Testing an Optimization Model for Optimal Sewer Layout and Wastewater Treatment Locations

Faisal M. Alfaisal[1]

[1] Department of Civil Engineering, King Saud University, Riyadh, Saudi Arabia

Email: falfaisal@ksu.edu.sa

Overview

- Introduction.
- Cost Functions.
- Methodology.
  - Connectivity Model.
- Two Example Systems.
- Results.
- Conclusion and Recommendations.

Introduction

- **Optimization model to minimize total costs of sewer layout and WWTPs locations, taking into consideration mass balance and energy constraints.**

- **The Iso-nodal Line (INL) concept is used for solving water collection/branched system problems.**

- **The application of the model is illustrated through two simple examples and the results are discussed.**

Literature review

Cost Functions

Reference	Overall cost
Mays et al. (1983)	= $2.88Q^{0.99}$ (Capital cost of WWTP). = $0.0825Q^{0.96}$(Operation and maintenance costs of WWTP). = $80Q^{0.461}$ (Capital cost of pipeline). = $4.56x10^{-3}$ *distance(mi)*$Q^{0.495}$(operation and maintenance costs of pipeline). * All flow rates Q are in gallons per day
Al-A'ama and Nakhla (1995)	= 2.03$/$m^3$ The cost included capital cost (= 1.33 US$/$m^3$), tertiary treatment (= 0.16 US$/$m^3$), collection (= 0.3 US$/m^3) and distribution (= 0.06 US$/$m^3$).
Brand and Ostfeld (2011)	= 0.33$/$m^3$ (capital costs of WWTP)
Kajenthira et al. (2012)	Secondary TWW in the range of 0.13–0.63 US$/$m^3$, Tertiary TWW in the range of 1.19–2.03 US$/$m^3$.
Al-Zahrani et al. (2016)	TWW reuse ranges from 0.82 to 2.03 US$/$m^3$ with an average cost of 1.43 US$/$m^3$.

Connectivity Model

Example:

- 3- INL (i,j,k).
- 2 nodes in each INL ($i_1, i_2; j_1, j_2; k_1, k_2$).
- Possible Layouts to INL (k) are Layout 1, Layout 2, and Layout 3.

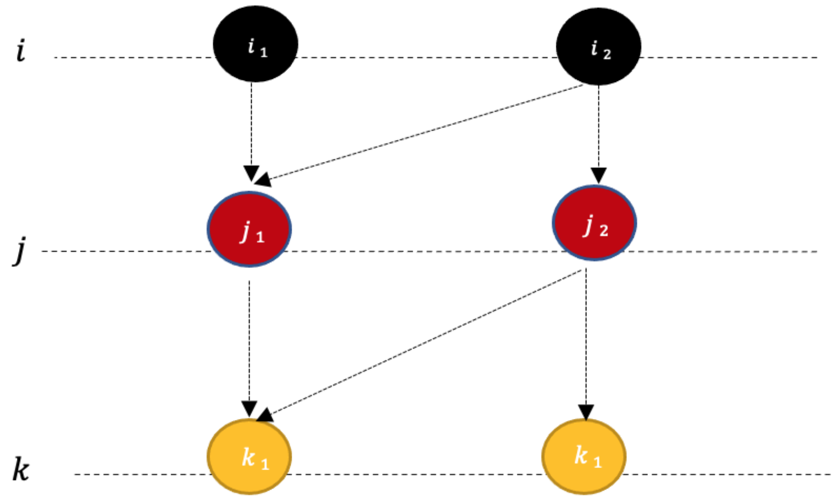

Fig 1. Possible connectivity lines at Isondal line i and j.

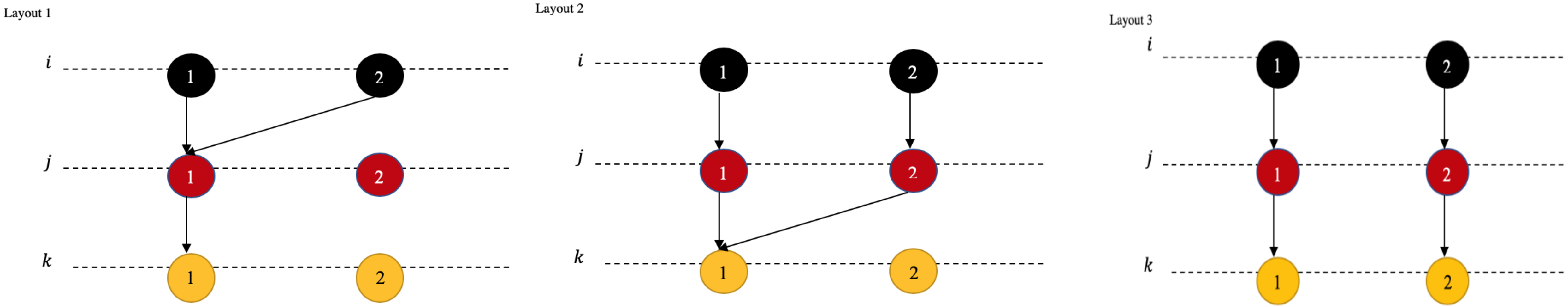

Fig 2. Possible Layouts to Isondal line k.

Mathematical Formulation

- The mathematical formulation contains of objective function, constraints, decision variables;
  - Objective function which is minimizing the total costs of size, type, and location of sewer pipe and WWTP.
  - Subject to; Connectivity model, Continuity equations, Hydraulic equations constraints.
  - Variables are discharges that are bounded between lower and upper values.

- The model is formulated using MINLP in GAMS, solved by the BARON solver.

Test Example 1

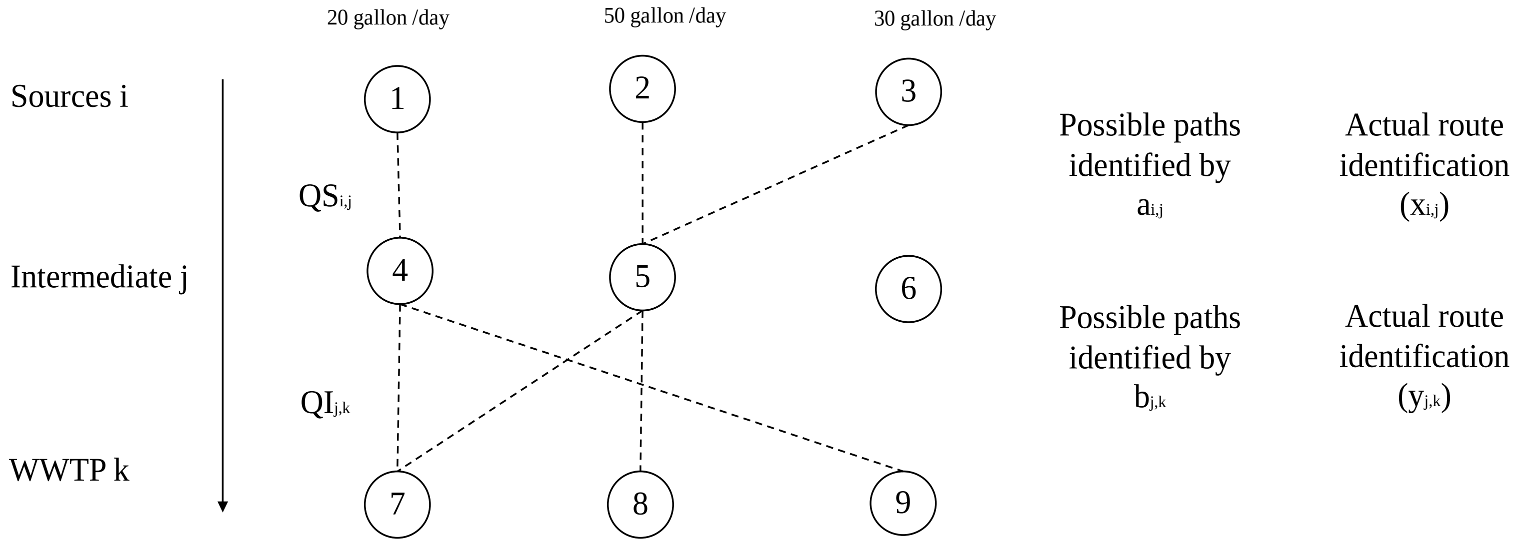

Fig 3. Input Values for the Model in GAMS for Example 1

Optimal Solution = $ 820

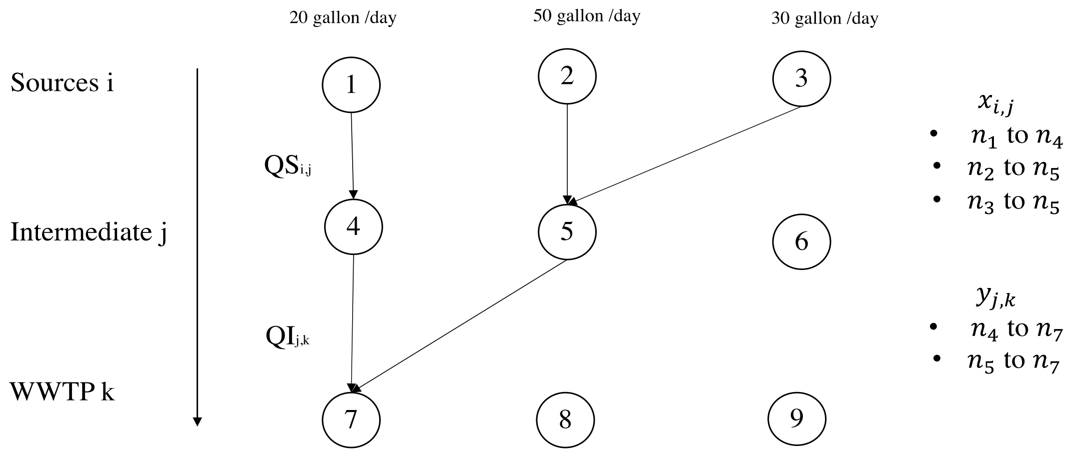

Fig 4. The Optimum Configuration for Example 1

Test Example 2

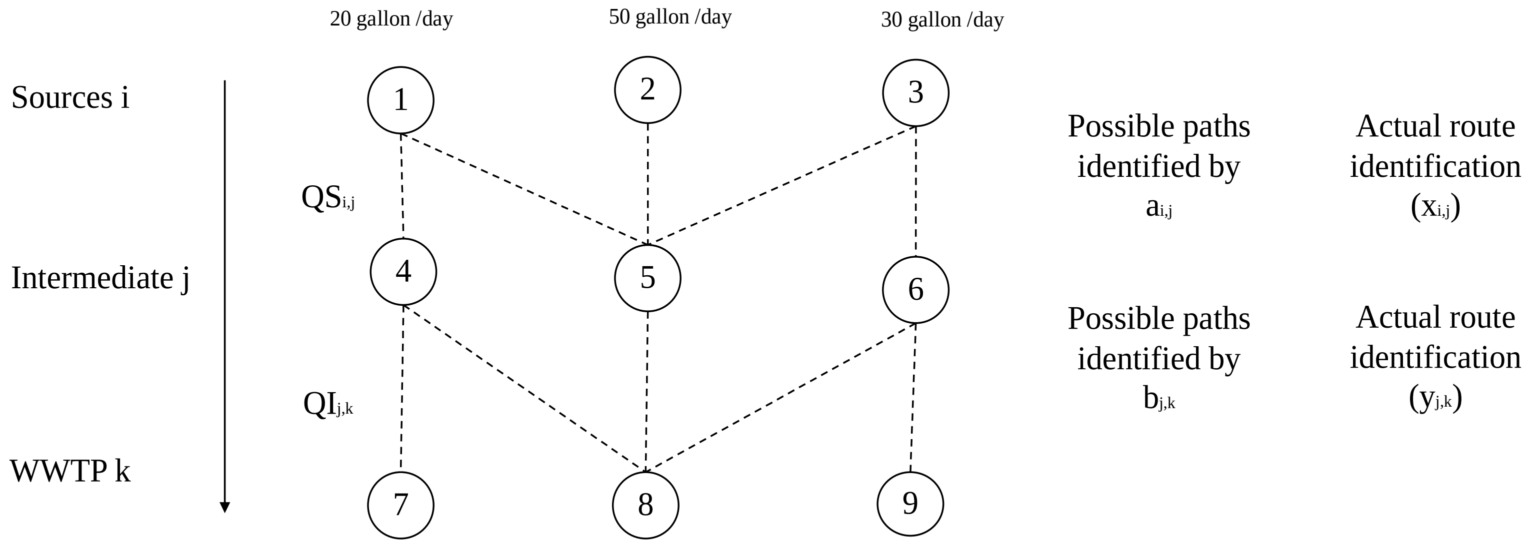

Fig 5. Input Values for the Model in GAMS for Example 2

Optimal Solution = $ 300

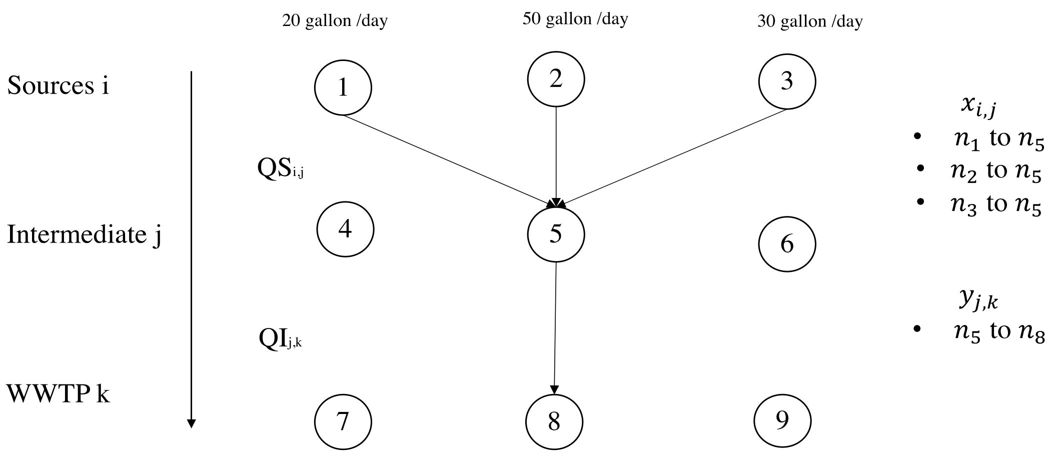

Fig 6. The Optimum Configuration for Example 2

Conclusion and Recommendations

- Wastewater systems are very expensive so developing such novel approaches [Connectivity model] would help to minimize the total costs.
- The simple scenario demonstrates that using the method allows for significant cost saving for large systems while further testing and developments may be needed.
- The methodology minimizes the total costs without considering the capacity limitation of a WWTP.
- The methodology is beneficent the planning and designing regional/local wastewater systems.
- Hydraulic constraints including Pipe diameter and Lifting station can be added to consider commercial diameter and total dynamic head in the system simultaneously. **(Alfaisal and Mays,2021)**

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