**Parameters:**

1. Qij – flow in link ij defined based on the branched network configuration, predetermined
2. Lij – length of link ij [km]
3. CPk – Cost of piping $/m for each pipe size k
4. Cm – Cost of pump with power m, $
5. βm – pump efficiency with power m, %
6. CMP – Operations and maintenance cost for pump station, $;
7. HLmax – upper bound of hydraulic loss [m].
8. Hout – head pressure at link ij [m] – pipes flowing out
9. Hin – head pressure at link ij [m] – pipes flowing in
10. ein – pipe elevation at link ij [m] – pipes flowing in
11. eout – pipe elevation at link ij [m] – pipes flowing out
12. Vmin = 0.6 [m/s] (equivalent to 2 ft/s);
13. Vmax = 3 [m/s] (equivalent to 10 ft/s);
14. GEi – ground elevation of node i [m].
15. g – Standard gravity constant (9.80665 m/s2)
16. ρ: mass concentration (or density) of water.

**Objectives:**

1. Pipe cost:
2. Pump cost:
3. ~~Operation and maintenance costs:~~

**Decision variable:**

1. dijk -- binary variable {0,1} for each discrete size k [m], defines the pipe diameter for link ij [m]
2. HLij -- continuous variable representing the hydro loss in link ij [m]
3. pijm – binary variable {0,1} indicating if a pump is needed in link ij with power m [kw].
4. prij -- continuous variable representing the pressure injected by the pump at link ij [m] ~~with power m [kw]~~.
5. ei – pipe elevations at node i [m]
6. Hi – continuous variable representing the head pressure at node i [m]

**Constraints:**

1. where and 10700 and 140 are defined by the Hazen Williams equation and units of analysis (See Mays textbook P472)
2. where the bounds are set first to be non-binding and can be changed later.
3. only select one pipe size k for each link
4. only select one pump type m for each link
5. if pump is set in link ij, compute the power it produces. Otherwise, the pressure by pump is zero.
6. energy balance.
7. Velocity must be between 0.6 and 3 m/s. (Inclusion of minimum pipe sizes and minimum velocity constraints results in no feasible solutions; therefore, the minimum velocity constraint was removed.
8. upper bound is arbitrary maximum depth assuming 1 foot or 0.3048 meters of cover beneath the surface is needed for the pipes, and lower bound is minimum depth assuming 10m.
9. the head pressure at each node must be between 45 psi and 80 psi and convert them to meter. Global