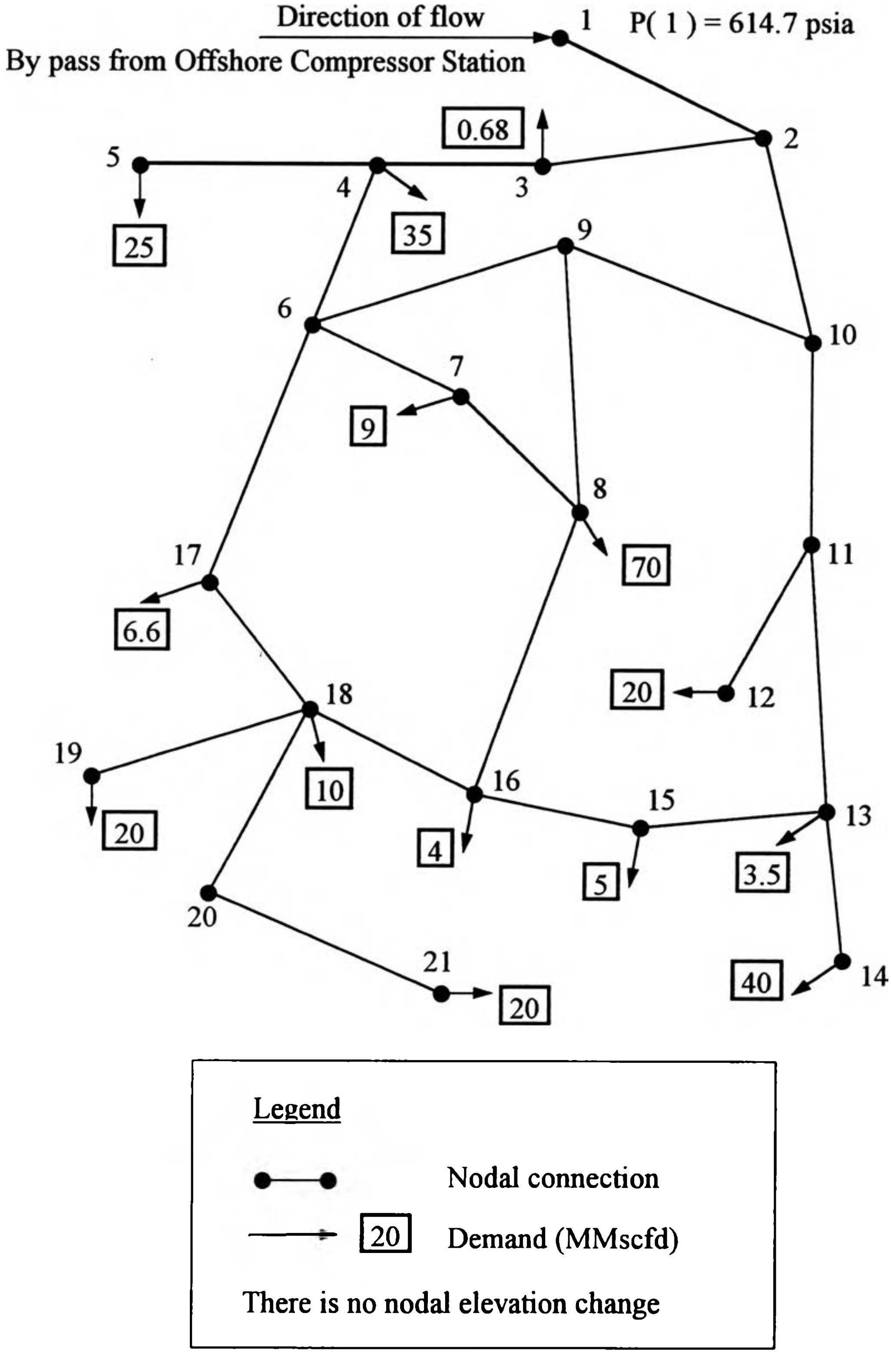

Fig. 4.2 Topological representation with demand rates to ind'ıstries.

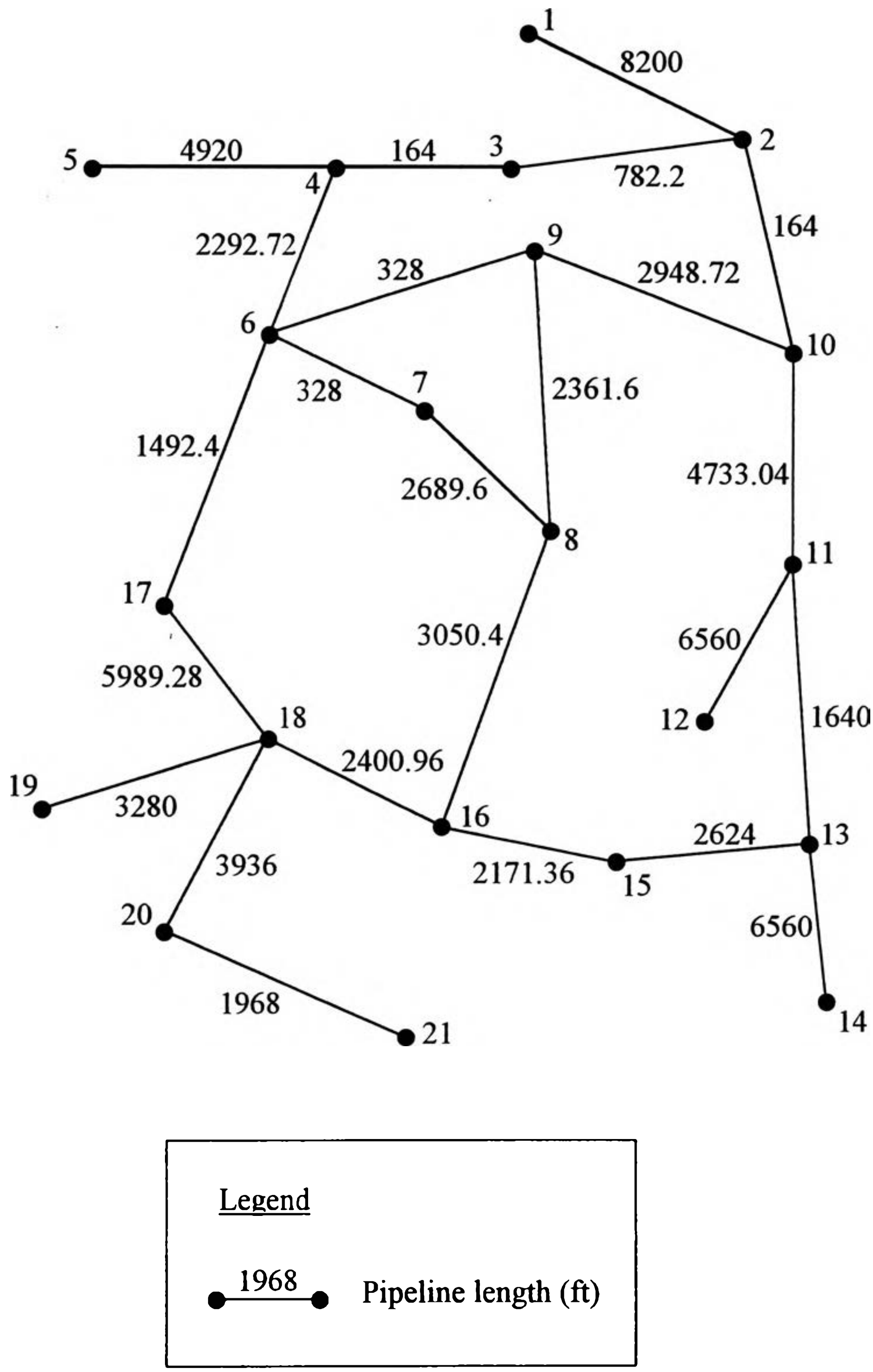

Fig. 4.3 Gas transmission network with internodal distances.

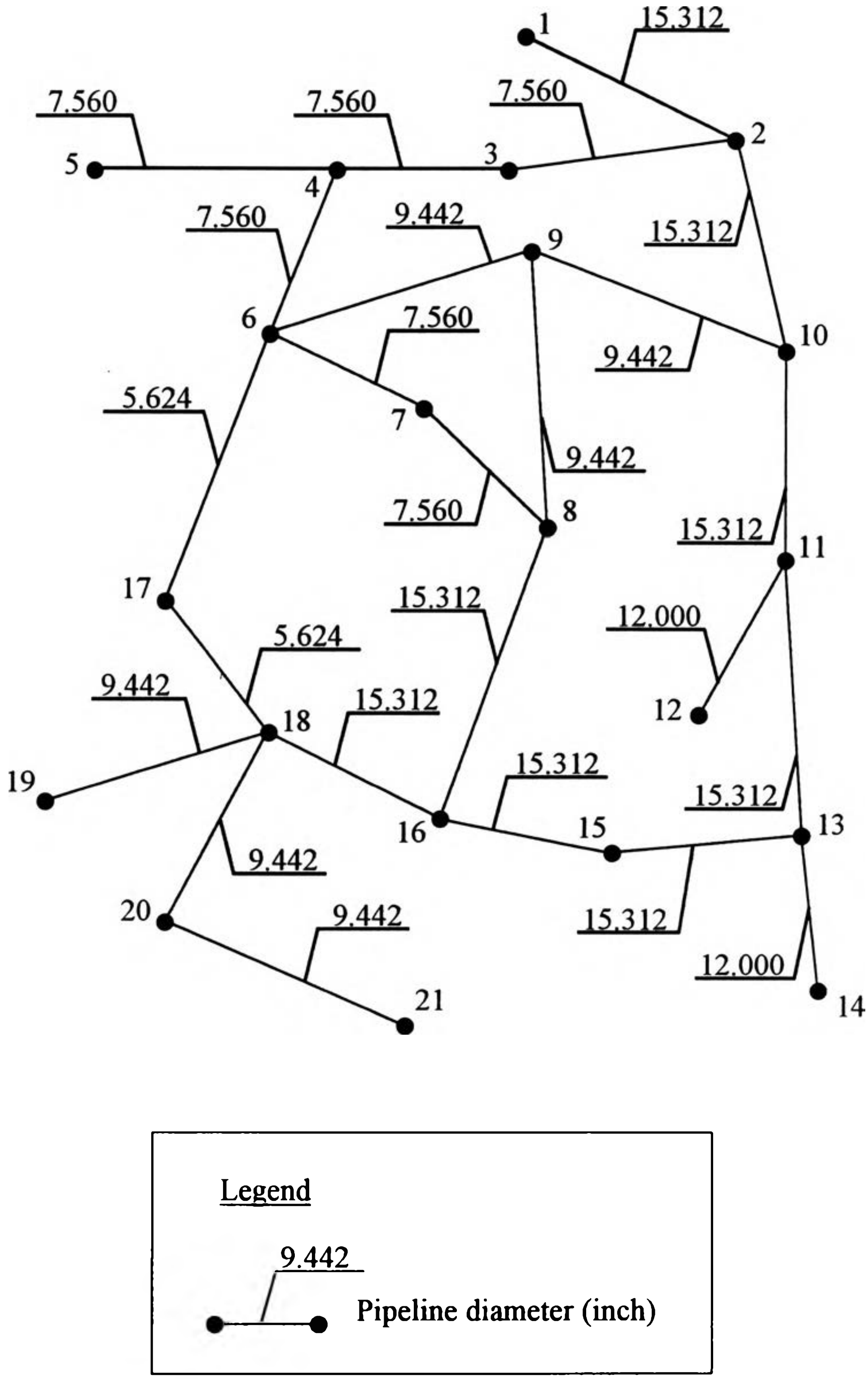

Fig. 4.4 Gas transmission network with pipeline sizes.

Figs. 4.1 through 4.4 display the sketched topological representation of the gas transmission pipeline system in the area at Eastern Seaboard Estate, Rayong Province, Thailand. It contains 21 nodes and 24 nodal connections.

This particular network discussed herein concerns gas flow rates distribution to supply industry consumption as fuel during Gas Separation Plant shut-down. Therefore, it is considered to have no boosting compressor from onshore compressor station to build-up pressure. The gas flow is by pass through the system from offshore far away about 415 km. at the beginning of node 1 with initial specified pressure at 614.7 psia as shown in Fig. 4.2.

The program testing was undertaken for analyzing the gas flow rates to monitor the degree accuracy with TGNET code in order to increase the capability of the program.

The network and property parameters are taken into account in the computer program as follows:

From Gas Transmission Pipelines Department, PTT (British units):

N	=	21	Number of nodes
MW	=	17.04	Average molecular weight of natural gas
RG	=	1543.3	Universal gas constant
TG	=	110.	Gas temperature
ZAVG	=	0.925	Average compressibility factor
VT	=	0.01	Average viscosity
PSC	=	14.73	Pressure at standard conditions
TSC	=	60.	Temperature at standard conditions

ZSC	=	1.	Compressibility factor at standard conditions
NC	=	24	Number of nodal connections
NDL	=	24	Number of pipeline connections
NT	=	6	Number of nodes with T_i = 1, or T_i = 3
NV	=	15	Number of nodes with specified injection or withdrawal rate
ITMAX	=	30	Maximum number of iterations

The following data are used from Figs. 4.2 through 4.4 as shown in Tables 4.1 through 4.4.

Table 4.1 Data for gas transmission pipeline connections

I	J	C(I , J)	D(I , J)	L(I , J)	FF(I , J)	E(I , J)
1	2	1	15.312	8200.00	0.0105	0.00015
2	3	1	7.560	787.20	0.0105	0.00015
2	10	1	15.312	164.00	0.0105	0.00015
3	4	1	7.560	164.00	0.0105	0.00015
4	5	1	7.560	4920.00	0.0105	0.00015
4	6	1	7.560	2292.72	0.0105	0.00015
6	7	1	7.560	328.00	0.0105	0.00015
6	9	1	9.442	328.00	0.0105	0.00015
6	17	1	5.624	1492.40	0.0105	0.00015
7	8	1	7.560	2689.60	0.0105	0.00015
8	9	1	9.442	2361.60	0.0105	0.00015
8	17	1	15.312	3050.40	0.0105	0.00015
9	10	1	9.442	2948.72	0.0105	0.00015
10	11	1	15.312	4733.04	0.0105	0.00015
11	12	1	12.000	6560.00	0.0105	0.00015
11	13	1	15.312	1640.00	0.0105	0.00015
13	14	1	12.000	6560.00	0.0105	0.00015
13	15	1	15.312	2624.00	0.0105	0.00015
15	16	1	15.312	2171.36	0.0105	0.00015

Table 4.1 (Continued)

I	J	C(I , J)	D(I , J)	L(I , J)	FF(I , J)	E(I , J)
16	18	1	15.312	2400.96	0.0105	0.00015
17	18	1	5.624	5989.28	0.0105	0.00015
18	19	1	9.442	3280.00	0.0105	0.00015
18	20	1	9.442	3936.00	0.0105	0.00015
20	21	1	9.442	1968.00	0.0105	0.00015

Note:

I = Upstream node

J = Downstream node

C(I , J) = 1 Pipeline connection

D(I , J) = Pipeline diameter joining node I and node J (inch)

L(I , J) = Pipeline length joining node I and node J (ft)

E(I , J) = Pipeline roughness joining node I and node J (ft)

FF(I , J) = Initial approximation for the Fanning friction factor

Table 4.2 Initial guesses and specified pressures for gas transmission system

I	P(I)	I	P(I)	I	P(I)
1	614.7	8	532.0	15	525.0
2	520.0	9	534.0	16	527.0
3	522.0	10	536.0	17	529.0
4	524.0	11	538.0	18	531.0
5	526.0	12	540.0	19	533.0
6	528.0	13	521.0	20	535.0
7	530.0	14	523.0	21	537.0

Note:

P(I) = Nodal pressure at node I (psia)

Table 4.3 Node-type for gas transmission system

I	T(I)	I	T(I)	I	T(I)
1	3	5	3	12	3
14	3	19	3	21	3

Note:

T(I) = 3 Terminal node with specified injection or withdrawal rate

Table 4.4 Gas transmission system with specified withdrawal rates

I	V(I)	I	V(I)
3	0.68	4	35.00
5	25.00	7	9.00
8	70.00	12	20.00
13	3.50	14	40.00
15	5.00	16	4.00
17	6.60	18	10.00
19	20.00	21	20.00

Note:

V(I) = Specified withdrawal rate at node I (MMscfd)

There is no elevation change in this network.

4.1.2 Data Output

After 15 iterations for the Newton-Raphson method. Convergence was achieved. The results are shown in Tables 4.5 through 4.7.

Table 4.5 Converged pressures for gas transmission system

I	P(I)	I	P(I)	I	P(I)
1	614.700	8	279.061	15	288.746
2	375.983	9	298.137	16	280.268
3	311.578	10	372.325	17	282.001
4	296.731	11	316.123	18	276.456
5	214.962	12	310.468	19	265.618
6	296.042	13	300.020	20	263.398
7	291.961	14	275.388	21	256.620

Table 4.6 The flow rates distribution for gas transmission system

I - J	QSC(I , J)	I - J	QSC(I , J)	I - J	QSC(I , J)
1 - 2	268.780	2 - 3	64.297	2 - 10	204.483
3 - 4	63.618	4 - 5	25.000	4 - 6	3.619
6 - 7	23.187	9 - 6	29.112	6 - 17	9.542
7 - 8	14.187	9 - 8	32.268	16 - 8	23.544
10 - 9	61.378	10 - 11	143.099	11 - 12	20.000
11 - 13	123.103	13 - 14	40.000	13 - 15	79.601
15 - 16	74.601	16 - 18	47.057	17 - 18	2.943
18 - 19	20.000	18 - 20	20.000	20 - 21	20.000

Table 4.7 The Fanning friction factors for gas transmission system

I - J	F(I , J)	I - J	F(I , J)	I - J	F(I , J)
1 - 2	0.003087	2 - 3	0.003555	2 - 10	0.003087
3 - 4	0.003555	4 - 5	0.003555	4 - 6	0.003559
6 - 7	0.003555	9 - 6	0.003397	6 - 17	0.003784
7 - 8	0.003556	9 - 8	0.003397	16 - 8	0.003089
10 - 9	0.003397	10 - 11	0.003087	11 - 12	0.003239

Table 4.7 (Continued)

I - J	F(I , J)	I - J	F(I , J)	I - J	F(I , J)
11 - 13	0.003087	13 - 14	0.003238	13 - 15	0.003088
15 - 16	0.003088	16 - 18	0.003088	17 - 18	0.003786
18 - 19	0.003398	18 - 20	0.003398	20 - 21	0.003398

Note:

QSC(I , J) = The gas flow rate at standard conditions (MMscfd) for flow from node I to node J

F(I , J) = The Fanning friction factor for flow within pipeline connecting node I and node J

4.2 Liquid Network

4.2.1 Data Input

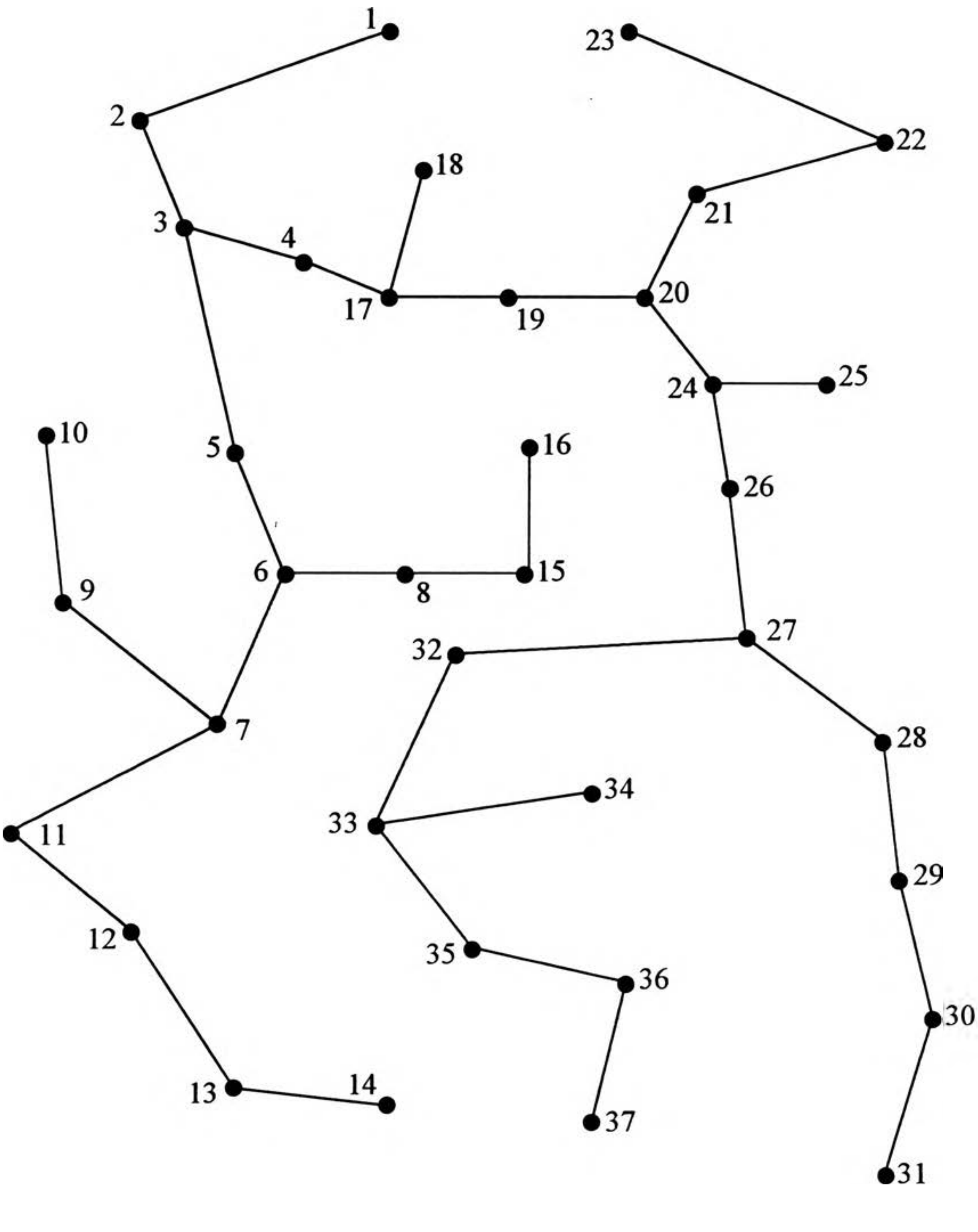

Fig. 4.5 Sketch of the branched network of water transmission tunnel system.

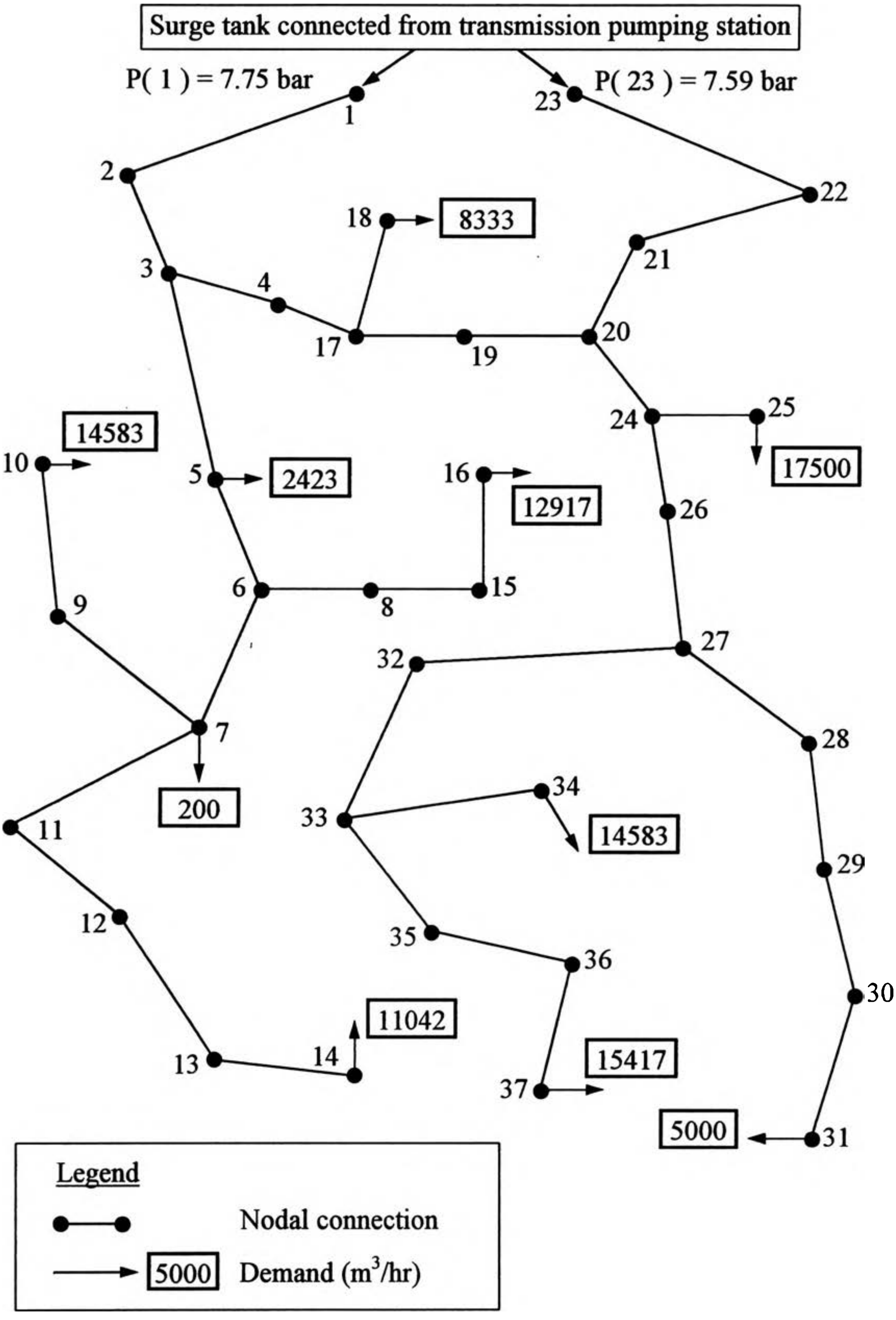

Fig. 4.6 Topological representation with demand rates to customers.

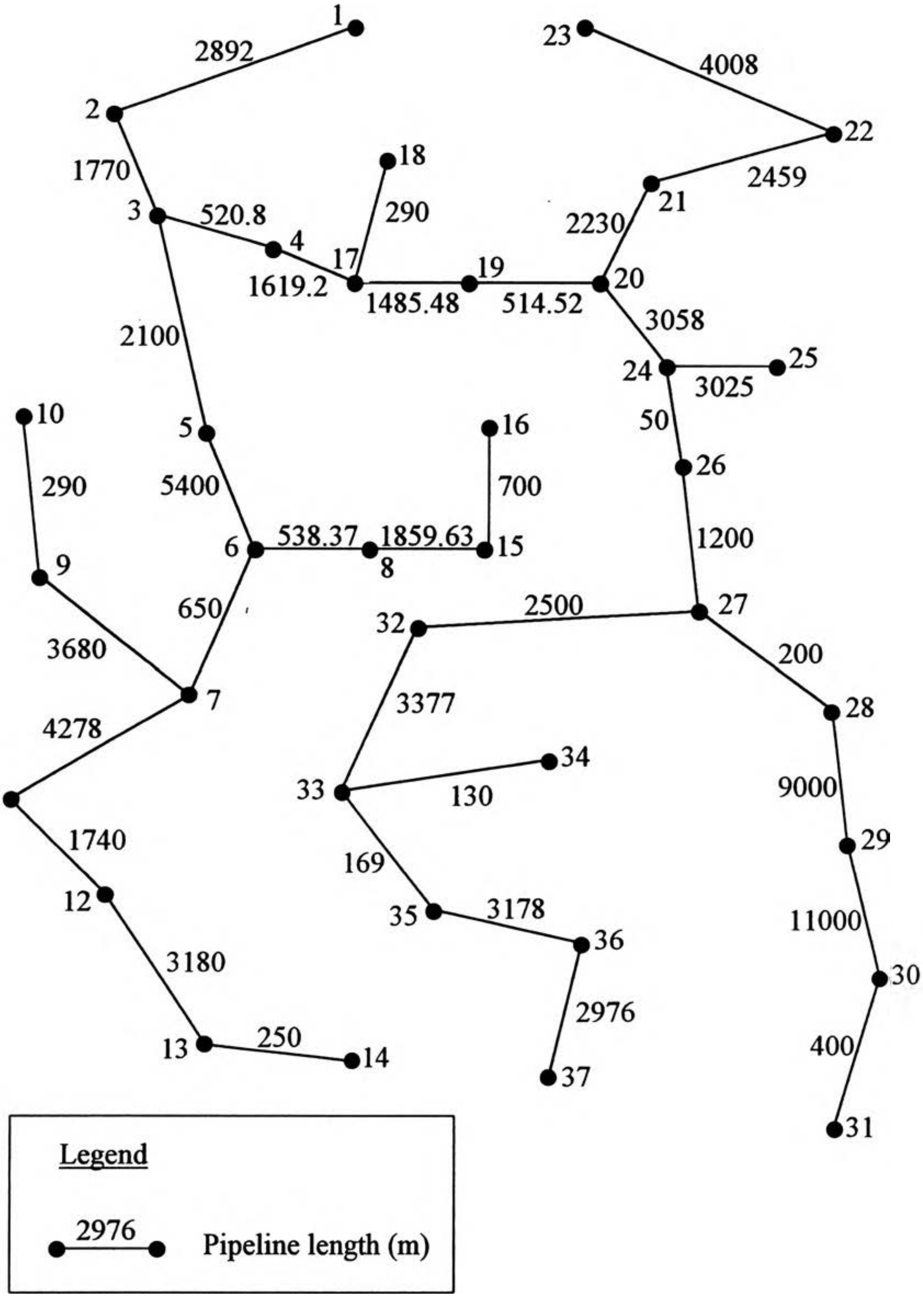

Fig. 4.7 Water transmission tunnel network with internodal distances.

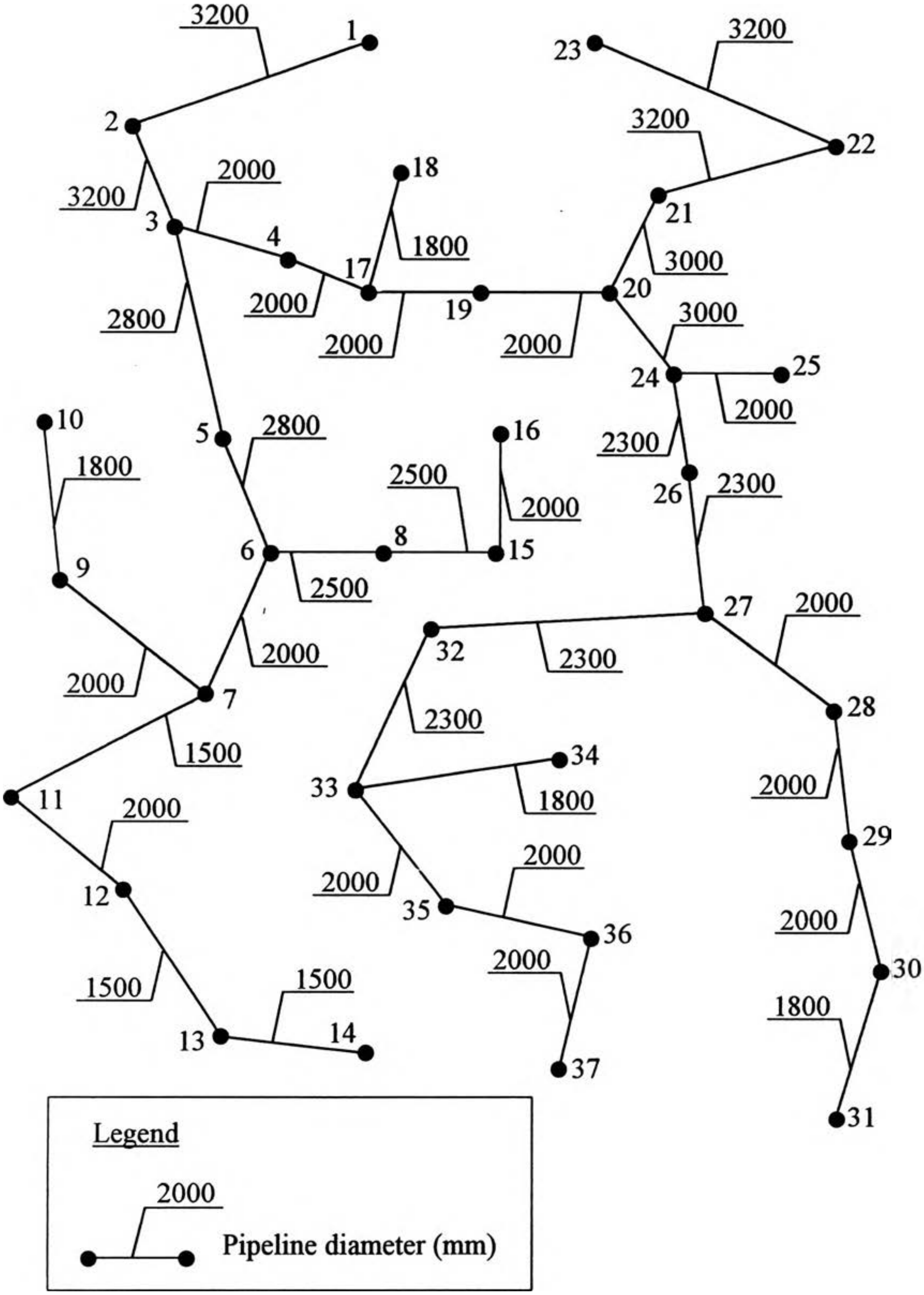

Fig. 4.8 Water transmission tunnel network with pipeline sizes.

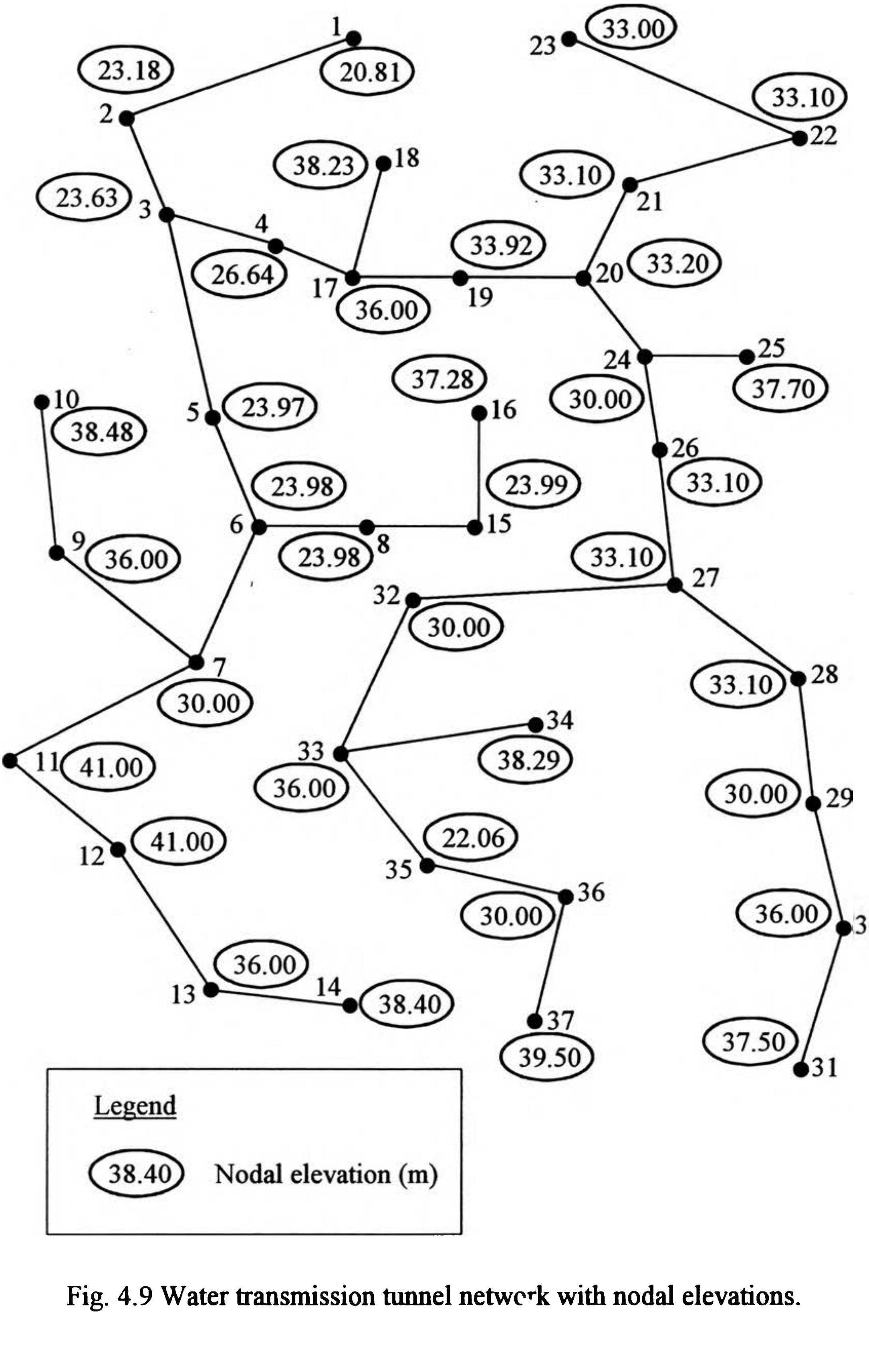

Fig. 4.9 Water transmission tunnel network with nodal elevations.

Figs. 4.5 through 4.9 display the sketched topological representation of the water transmission tunnel system in the area at East of Bangkok, in Metropolitan Waterworks Authority.

Transmission tunnel have total length about 35 km., 2.0-3.4 m. and 20 m. underground. This particular network is the part of the treated water transmission and distribution systems. It contain 37 nodes and 36 nodal connections. This network is supplied from a surge tank that connected to transmission pumping station at beginning of node 1 and 23 with the specified pressure of 7.75 and 7.59 bar respectively.

The PICCOLO code was designed for the water transmission tunnel system. It was used to simulate in order to assist the operation, maintenance, design and planning for the Metropolitan Water Administration at the SAMSEN branch. This model network have been calibrated by comparing computed pressures and flows with those measured in the field test according to operational demand supplied to the customers as shown in Fig. 4.6.

The program testing was done to simulate for analyzing the flow rates distribution in order to ensure the model results are approach to the best correlation with PICCOLO.

The network and property parameters are obtained for this hydraulic network in the computer program as follows:

From Water Transmission Tunnel and Control Center, MWA (SI units):

N = 37 Number of nodes

VT	=	1.0	Viscosity
DT	=	1000.0	Density
NC	=	36	Number of nodal connections
NDL	=	36	Number of pipeline connections
NT	=	10	Number of nodes with $T_i = 1$, or $T_i = 3$
NV	=	10	Number of nodes with specified injection or withdrawal rate
ITMAX	=	30	Maximum number of iterations

The following data are used from Figs. 4.6 through 4.9 as shown in Tables 4.8 through 4.12

Table 4.8 Data for water transmission pipeline connections

I	J	C(I , J)	D(I , J)	L(I , J)	FF(I , J)	E(I , J)
1	2	1	3200	2892.00	0.0275	0.5
2	3	1	3200	1770.00	0.0275	0.5
3	4	1	2000	520.80	0.0275	0.5
4	17	1	2000	1619.21	0.0275	0.5
5	6	1	2800	5400.00	0.0275	0.5
6	7	1	2000	650.00	0.0275	0.5
6	8	1	2500	538.37	0.0275	0.5
7	9	1	2000	3680.00	0.0275	0.5
7	11	1	1500	4278.00	0.0275	0.5
8	15	1	2500	1859.63	0.0275	0.5
9	10	1	1800	290.00	0.0275	0.5
11	12	1	2000	1740.00	0.0275	0.5
12	13	1	1500	3180.00	0.0275	0.5
13	14	1	1500	250.00	0.0275	0.5
15	16	1	2000	700.00	0.0275	0.5
17	18	1	1800	290.00	0.0275	0.5
17	19	1	2000	1485.48	0.0275	0.5
19	20	1	2000	514.52	0.0275	0.5

Table 4.8 (Continued)

I	J	C(I , J)	D(I , J)	L(I , J)	FF(I , J)	E(I , J)
20	21	1	3000	2230.00	0.0275	0.5
20	24	1	3000	3058.00	0.0275	0.5
21	22	1	3200	2459.00	0.0275	0.5
22	23	1	3200	4008.00	0.0275	0.5
24	25	1	2000	3025.00	0.0275	0.5
24	26	1	2300	50.00	0.0275	0.5
26	27	1	2300	1200.00	0.0275	0.5
27	28	1	2000	200.00	0.0275	0.5
27	32	1	2300	2500.00	0.0275	0.5
28	29	1	2000	9000.00	0.0275	0.5
29	30	1	2000	11000.00	0.0275	0.5
30	31	1	1800	400.00	0.0275	0.5
32	33	1	2300	3377.00	0.0275	0.5
33	34	1	1800	130.00	0.0275	0.5
33	35	1	2000	169.00	0.0275	0.5
35	36	1	2000	3178.00	0.0275	0.5
36	37	1	2000	2976.00	0.0275	0.5

Note:

I = Upstream node

J = Downstream node

C(I , J) = 1 Pipeline connection

D(I , J) = Pipeline diameter joining node I and node J (mm)

L(I , J) = Pipeline length joining node I and node J (m)

E(I , J) = Pipeline roughness joining node I and node J (mm)

FF(I , J) = Initial approximation for the Fanning friction factor

Table 4.9 Initial estimate and fixed pressures for water transmission system

I	P(I)	I	P(I)	I	P(I)
1	7.75	2	6.04	3	6.02
4	6.00	5	6.98	6	6.96
7	6.94	8	6.92	9	6.90
10	5.98	11	5.96	12	5.94
13	5.92	14	5.90	15	4.98
16	4.96	17	4.94	18	4.92
19	5.93	20	3.98	21	3.96
22	3.94	23	7.59	24	5.59
25	6.31	26	6.01	27	6.99
28	6.97	29	6.95	30	6.93
31	6.91	32	5.99	33	5.97
34	5.95	35	5.93	36	5.91
37	4.99	-	-	-	-

Note:

P(I) = Nodal pressure at node I (bar)

Table 4.10 Node-types for water transmission tunnel system

I	T(I)	I	T(I)	I	T(I)
1	1	10	3	14	3
16	3	18	3	23	1
25	3	31	3	34	3
37	3	-	-	-	-

Note:

T(I) = 1 Specified pressure at node I

T(I) = 3 Specified injection or withdrawal rate at terminal node I

Table 4.11 Water transmission tunnel system with specified withdrawal rates

I	V(I)	I	V(I)
5	2423.00	7	200.00
10	14583.00	14	11042.00
16	12917.00	18	8333.00
25	17500.00	31	5000.00
34	14583.00	37	15417.00

Note:

V(I) = Specified withdrawal rate at node I (m^3/hr)

Table 4.12 Nodal elevations for water transmission tunnel system

I	Z(I)	I	Z(I)	I	Z(I)
1	20.81	2	23.18	3	23.63
4	26.64	5	23.97	6	23.98
7	30.00	8	23.98	9	36.00
10	38.48	11	41.00	12	41.00
13	36.00	14	38.40	15	23.99
16	37.28	17	36.00	18	38.23
19	33.92	20	33.20	21	33.10
22	33.10	23	33.00	24	33.10
25	37.70	26	33.10	27	33.10
28	33.10	29	30.00	30	36.00
31	37.30	32	30.00	33	36.00
34	38.29	35	22.06	36	30.00
37	39.50	-	-	-	-

Note:

Z(I) = Nodal elevation at node I (m)

4.1.2 Data Output

After 13 iterations, the Newton-Raphson method converged. The results are shown in Tables 4.13 through 4.15.

Table 4.13 Converged pressures for water transmission tunnel system

I	P(I)	I	P(I)	I	P(I)
1	7.750	2	7.285	3	7.097
4	6.804	5	6.760	6	6.065
7	5.263	8	6.051	9	4.287
10	3.992	11	2.993	12	2.886
13	2.474	14	2.171	15	6.001
16	4.656	17	5.892	18	5.658
19	6.117	20	6.195	21	6.654
22	7.006	23	7.590	24	5.703
25	4.790	26	5.688	27	5.334
28	5.331	29	5.517	30	4.797
31	4.643	32	5.090	33	3.776
34	3.530	35	5.105	36	3.955
37	2.677	-	-	-	-

Table 4.14 The flow rates distribution for water transmission tunnel system

I - J	Q(I , J)	I - J	Q(I , J)	I - J	Q(I , J)
1 - 2	43844.70	2 - 3	43842.49	3 - 4	2677.73
3 - 5	41164.28	4 - 17	2677.64	5 - 6	38740.03
6 - 7	25825.85	6 - 8	12916.30	7 - 9	14583.72
7 - 11	11041.73	8 - 15	12916.43	9 - 10	14583.78
11 - 12	11041.73	12 - 13	11041.75	13 - 14	11042.01
15 - 16	12916.25	17 - 18	8332.79	19 - 17	5656.31
20 - 19	5656.57	21 - 20	58152.87	20 - 24	52503.21

Table 4.14 (Continued)

I - J	Q(I , J)	I - J	Q(I , J)	I - J	Q(I , J)
22 - 21	58153.02	23 - 22	58158.40	24 - 25	17500.07
24 - 26	35002.49	26 - 27	35002.59	27 - 28	4999.80
27 - 32	30002.08	28 - 29	4999.83	29 - 30	4999.82
30 - 31	4999.83	32 - 33	30001.70	33 - 34	14582.77
33 - 35	15413.43	35 - 36	15418.07	36 - 37	15417.19

Table 4.15 The Fanning friction factors for water transmission tunnel system

I - J	F(I , J)	I - J	F(I , J)	I - J	F(I , J)
1 - 2	0.005760	2 - 3	0.005760	3 - 4	0.006607
3 - 5	0.005966	4 - 17	0.006607	5 - 6	0.005967
6 - 7	0.006542	6 - 8	0.006166	7 - 9	0.006548
7 - 11	0.007107	8 - 15	0.006166	9 - 10	0.006743
11 - 12	0.006552	12 - 13	0.007107	13 - 14	0.007107
15 - 16	0.006549	17 - 18	0.006752	19 - 17	0.006569
20 - 19	0.006569	21 - 20	0.005856	20 - 24	0.005857
22 - 21	0.005758	23 - 22	0.005758	24 - 25	0.006545
24 - 26	0.006292	26 - 27	0.006292	27 - 28	0.006574
27 - 32	0.006293	28 - 29	0.006574	29 - 30	0.006574
30 - 31	0.006765	32 - 33	0.006293	33 - 34	0.006743
33 - 35	0.006547	35 - 36	0.006547	36 - 37	0.006547

Note:

Q(I , J) = The water flow rate (m^3/hr) for flow from node I to node J