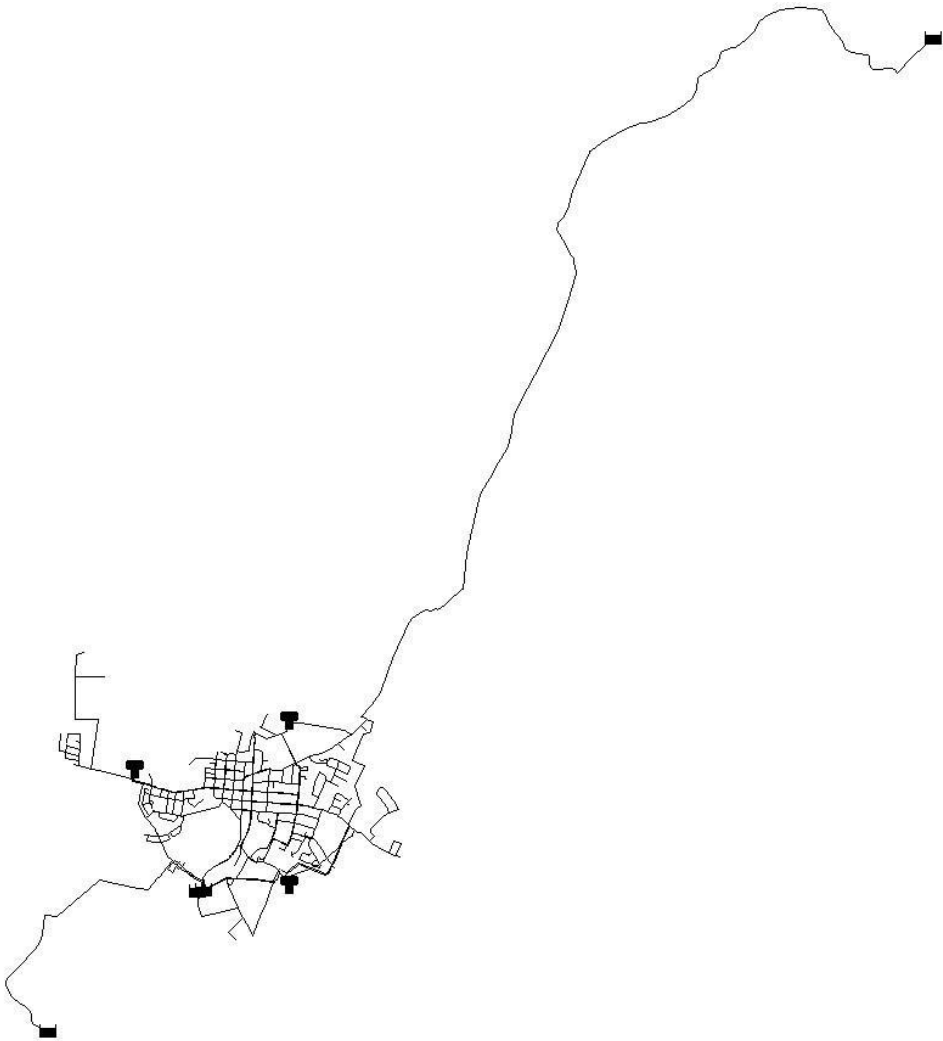


SYSTEM ID: KY 14

NARRATIVE DESCRIPTION

The KY 14 system is based on a real-world water distribution system in Kentucky. It serves 2,709 customers and sells water for \$4.91 to \$6.42 per 1,000 gallons. The system has an average demand of 2.12 MGD. The network was used by Schal et al. (2014) as part of a classification study. A general schematic of the system is shown below. The system has four reservoirs, six pumps, three elevated storage tanks, and 64.5 miles of pipe. Water loss within the system is estimated to be 28%.

NETWORK SCHEMATIC:



HISTORY OF THE NETWORK FILE

The KY 14 system was originally created by Stacey Schal in 2014 as part of an article “A Graphical Procedure for Sensor Network Placement Guidance for Small Utilities” which was published in 2016 in the *American Water Works Association Journal*.

ORIGINAL REFERENCE:

Schal, S., Bryson, L.S. and Ormsbee, L., 2014. A graphical procedure for sensor-placement guidance for small utilities. *Journal-American Water Works Association*, 106(10), pp.E459-E469. <https://doi.org/10.5942/JAWWA.2014.106.0093>

ABSTRACT: Efforts to improve water security have led to the development of contamination warning systems aimed at providing early indication of accidental or intentional contamination in drinking water distribution systems. Sensors that detect changes in water quality are a critical component of a contamination warning system. Because the extent of any monitoring system is constrained by a limited budget, focus is placed on optimizing the placement of sensors to maximize contamination detection and protect human health. Robust models and algorithms have been developed to recommend sensor deployment, but many require hydraulic or water quality models. Small utilities typically do not possess the resources to develop these models; therefore, researchers for this study developed the Water Quality Sensor Placement Tool to recommend placement of one water quality sensor without a model or complicated algorithm. This simple graphical procedure allows utility managers to use basic information about the geometry of their network to determine near-optimal sensor placement in limited time without complicated software.

ADDITIONAL CITATIONS:

The original publication of Schal et. al. (2014) and by inference the KY 14 system have been cited by 3 additional authors. These may be accessed by moving your cursor over the following link while simultaneously depressing the CTRL key on your keyboard: [3 Citations](#)

AVAILABLE INFORMATION

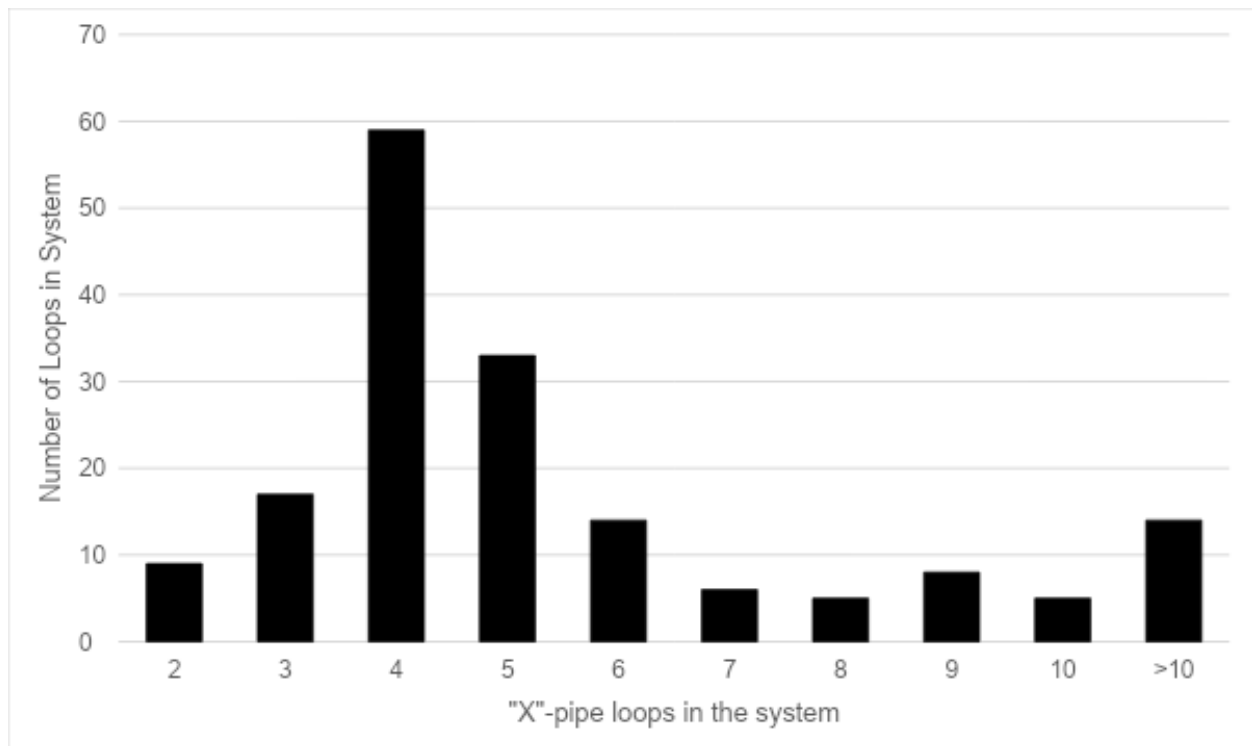
| | |
|---|---------|
| Physical attributes | Yes |
| Schematic diagram | Yes |
| Network geometry data | Yes |
| GIS data file | Yes |
| Background map | Yes |
| Elevation data | Yes |
| Pipe data | Yes |
| <i>Pipe material</i> | Yes |
| <i>Pipe age</i> | Yes |
| <i>Pipe pressure class</i> | No |
| <i>Nominal or actual diameters</i> | Nominal |
| Pump data | Yes |
| <i>Useful horsepower</i> | Yes |
| <i>Pump operating curves</i> | No |
| Tank data | Yes |
| <i>Elevation data</i> | Yes |
| <i>Stage storage curves</i> | No |
| <i>Water quality information</i> | No |
| Valve data | No |
| <i>PRV/FCV data</i> | |
| <i>Isolation valve data</i> | |
| <i>Hydrant data</i> | |
| Demand data | Yes |
| <i>Total system demand</i> | Yes |
| <i>Nodal demand data</i> | Yes |
| <i>Temporal data demands</i> | Yes |
| <i>System leakage</i> | No |
| Hydraulic data | No |
| <i>Hydraulically calibrated model</i> | |
| <i>Field hydraulic calibration data</i> | |
| Water quality data | No |
| <i>Disinfection method</i> | |
| <i>Chlorine residual data</i> | |
| <i>Booster station data</i> | |
| <i>Fluoride/Chloride field data</i> | |
| <i>Water quality calibrated model</i> | |
| Operational data | Yes |
| <i>SCADA datasets</i> | No |
| <i>Operational rules</i> | Yes |

SYSTEM CLASSIFICATION:

PIPE/LOOP HISTOGRAM:

Hoagland et al. (2015) designed a network classification algorithm for use in classifying water distribution systems as either “branched,” “looped,” or “gridded” based on the observed frequency of network loops with different numbers of distinct pipe segments. The frequency distribution for the KY 14 system is provided below. Using this information, Hoagland et al., classified this system as being a GRIDDED system.

| | |
|-------------------------------------|-------|
| # Total Pipes: | 548 |
| # Branch Pipes: | 79 |
| Ratio (Branch Pipes / Total Pipes): | 0.144 |



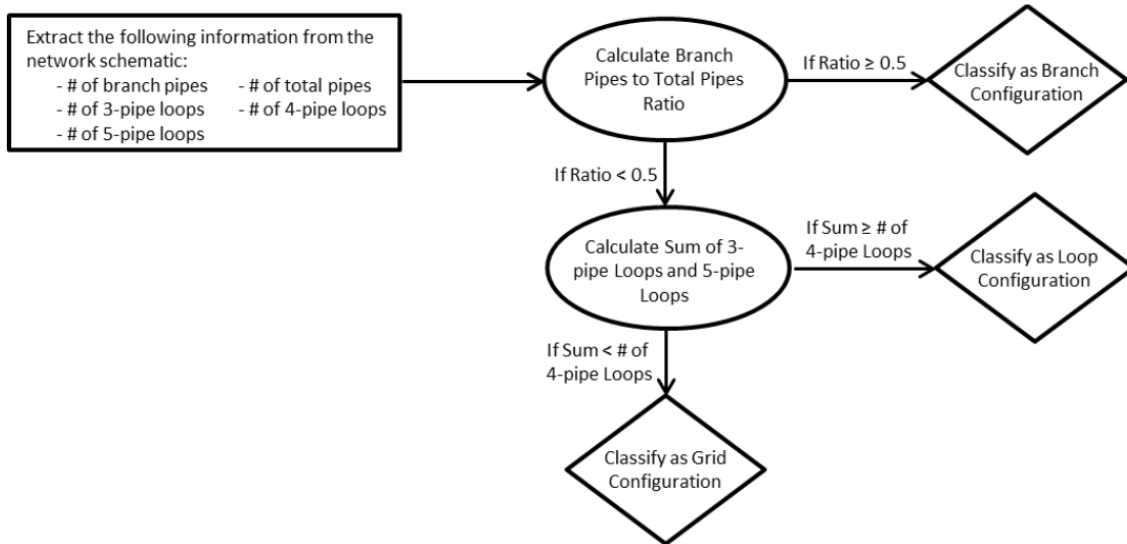


Figure 3.4. Classification Algorithm (Hoagland et al., 2015)

Hoagland, Steven & Schal, Stacey & Ormsbee, Lindell & Bryson, Lindsey. (2015). Classification of Water Distribution Systems for Research Applications. 696-702. 10.1061/9780784479162.064.

NETWORK STRUCTURE METRICS:

Building on the work of Hoagland et al., (2015), Hwang & Lansey (2017) created an expanded classification system that allows for further classification of a system as being either a transmission or distribution branched, looped, gridded, or hybrid system. Their algorithm streamlines the classification system by removing unnecessary nodes that do not contribute to the structure of the system while still retaining their use as intermediate points for demand data entry. A full description of the algorithm can be found in the cited reference.

Application of the Hwang and Lansey classification algorithm to the system yields the following statics and associated classification:

| Parameter | Value |
|-------------------------------|-------------------------|
| Edges | 553 |
| Pipes | 543 |
| Nodes | 384 |
| Average Diameter | 10.5 |
| Reduced Nodes | 273 |
| Reduced Edges | 442 |
| Branched Edges | 76 |
| Branched Index | 0.1 |
| Meshed Connectedness | 0.2 |
| Reduced Meshed Connectedness | 0.31 |
| Link Density | 0 |
| Average Node Degree | 2.9 |
| Hwang & Lansey Classification | Distribution Dense-Grid |

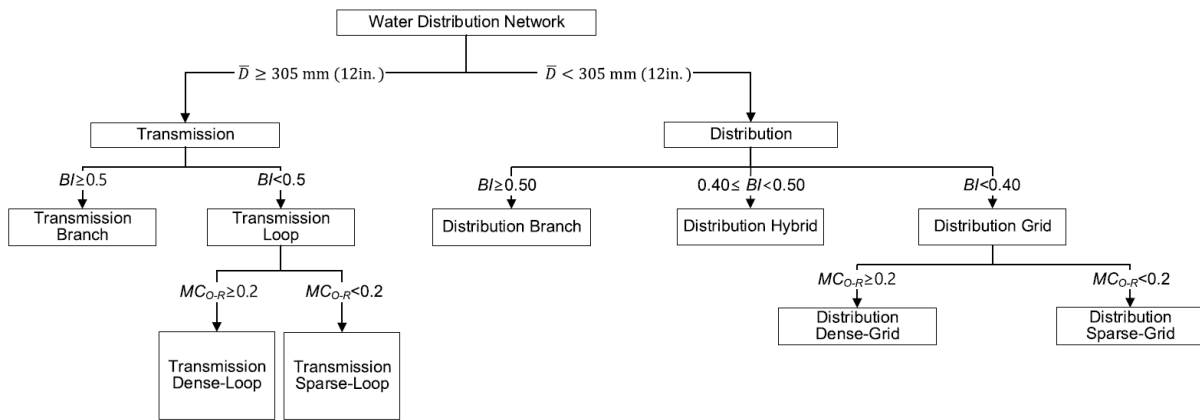


Figure 7. Water Distribution System Classification Flowchart (Hwang & Lansey, 2017)

Hwang H. & Lansey, K. (2015) "Water distribution system classification using system characteristics and graph theory metrics." *Journal of water resource planning and management* 143(12) [https://doi.org/10.1061/\(ASCE\)WR.1943-5452.0000850](https://doi.org/10.1061/(ASCE)WR.1943-5452.0000850)

DETAILED DATA SUMMARIES

PHYSICAL ASSETS:

| Asset Type: | # of Assets |
|--------------------|--------------------|
| Master Meters | 0 |
| Tanks | 3 |
| Pumps | 6 |
| Water Sources | 4 |

NETWORK CHARACTERISTICS:

| | |
|---------------------|---------|
| # Total Pipes: | 548 |
| # Junctions | 366 |
| # Reservoirs | 4 |
| # Tanks | 3 |
| # Regulating Valves | 0 |
| # Isolation Values | Unknown |
| # Hydrants | Unknown |
| Elevation Data | YES |

PIPE DATA:

| Diameter (in) | Length (ft) |
|----------------------|--------------------|
| 1.5 | 494 |
| 2 | 6,346 |
| 4 | 34,228 |
| 6 | 82,645 |
| 8 | 40,716 |
| 12 | 32,654 |
| 16 | 24,497 |
| 20 | 66,029 |

PUMP DATA:

| | |
|-----------------|-----|
| Pump Horsepower | YES |
| Pump Curves: | NO |

DEMAND STATISTICS:

| Demographic Type | Population | Households |
|-------------------------|-------------------|-------------------|
| Directly Serviceable: | 6,667 | 3,084 |
| Indirectly Serviceable: | 13,824 | 5,827 |
| Total Serviceable: | 20,491 | 8,911 |

| Production Statistics | |
|-------------------------------------|---------|
| Total Annual Volume Produced (MG): | 774.365 |
| Total Annual Volume Purchased (MG): | |
| Total Annual Volume Provided (MG): | 774.365 |
| Estimated Annual Water Loss: | 28% |

| Water Costs | |
|------------------------------------|-----------------------|
| Customer Type | Cost per 1000 gallons |
| Customers within the municipality | \$4.91 |
| Customers outside the municipality | \$6.42 |

CUSTOMERS AND USAGE:

| Customer Type | Customer Count | Average Demand (MG) |
|---|-----------------------|----------------------------|
| Wholesale: | 1 | 363.968 |
| Residential: | 2,405 | 104.039 |
| Commercial: | 227 | 31.574 |
| Institutional: | 37 | 5.975 |
| Industrial: | 10 | 42.478 |
| Other: | 29 | 8.490 |
| Total Customers: | 2,709 | |
| Flushing, Maintenance & Fire Protection: | | |
| Total Water Usage: | | 556.524 |

DATA FILE ATTRIBUTES:

| ATTRIBUTE | | UNITS |
|------------------------|---|----------------|
| Pipe Length & Diameter | X | Feet & inches |
| Pipe Age | X | Year Installed |
| Node Elevation | X | Feet |
| Node Demand | X | GPM |
| Valves | | |
| Hydrants | | |
| Tank Levels | X | Feet |
| Tank Volume | X | Cubic Feet |
| PRVs | | |
| WTP | | |
| WTP Capacity | | |
| Pump Data | X | HP |