CEE 371 – Fall 2009 – Design Problem 1 (work in teams of 3)
DESIGN OF AMHERST TRANSMISSION MAIN

Background

The drinking water sources for the Town of Amherst include two surface water (reservoir) supplies and several groundwater wells. To meet water demands, the Town must connect a new well to the distribution system. The well (Well #4) is located in South Amherst near Hop Brook in the Lawrence Swamp aquifer – see attached map (Figure 1).

The water must be treated -– disinfection, addition of fluoride, and addition of chemicals to reduce corrosivity prior to the distribution system. This treatment is accomplished on-line (injection of chemicals to transmission main) at the Baby Carriage Brook Water Treatment Plant (BCBWTP) located approximately 4,700 ft west of Well #4. After the on-line treatment at the WTP, the transmission main proceeds 1,600 ft west to South East Street, and then travels about 5,800 ft north to Station Road where it connects to the distribution system.

The estimated safe yield of Well #4 is 1.6 MGD. The ground elevation at the well head is 172 ft and the water level while pumping at the safe yield is at an elevation of 125 ft. The BCBWTP is an on-line (transmission main) facility that causes a head loss of 12 psi at the design flow of 1.6 MGD. The overflow elevation of the distribution storage tanks in the Amherst system is approximately 470 ft. For design purposes, set the hydraulic grade line (HGL) at 480 ft for the connection of the new transmission main with the existing 12 inch pipe at the intersection of South East St. and Station Rd (ground elevation of 228 ft).

Design Task

Your team has been requested by the Town to design a transmission main from Well #4 to the distribution system. The main must be capable of supplying a design flow of 1.6 MGD, must meet hydraulic design criteria, and must be the most economical choice. Additional information for the problem follows:

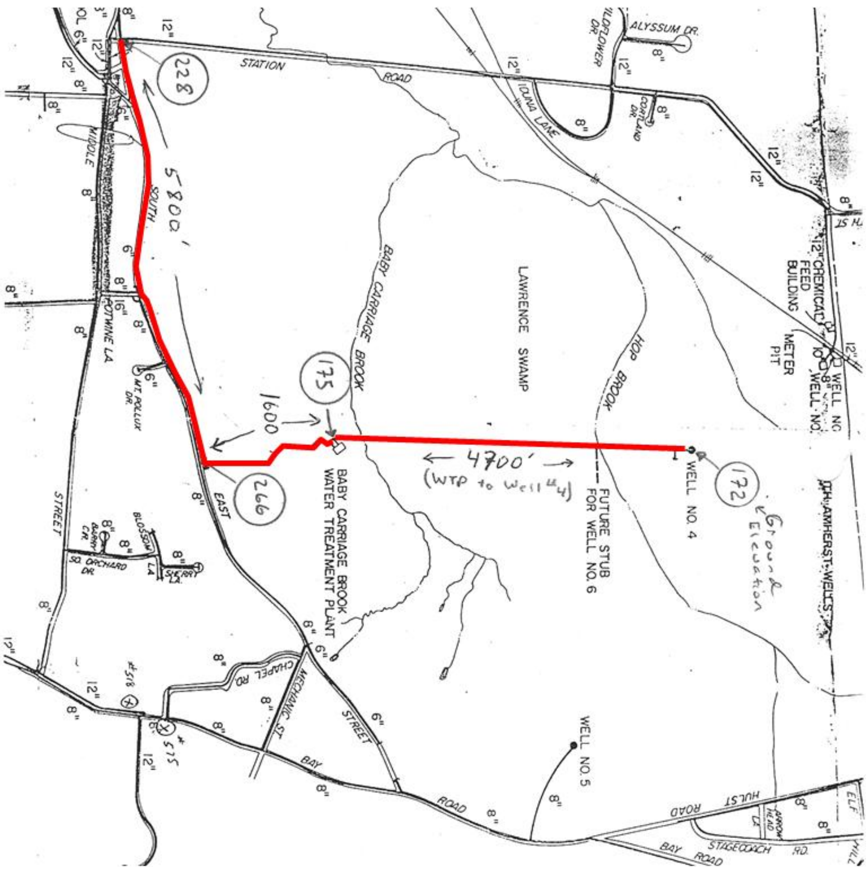
- Design for a cement lined ductile iron pipe
- Construction costs have been provided in a course handout
- Assume that costs for engineering and contingencies are 20% of construction costs
- Project will be financed with municipal bonds at 7.0 % interest over 20 years
- Assume the well pump (including motor) operates at 80% efficiency
- Electric power costs 9.5 cents per kw-hr

Prepare a short design report to present hydraulic and economic analyses that lead to a recommended diameter for a cement lined ductile iron (CCDI) pipe transmission main. Be sure to state your assumptions, clearly outline and show the technical aspects of the problem, and use tables and graphs to show the results of your hydraulic and economic analyses. Include a profile sketch of the system (along the pipeline) showing the well, ground elevation, the BCBWTP, and the hydraulic grade line for the recommended pipe size.

Supporting Information:

Cement Lined Ductile Iron Pipe Costs

Pipe Diameter (inches)	Installed cost[1] ($/linear ft)
6	47
8	51
10	57
12	62
14	66
16	72
18	78
20	86
24	109
27	124
30	139
36	160



This design project can be done in many ways. However, you do it, it is essential that you present your work in a clear and professional way. You want to get right to the point (not wasting your client's time), but at the same time make it very clear how you arrived at your conclusions. The easier you can make it for

[1] Installed costs include: Materials and Construction. Based on costs in December 2000; when ENR CCI = 6282.76 (using 1913 as base).

your client to understand your method and results, the more successful you will be. Therefore, graphical presentations can be quite helpful.

I will not attempt to present a “finished product” here, but will just cover some of the key elements and calculations.

1. Calculate headloss for each of the proposed pipe diameters. I used the Hazen-Williams equation:

$$H_L = 4.73\frac{Q^{1.85}L}{C^{1.85}D^{4.87}}$$

Where Q is in ft^3/s; and D is in ft. But you could have used the Darcy Weisbach equation too.

2. Then the pump head can be calculated starting from the Bernoulli equation:

$$Z_A + \frac{P_A}{\gamma} + \frac{V_A^2}{2g} + H_p = Z_B + \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + H_L$$

Which simplifies to

$$H_p = (Z_B - Z_A) + H_L$$

when velocity is constant, and the system begins and ends at atmospheric pressure, as is the case for this problem.

3. With headloss you can calculate power in kilowatts.

$$P = \frac{0.0846QH_L}{\eta}$$

4. Next update capital cost

$$\text{updated capital cost} = \text{old cost}\left(\frac{\text{current ENR CCI}}{\text{old ENR CCI}}\right)$$

5. And determine CRF

$$CRF = \frac{i}{(1+i)^n - 1} + i$$

$$CRF = \frac{0.07}{(1+0.07)^{20} - 1} + 0.07 = 0.0944$$

6. Finally determine annual fixed costs

Annual Fixed Cost ($/yr) =   CRF x total Fixed Costs

7. Determine annual power costs

Annual Power Cost = (pump power [kW]) x (power cost $/kW-hr]) x (# of hrs/year)

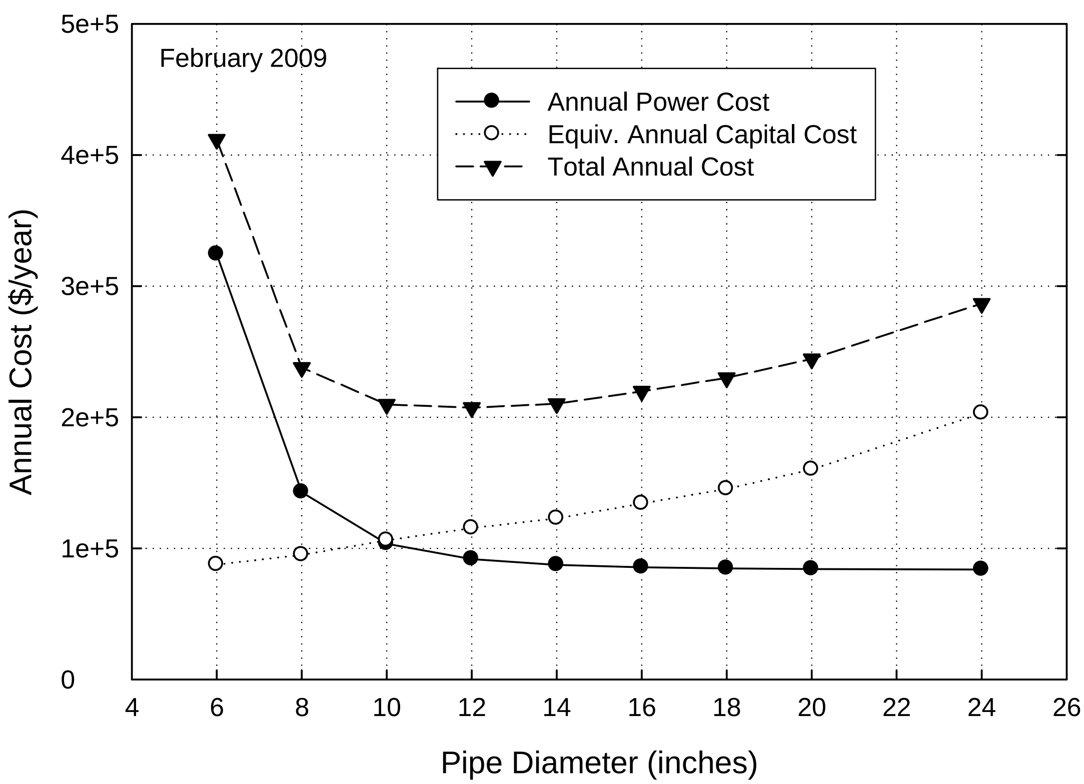
8. Add up annual fixed and power costs to get total annual costs. You show go as far up the pipe size scale as you need to in order to convince your client that you've covered the optimal sizes. At the very least you should do this for 8 pipe sizes.

Result of Calculations for the Amherst Design Problem

Table 1 Transmission Main Design: Hydraulics & Economics

			Annual	Dec-00	Feb-09	Annual	Total
Diameter	Pump Head	Power	Power Cost	Unit Cost	Tot Cap. Cost	Cap Cost	Ann. Cost
(inches)	(ft)	(kW)	($/yr)	($/ft)	($)	($/yr)	($/yr)
6	1486	390	324285	47	926828	87486	411771
8	654	172	142838	51	1005707	94932	237770
10	474	124	103535	57	1124025	106100	209635
12	420	110	91761	62	1222624	115407	207169
14	401	105	87415	66	1301503	122853	210267
16	392	103	85557	72	1419822	134021	219578
18	388	102	84671	78	1538140	145190	229861
20	386	101	84213	86	1695898	160081	244293
24	384	101	83810	109	2149452	202893	286703

9. Now present these results in the form of a annual cost vs pipe diameter graph as was shown in class.



10. Calculate HGL and graph along with ground elevation and key system landmarks.