CE 3372 – Water Systems Design
Exercise Set 4

Purpose: Review and application of head loss models used in water transmission and distribution system analysis

Exercises

1. Equation 1 is the Hazen-Williams discharge formula in US Customary Units.

$$Q = 1.318 C_h A R^{0.63} S^{0.54} \tag{1}$$

where;
Q is the discharge in ft^3/sec;
A is the cross section area of pipe in ft^2 ($A = \frac{\pi D^2}{4}$; D is the pipe diameter.);
C_h is the Hazen-Williams friction coefficient (depends on pipe roughness);
R is the hydraulic radius in ft; and
S is the slope of the energy grade line ($\frac{h_f}{L}$); L is the length of pipe.

(a) Look up the Hazen-Williams loss coefficient (C_h) for enamel coated, steel pipe and cite your data source.

(b) Estimate the head loss in a 10,000 foot length of 5-foot diameter, enamel coated steel pipe that carries carries 60^{o}F water at a discharge of 295 cubic-feet per second (cfs), using the Hazen-Williams head loss model.

2. Equation 2 is the Hazen-Williams discharge formula in SI Units.

$$Q = 0.849 C_h A R^{0.63} S^{0.54} \tag{2}$$

where;
Q is the discharge in m^3/sec;
A is the cross section area of pipe in m^2 ($A = \frac{\pi D^2}{4}$; D is the pipe diameter.);
C_h is the Hazen-Williams friction coefficient (depends on pipe roughness);
R is the hydraulic radius in m; and
S is the slope of the energy grade line ($\frac{h_f}{L}$); L is the length of pipe.

(a) Look up the Hazen-Williams loss coefficient (C_h) for Acrylonite Butadiene Styrene (ABS) pipe and cite your data source.

(b) Estimate the head loss in a 3,050 meter length of 1.5-meter diameter, ABS pipe that carries carries 20^{o}C water at a discharge of 8.35 cubic-meters per second (cms), using the Hazen-Williams head loss model.

3. Equation 3 is an explicit formula (based on the Darcy-Weisbach head loss model and the Colebrook-White frictional loss equation)for estimating discharge from head loss and material properties (Swamee and Jain, 1976).

$$Q = -2.22D^{5/2} \times \sqrt{gh_f/L} \times [log_{10}(\frac{k_s}{3.7D} + \frac{1.78\nu}{D^{3/2}\sqrt{gh_f/L}})] \quad (3)$$

where;

Q is the discharge in L^3/T;
D is the pipe diameter;
h_f is the head loss in the pipe;
g is the gravitational acceleration constant;
L is the length of pipe;
k_s is the pipe roughness height;
ν is the viscosity of liquid in the pipe;

(a) Find the viscosity for water at 50^{o}F. Cite the source of your value.

(b) Find the sand roughness height of ductile iron pipe. Cite the source of your value.

(c) How deep is a column of water if the pressure at the bottom of the column is 20 psi?

(d) Estimate the discharge in the 3 mile long, 24-inch diameter, ductile iron pipeline connecting points A and B depicted in Figure 1. Point A is 30 feet higher in elevation than point B. The pressure at point B is 20 pounds per square-inch (psi) greater than the pressure at point A.

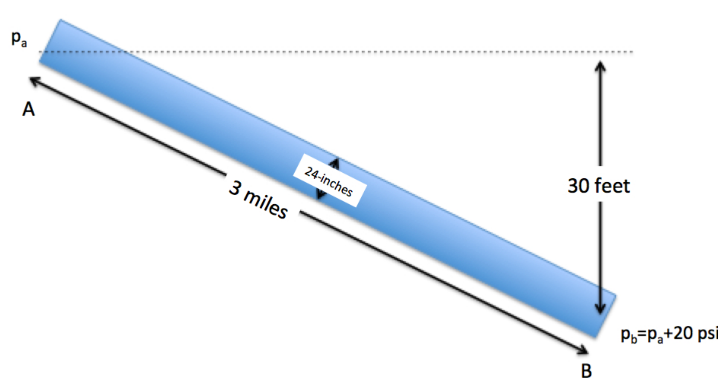

Figure 1: Pipeline Schematic

4. Equation 4 is a formula to estimate the required pipe diameter for a particular discharge, head loss, and roughness (Swamee and Jain, 1976).

$$D = 0.66[k_s^{1.25} \times (\frac{LQ^2}{gh_f})^{4.75} + \nu Q^{9.4} \times (\frac{L}{gh_f})^{5.2}]^{0.04} \tag{4}$$

where;

D is the pipe diameter;
k_s is the pipe roughness height;
L is the length of pipe;
g is the gravitational acceleration constant;
Q is the discharge in L^3/T;
h_f is the head loss in the pipe;
ν is the viscosity of liquid in the pipe;

(a) Find the viscosity for water at 60^oF. Cite the source of your value.

(b) Find the sand roughness height of cast-iron pipe. Cite the source of your value.

(c) Estimate the diameter of a cast-iron pipe needed to carry 60^oF water at a discharge of 10 cubic-feet per second (CFS) between two reservoirs 2 miles apart with an elevation difference between the water surfaces in the two reservoirs of 20 feet as depicted in Figure 2.

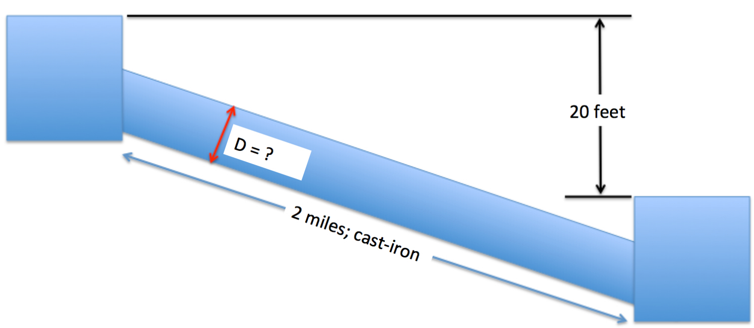

Figure 2: Pipeline connecting two reservoirs

5. Figure 3 is an aerial image of a parallel pipeline system in California.

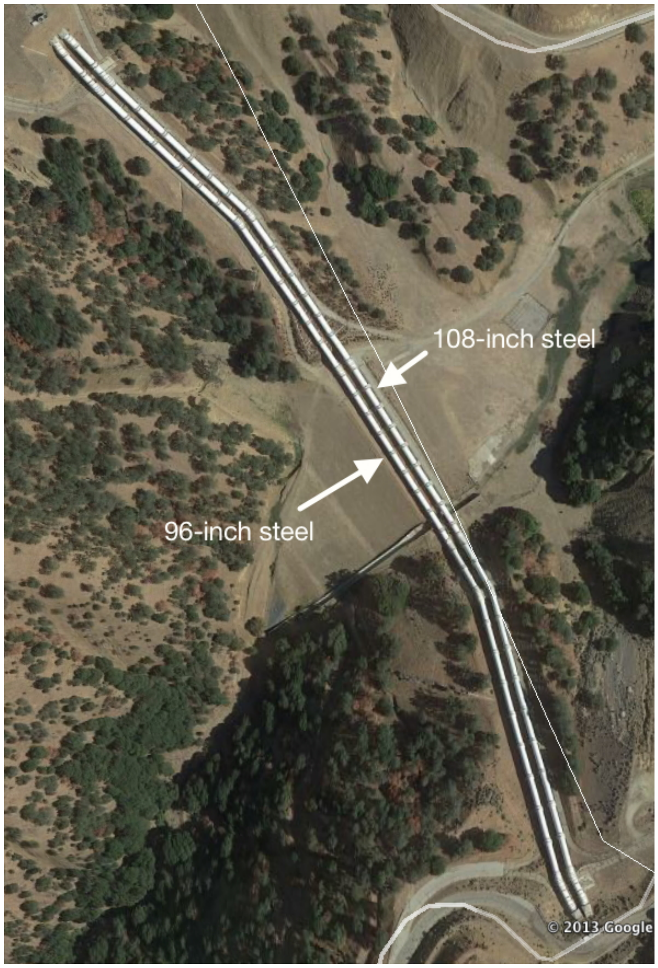

Figure 3: Parallel Pipeline System

The left pipeline is a 96-inch diameter steel pipe, whereas the right pipeline is a 108-inch diameter steel pipe. Water at 50^{o}F has kinematic viscosity of $1.45 \times 10^{-5}~ft^2/s$. The sand roughness of ductile iron is $1.64 \times 10^{-4}~ft$. If the head difference for the one-mile long pipelines between the thrust blocks is 120 feet, determine the discharge in each pipe in cubic-feet-per-second.

References

Swamee and Jain, A. K., 1976. Explicit equations for pipe-flow problems. ASCE J. of Hyd. Div., 102(HY5) pp. 657-664