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Estimating the Cost of Product Water Conveyance from Desalination Plants

S. A. Reed
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OAK RIDGE NATIONAL LABORATORY
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U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy $4.50; Microfiche $3.00

ORNL/TM-6290

Contract No. W-7405-eng-26

Engineering Technology Division

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Date Published - August 1978

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ACKNOWLEDGMENT

Base case optimization and development of costing methodology were under the direction of K. D. Cook, Estimating Engineering Department, UCND Engineering Division.

ESTIMATING THE COST OF PRODUCT WATER CONVEYANCE FROM DESALINATION PLANTS

S. A. Reed   M. L. Marsh*

ABSTRACT

Methods are presented for estimating the costs of transporting, by pipeline, product water from desalination plants. Cost curves are presented for conveying from 19 to 380 × 10^3 m^3/day (5 to 100 Mgd) to distances to 80 km (50 mile). Sand is used as the reference soil, and adjustment factors are given for earth, shale, hard rock, and swampland.

Costs are given as a function of distance and include pipeline construction, pumping stations, power lines, and electrical switchgear.

1. INTRODUCTION

There are many arid areas in the world where desalted seawater or brackish waters provide all or most of the municipal and industrial water supply. The installed desalting capacity worldwide is increasing rapidly; for example, the industrial capacity alone increased nearly 946 × 10^3 m^3/day [250 million gallons per day (Mgd)] during the period 1974–1976.† Much of this new capacity was in the Middle East.

The cost of transporting the desalted water can be a significant cost factor depending upon the amount of water, distance, and terrain and must be considered in the overall cost of water in the early stages of planning new or additional capacity. This report was prepared to provide water planners a means of estimating conveyance costs. The economic data used to prepare the estimating curves are included in an appendix so that the individual costs can be escalated appropriately at some future date. In this report all costs are presented in first quarter 1978 dollars.

*Estimating Engineering Department, UCND Engineering Division.

†Desalting Plant Inventory Report No. 6, Office of Water Research and Technology, U.S. Department of the Interior (October 1977).

2. GROUND RULES

In order to obtain general criteria for such a wide scope study, a system is conceived which is as simple in form as possible. This is a multiplex of a standard pipeline. However, to facilitate the desired simplicity, a number of conditions are applied.

First, the minimum economical discharge rate of a desalination plant is taken to be 19 x 10^3 m^3/day (5 Mgd). Therefore, this unit of flow is the basis of the multiplex, such that all other capacities are multiples of this 19 x 10^3 m^3/day unit.

Secondly, the pumping stations are capable of producing 91 m (300 ft) of head. This amount of head is lost every 8 km (7.5 miles) of linear, level pipe. Hence, a pumping station is required every 8 km.

The third condition is generalized earth work. Sand is used as a reference soil, since it is the easiest to work with and, therefore, the least expensive. From this base, multipliers are used to adjust cost to compensate for earth, shale, hard rock, and swamp terrains.

Next, the pipeline is buried in a 1.5-m (5-ft) deep trench and is not supported by any means other than the soil on which it rests. Also, this pipeline is of nonseismic quality, since a rupture will not harm the environment.

Furthermore, elevation gains are considered only up to 304.8 m (1000 ft). Anything above 304.8 m is assumed uneconomical and therefore will require tunneling to reduce the gain to less than 1000 ft. Neither tunneling nor any other natural barriers are considered in this study.

Finally, water purity and ambient temperature are not considered, since these have negligible effects on the performance of the system.

3. METHOD OF CALCULATION

A. Classify conditions:

1. Quantity to be transported - m^3/day (Mgd)
2. Distance to be transported — kilometers (miles)
3. Elevation gain — meters (feet)

4. Terrain
    a. Sand
    b. Earth
    c. Shale
    d. Hard rock
    e. Swamp

B. Convert elevation gain in meters (or feet) to a linear distance of level pipe. The friction head loss of this distance of pipe corresponds to the head loss due to vertical gain. Make this conversion using the data of Fig. 1. Add this to transport distance to determine the effective distance.

C. Using the effective distance and Figs. 2 or 3, find cost for the appropriate quantity.

D. To find final cost. Adjust above cost for proper terrain using the data of Table 1.

Table 1. Terrain multipliers

Categories	Plant size × 10^3 m^3/day				
	19 (5 Mgd)	38 (10 Mgd)	95 (25 Mgd)	190 (50 Mgd)	380 (100 Mgd)
Sand	1	1	1	1	1
Earth	1.04	1.04	1.04	1.05	1.05
Shale	1.05	1.05	1.05	1.06	1.06
Hard rock	1.10	1.10	1.10	1.13	1.13
Swamp	1.12	1.12	1.12	1.16	1.16

Terrain multipliers are based solely on percent differences in excavation and backfill costs for different soil consistencies.

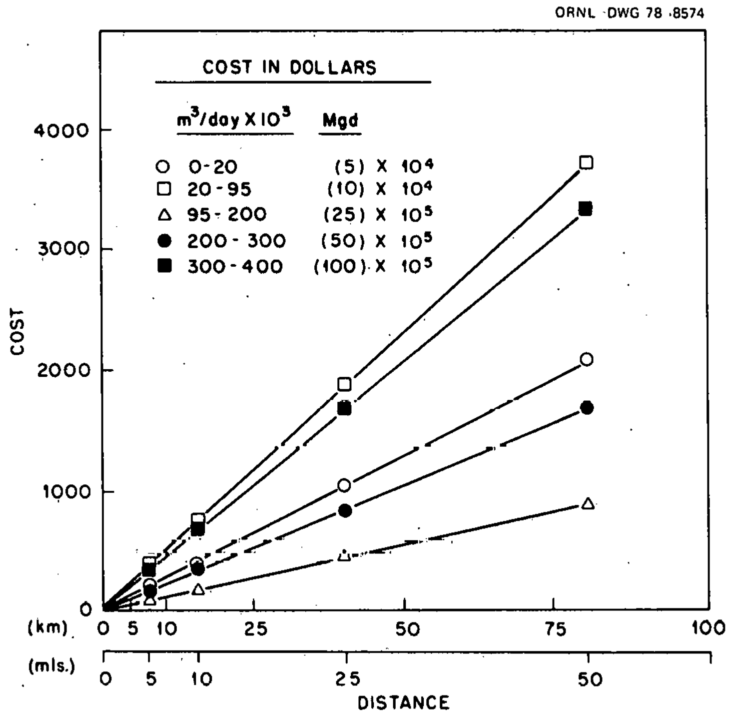

Fig. 1. Pipeline cost as a function of distance.

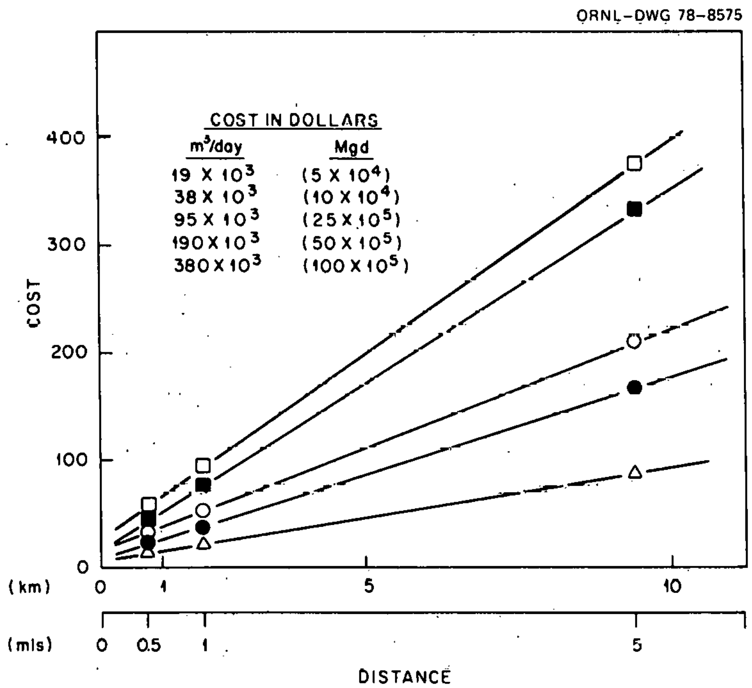

Fig. 2. Pipeline cost as a function of distance (insert from Fig. 1).

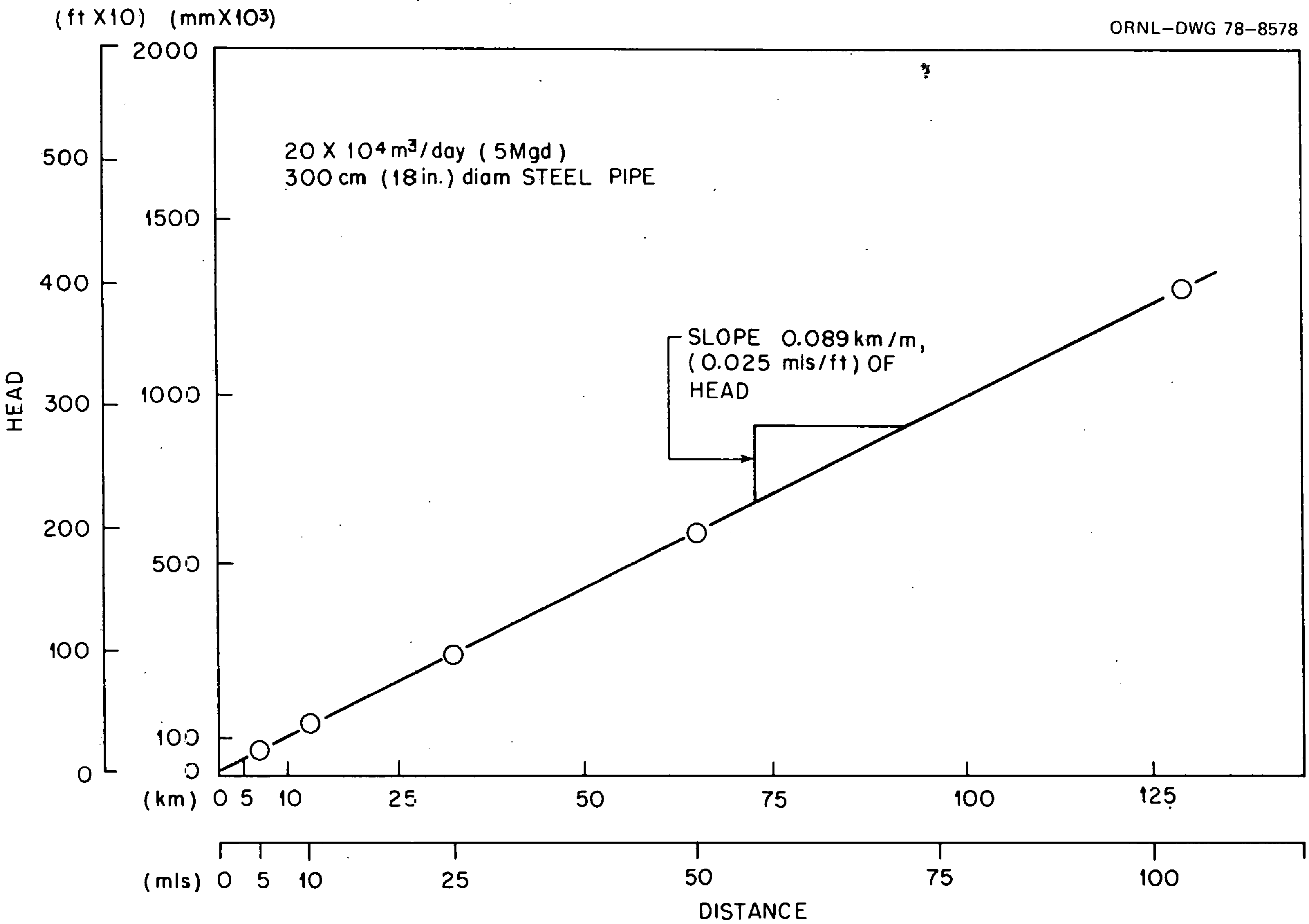

Fig. 3. Head vs distance.

APPENDIX

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Table A1. Pipeline cost ($ × 10^3/mile)

Kilometers	(Miles)	Pump station	Piping	Electrical transmission line	Total
		Plant size, 19 × 10^3 m^3/day (5 Mgd)			
0.8	(0.5)	145	158	38.2	341
1.6	(1)	145	316	76.4	537
8.0	(5)	145	1,580	382.0	211
16.0	(10)	290	3,160	764.0	421
40.0	(25)	580	7,900	1,910.0	10,400
80.0	(50)	1,015	15,800	3,820.0[a]	20,600
120.0	(75)	1,450	15,800	3,820.0[a]	21,100
		Plant size, 38 × 10^3 m^3/day (10 Mgd)			
0.8	(0.5)	209	316	38.2	563
1.6	(1)	209	632	76.4	917
8.0	(5)	209	3,160	382.0	3,750
16.0	(10)	418	6,320	764.0	7,500
40.0	(25)	836	15,800	1,910.0	18,500
80.0	(50)	1,436	31,600	3,820.0[a]	36,900
120.0	(75)	2,090	31,600	3,820.0[a]	37,500
		Plant size, 95 × 10^3 m^3/day (25 Mgd)			
0.8	(0.5)	401	790	38.2	1,230
1.6	(1)	401	1,580	76.4	2,060
8.0	(5)	401	7,900	382.0	8,680
16.0	(10)	802	15,800	764.0	17,400
40.0	(25)	1,604	39,500	1,910.0	43,000
80.0	(50)	2,807	79,000	3,820.0[a]	85,600
120.0	(75)	4,010	79,000	3,820.0[a]	86,800
		Plant size, 190 × 10^3 m^3/day (50 Mgd)			
0.8	(0.5)	741	1,580	38.2	2,360
1.6	(1)	741	3,160	76.4	3,980
8.0	(5)	741	15,800	382.0	16,900
16.0	(10)	1,482	31,600	764.0	33,800
40.0	(25)	2,964	79,000	1,910.0	83,900
80.0	(50)	5,187	15,800	3,820.0[a]	167,000
120.0	(75)	7,410	158,000	3,820.0[a]	169,000
		Plant size, 380 × 10^3 m^3/day (100 Mgd)			
0.8	(0.5)	1,407	3,160	38.2	4,610
1.6	(1)	1,407	6,320	76.4	7,800
8.0	(5)	1,407	31,600	382.0	33,400
16.0	(10)	2,814	63,200	764.0	66,800
40.0	(25)	5,628	158,000	1,910.0	166,000
80.0	(50)	9,849	316,000	3,820.0[a]	330,000
120.0	(75)	14,070	316,000	3,820.0[a]	334,000

[a]80 km (50 miles), extra 45 km (25 miles) same — maximum distance run is allowance for elevation head.

Table A2. Pumping station costs ($ x 10^3/mile)

Plant size 1 x 10^3 m^3/day (Mgd)	Piping	Reservoir	Power	Subtotal (directs)	35% Indirects	20% Engineering	30% Contingency	Totals
19 (5)	37	5	30	72	25	19	29	145
38 (10)	57	6	40	103	36	28	42	209
95 (25)	113	11	70	199	69	53	80	401
190 (50)	215	29	132	367	128	99	148	742
380 (100)	415	34	246	695	243	183	281	1407

Table A3. Piping equipment costs
$

Component	Material	Labor	
Reducer [45.8—30.5 mm (18—12 in.)]	180	120	
Gate valve [30.5 mm (12 in.)]	1900	57	
Check valve [30.5 mm (12 in.)]	1200	170	
Tee [30.5 mm (12 in.)]	150	140	
Vertical [910 m^3/sec (4000 gpm)]			
Turbine pump	4300	540	Pump set
Motor [298 kW (400 hp)]	7900	680	Pump set

Table A4. Excavation and concrete required for each complete reservoir

1 x 10^3 m^3/day (Mgd)	m^3 (yd^3)	\$/m^3 (\$/yd^3)	\$
	Excavation		
19 (5)	51 (66)	1.65 (1.25)	80
38 (10)	73 (95)	1.65 (1.25)	120
95 (25)	138 (180)	1.65 (1.25)	230
190 (50)	252 (330)	1.65 (1.25)	400
380 (100)	474 (620)	1.65 (1.25)	800
	Concrete		
19 (5)	23 (30)	183[a] (140)	4,200
38 (10)	31 (41)	183[a] (140)	5,700
95 (25)	48 (63)	183[a] (140)	8,800
190 (50)	95 (129)	183[a] (140)	18,000
380 (100)	183 (239)	183[a] (140)	33,000

[a]Includes rebar and forming.

Table A5. Power supply equipment costs

Category		Quantity	Type	Cost, $	
1 x 10^3 m^3/day	(Mgd)			Material	Labor
		Transformers			
19	5	1	750 kVa	12,700	500
38	10	1	1000 kVa	15,000	600
95	25	1	2000 kVa	21,000	700
190	50	2	2000 kVa	42,000	1400
380	100	3	2500 kVa	75,000	2400
		Starters			
19	5			15,900	300
38	10			23,600	500
95	25			47,100	1000
190	50			86,600	1800
380	100			165,000	3400

Table A6. Pipeline costs

	$/lin m	$/lin ft	$/km	$/mile
Earthwork				
Excavation (0.56 yd^3/lin ft) — $1.40 m /lin m^3($1.24/lin ft)				
Pipeline				
Pipe	84.80	25.85		
Coating and wrapping	8.20	2.50		
Subtotal	93.00	29.59	93,000	156,000
35% Indirects			34,125	54,600
20% Engineering			26,313	42,100
30% Contingency			39,500	63,200
Total			192,938	315,900

Table A7. Transmission line cost

Transmission lines are 13.2 kV, and are comprised of 15-m (50-ft) wooden poles on 61-m (200-ft) centers strung with three No. 4/0 stranded, hard drawn copper wires

	$/km	$/mile
Poles		
Material $255 each Labor $173 each		
Subtotal	7,250	11,600
Wire		
Subtotal	16,333	26,100
Total cost	23,583	37,700
35% Indirects	8,250	13,200
20% Engineering	6,375	10,200
30% Contingency	9,563	15,300
Total cost	47,771	76,400

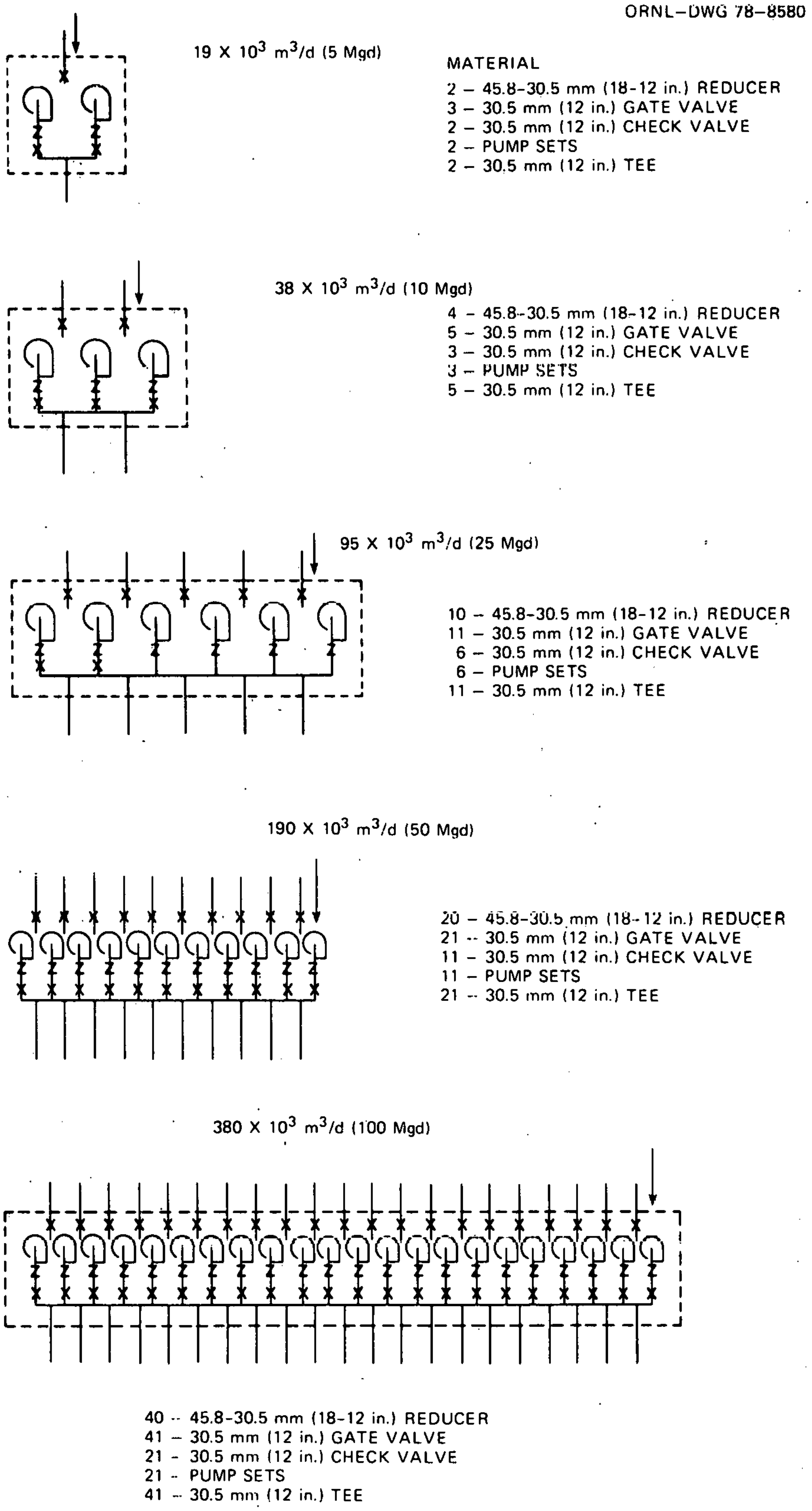

Fig. A1. Pump station piping schematic and material list.

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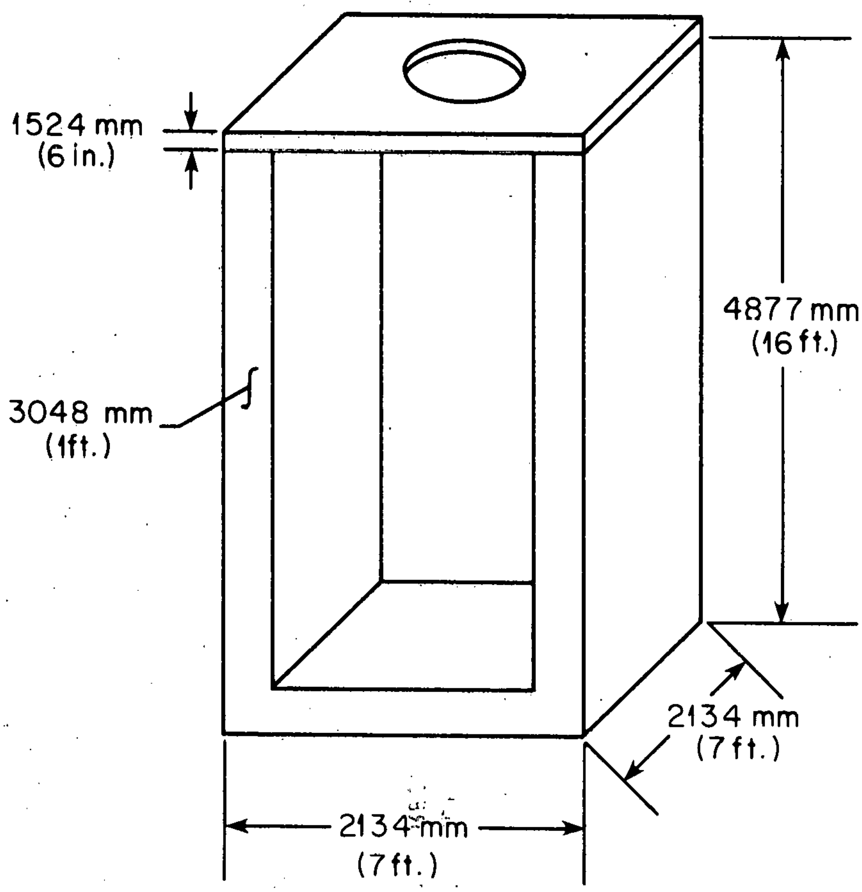


COMPLETE RESERVOIR IS BUILT UP OF MULTIPLE SECTIONS LIKE THE ONE SHOWN ABOVE. THE NUMBER OF SECTIONS CORRESPOND ONE TO ONE WITH THE PUMP SETS. ALSO, EACH RESERVOIR HAS TWO END WALL SECTIONS'

Fig. A2. Reservoir

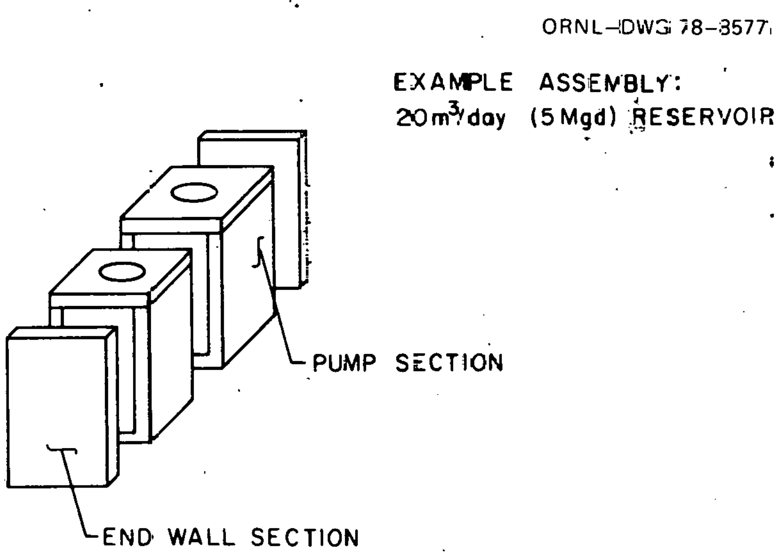
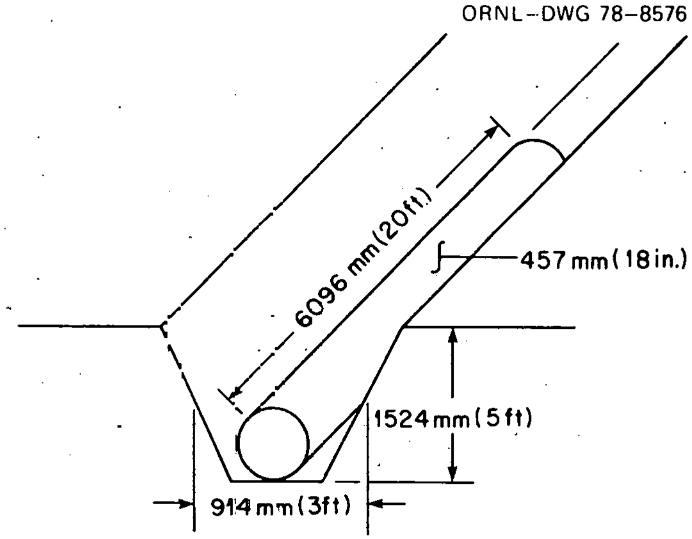


Fig. A3. Construction of reservoir.



THE PIPELINE IS A 457 mm (18 in.) DIAM, CARBON STEEL, SCHED 40, TARRED AND WRAPPED PIPE, AND IS COMPRISED OF 6096 mm (20 ft) WELDED SECTIONS.

THE EXCAVATION IS A 1524 mm (5 ft) DEEP BY 914 mm (3 ft) AVG WIDTH TRENCH. A HYDRAULIC EXCAVATOR PERFORMS ALL MATERIAL REMOVAL. HARD ROCK, HOWEVER, ALSO REQUIRES A DRILLING RIG. THE SWAMP EXCAVATION REQUIRES A BARGE MOUNTED DRAGLINE WITH A CLAMSHELL BUCKET.

THE BACKFILL OPERATION USES THE EXTRACTED MATERIAL IN ALL TERRAINS. THE MATERIAL NEEDS NO PROCESSING WITH THE EXCEPTION OF HARD ROCK WHICH MUST BE CRUSHED TO A 20 MESH CONSISTENCY.

Fig. A4. Method of pipeline construction.

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