

CHAPTER 5

TRANSPORTATION OF WATER

Water can be transported either by means of gravitational flow or pumping.

Gravitational flow: If the source of water is at such a height that the desired pressure can be available for transmission to the reservoir then the gravitational flow method is used.

Pumping: Water is pumped to elevated tank (water tower) or directly into mains.

Pumping directly into main has disadvantages:

1. In case of power interruption, supply of water stops.
2. To compensate the variations in water consumption, a number of pumps having varying capacities are installed and they have to be put in operation according to water requirements. These are not economical.

Pumping to elevated tank has many advantages:

1. The excess water during low consumption is stored in elevated tanks and utilized during peak hours. This is an economical method since the pumps can operate at their rated capacity, not varying capacity.
2. The stored water in elevated tank forms a reserve for fire & power failure conditions.

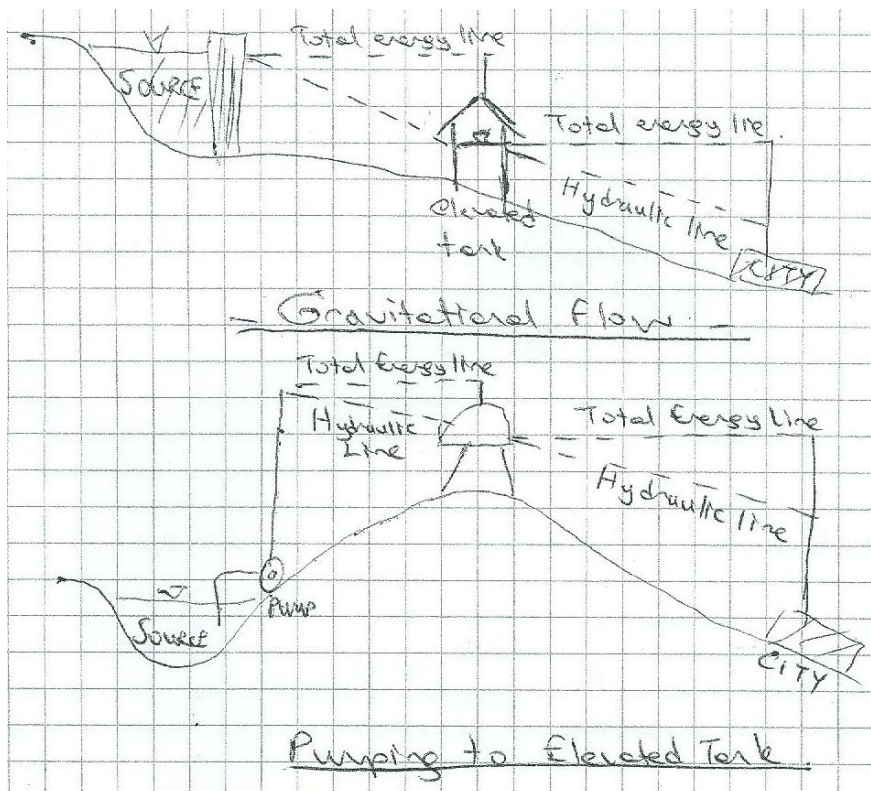


Figure 1. Gravitational flow and pumping to elevated tank

For transportation of water canals, flumes (open channels), tunnels and pressure pipes can be used.

Open Channels (just used for gravity flow):

1. They are designed to convey water under atmospheric pressure. For open channels, hydraulic gradient and free water surface are coincident.
2. Open channels are used when topographic conditions permit gravity flow with minimal excavation or fill.

Pipelines (can be used both gravity & pumping flow):

They may be laid above or below ground or partly buried.

Pipelines used in transportation systems require;

1. Gate Valves: They are often spaced about 400m apart for the draining of a section of a pipe for inspection or repair. They are placed on either side of a check valve to permit its removal for inspection or repair.
2. Check Valves: They allow flow in one direction only. They are normally located on upstream side of pumping equipment to prevent backflow.
3. Air Release Valves: They are needed at high points in the line to release trapped gases. If air valve is not provided, the presence of air will reduce the effective area of pipe. If pressure increases, solubility of air increases. If pressure drops, solubility of air decreases. So, at high points of lines, solubility of air drops regarding to pressure drops and then air bubbles in water will explode and the pipe will be damaged as a result.
4. Drains: They are located at low points in the line to permit removal of sediment and allow the conduit to be emptied.
5. Pressure Break Valve: Water pressure can be high at some parts of the line. In such a case, pipes that are resistant to high pressure should be chosen but this is not so economical. Because of this reason, high pressure should be dropped to acceptable level by the help of pressure break valves.

Criteria for Route Selection of Transmission Line

- A) Location of water source and location of town which water to be supplied are both known.
- B) Determine the location and level of service reservoir.
- C) Route should be selected such that:
 - Length should be minimized as much as possible.
 - Pumping should be avoided if possible.
 - High water pressure should be avoided.

- Number of appurtenances (gate valve, check valve, drain, air release valve, pressure break valve) should be minimized.
- Very low or high velocities should be avoided.
 - Low velocities cause sedimentation.
 - High velocities cause corrosion of pipe.
 - Range: 0.75 – 3 m/sec, usual range: 1 - 1.5 m/sec.
- Cost should be minimized.
- If horizontal pipe sections are used, release of air and drain the dirt will not be possible. So, in case of horizontal ground surface, artificial slopes are given to pipes to be laid.
- Convenient conduit type and material should be selected.

Hydraulic Considerations

As it was mentioned before, for transportation of water, open channels and pressure pipes can be used.

For open channels:

Manning's formula is commonly used.

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

For pipes under pressure:

- 1) Darcy-Weisbach formula is used for friction head loss calculations.

$$H_L = \frac{fL}{D} \frac{V^2}{2g}$$

f is friction factor and can be found from Moody's diagram or by Colebrook-White equation.

1.1) Colebrook-White equation

$$\frac{1}{\sqrt{f}} = -2 \log \left[\frac{k}{3.7D} + \frac{2.51}{Re\sqrt{f}} \right]$$

k is absolute roughness and this equation is solved by trial & error.

2) Hazen-Williams:

$$V = 0.85 C. R^{0.63}. S^{0.54} \quad \text{or}$$

$$Q = 0.28 C \cdot D^{2.63} \cdot S^{0.54}$$

This is an empirical formula for metric system.

Selection of Economic Pipe Diameter

A) Pumping is needed

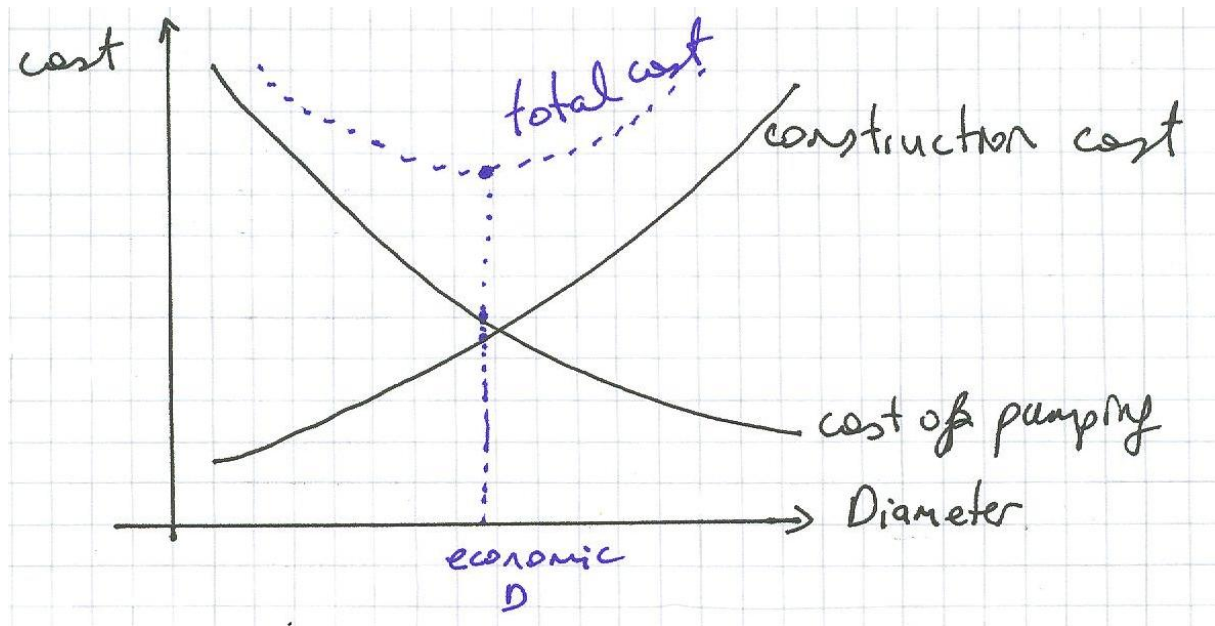


Figure 2. Economic pipe diameter selection when pumping is needed.

According to Figure 2;

As slope increases, velocity increases so smaller diameter is required.

As slope decreases, velocity decreases so larger diameter is required.

As diameter getting larger, construction cost increases.

As diameter getting larger, pumping cost decreases.

Example:

Determine the economic pipe diameter of the pipe if:

- $Q = 100$ L/sec
- Cost of electricity, $E=0.053$ USD/kW-h
- Pumping efficiency: 0.6
- Interest rate (opportunity + cost of financing + service fee) = 6%
- Depreciation (amortisation) = 3%

Solution:

$$\text{Annual pumping cost} = C_p = 0.736 \frac{1000 Q H}{75 \mu} E \cdot b$$

H = h+S.L and b = pumping hours in one year

$$\text{Then } C_p = \frac{0.736 \times 1000 \times 0.1 \times 0.053 \times (24 \times 365) \times (h+SL)}{75 \times 0.6}$$

$$C_p = 760 (h+SL)$$

Since h (static head) does not depend on pipe diameter and we may make the comparison per linear meter of pipe

$$C_p = 760 S \text{ (USD/m.year)}$$

If the construction cost of one meter length pipe is C_{CT} , annual construction cost of one meter pipe is C_c .

$$C_c = (\text{interest rate} + \text{depreciation}) C_{CT}$$

$$C_c = \frac{6 + 3}{100} C_{CT}$$

$$C_c = (9/100) C_{CT}$$

Then we prepare a table for pumping cost for different diameters and we use Hazen-Williams equation for slope calculation ($C_{HW} = 100$).

Diameter (mm)	Slope	$C_p = 760S$ (USD/m.year)
300	0.01	7.6
350	0.0049	3.724
400	0.0025	1.9

After this table, we will prepare another one for the construction cost.

Diameter (mm)	C_{CT} (taken from manufacturer)	C_c (USD/m)
300	56,5 USD/m	5.085
350	69.3 USD/m	6.237
400	110.7 USD/m	9.963

$$\text{Total Cost} = C_c + C_p$$

Then you will choose the most economic diameter, in that case 350mm diameter pipe is the most economical one.

B) Gravity Type of Flow

i) if the pipe diameter is uniform then select minimum diameter which corresponds to the available head and permissible velocity.

ii) if several pipe diameters or several transmission systems we have then use Lagrange's Method.

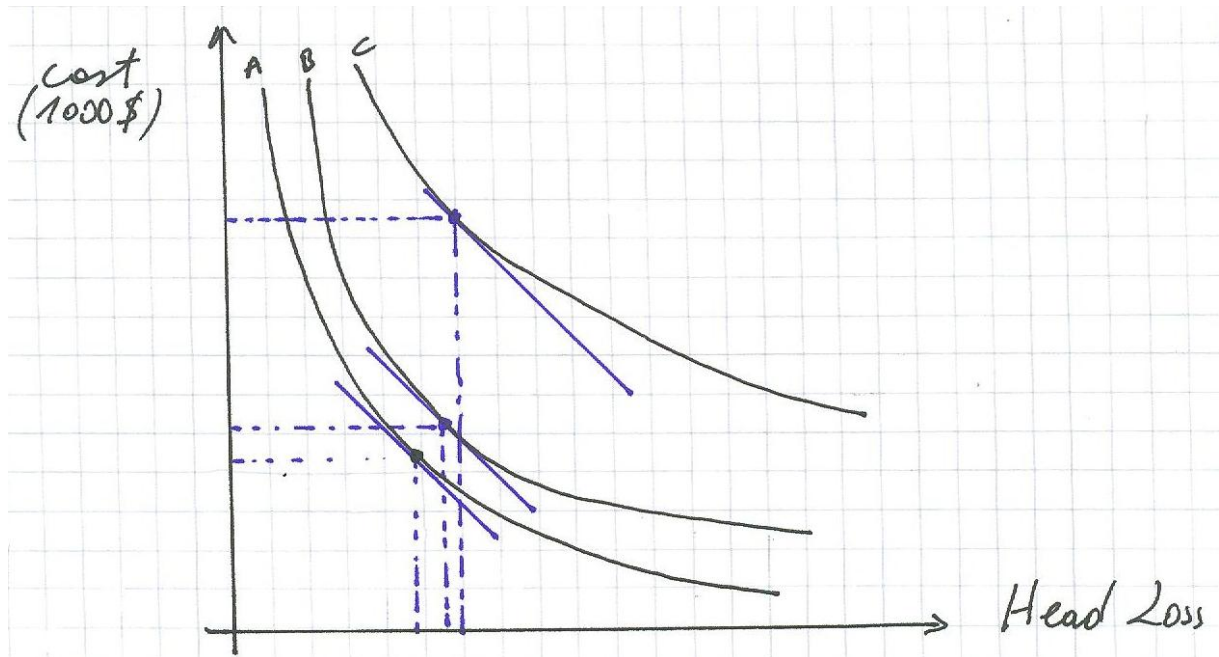


Figure 3. Lagrange's method to select most appropriate diameter series when gravity type of flow is used.

The method is an trial and error method and the steps are as following:

- 1) Select a tangent to A shown in the Figure 3.
- 2) Draw parallel tangents to A on B and C
- 3) Repeat the procedure by trial and error until $\Sigma h = H$ (available head)

Pipe Material Selection [1]

Factors which will be considered in the selection of sewer pipe materials and piping systems are:

- Availability of pipe in required sizes, strengths, etc .
- Availability of fittings, connections, and adapters .
- Ease of handling and installation .
- Physical strength .
- Flow characteristics or friction coefficient .
- Joint water tightness and ease of installation .

- Resistance to acids, alkalis, high temperature or corrosive wastes, and corrosive soils

CAST IRON

Cast iron is the oldest metal found in pipelines, and is relatively common since many pipelines installed over 100 years ago are still in operation. Installation techniques for cast-iron pipe are critical to its proper specification, as the installation depth determines the recommended maximum pressure that should be applied. Cast-iron pipe should be fully supported by the trench bottom because it is extremely brittle, and backfill should be free of rocks and debris. CI pipe is resistant to internal and external corrosion. CIS pipe is available in 2-inch through 15-inch diameters, in 4 to 7 meters laying lengths.

DUCTILE IRON

Cast iron pipe was the dominant pipe material until the 1950s when ductile iron was introduced. The metallurgy of the materials is very similar, but ductile iron has increased strength and ductility from carbon that exists as small spheroids. It is well suited for most sanitary sewers including river crossings, piping at wastewater treatment facilities, pipe located in unstable soils, highway and rail crossings, water line crossings, depressed sewers and piping aboveground. Pipe is available in diameters 3-inch through 54-inch, and in 5 – 6 meters laying lengths.

STEEL PIPES

Steel pipe is often used in system plumbing next to the pump. It is rarely used in main parts of the pipeline in buried installations. Steel pipe is used in buried applications only as a last resort due to its high cost, high friction loss, and because it easily corrodes. Occasionally, steel pipe must be used for very high pressure pipelines (10 – 40 ATM) where plastic pipe is not available with adequate pressure ratings.

REINFORCED CONCRETE

Reinforced concrete (RC) pipe will be used where high external loadings are anticipated and large diameters or tight joints are required . The advantages of RC pipe include a wide range of diameters, 12-inch through 108-inch, and laying lengths, 4 feet to 24 feet, which are available. A disadvantage is the lack of corrosion resistance to aggressive water and soil.

ASBESTOS CEMENT

Asbestos-cement (AC) pipe is made from a mixture of asbestos fibers and portland cement . AC pipe matches the durability of concrete pipe but weighs less and is manufactured in a wide variety of strength classifications and laying lengths .

PLASTIC PIPES

- PVC

Polyvinyl chloride (PVC) pipe is chemically inert to most acidic and alkaline wastes, and is totally resistant to biological attack . Since it is a nonconductor, PVC pipe is immune to nearly all types of underground corrosion caused by galvanic or electrochemical reactions, in addition to aggressive soils . Durability, light weight, a high strength-to-weight ratio, long laying lengths, watertight joints and smooth interior surfaces are characteristics which make PVC pipe an attractive alternative for use in sewer systems . Disadvantages include possible chemical instability due to long-term exposure to sunlight, excessive pipe deflection under trench loadings when installed improperly or subjected to high temperature wastes, and brittleness when exposed to very cold temperatures . PVC sewer pipe is available in diameters 4-inch through 24-inch, and in laying lengths of 10 to 20 feet.

- POLYETHYLENE

Polyethylene (PE) pipe is the second most common pipe used in stock water pipelines. It is flexible, comes in coils and is used for most "pull-in" type systems. Since it comes in coils, PE pipe takes fewer fittings to lay. This material is tough, flexible, and resistant to freeze damage.

[1] <http://140.194.76.129/publications/eng-manuals/em1110-3-174/c-6.pdf>