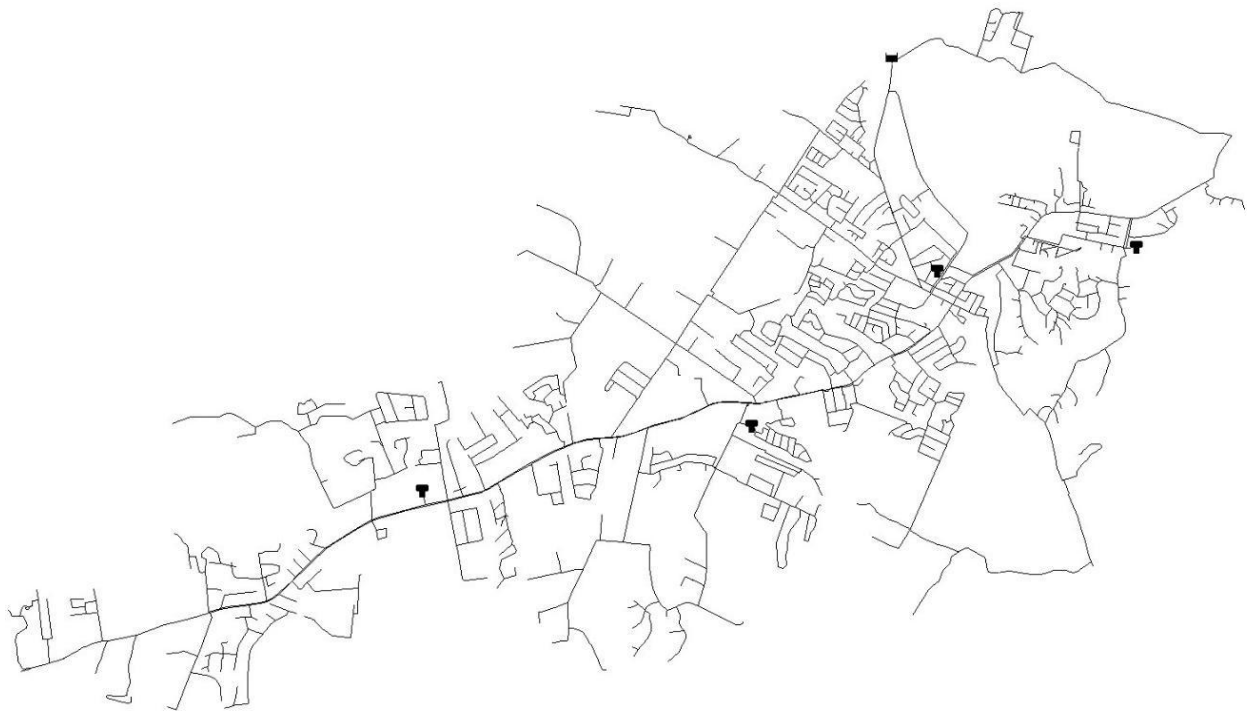


SYSTEM ID: KY 4

NARRATIVE DESCRIPTION

The KY 4 system is based on a real-world water distribution system in Kentucky. It serves 9,020 customers and sells water for \$6.46 to \$7.65 per 1,000 gallons. The system has an average demand of 1.51 MGD. The network was used by Jolly et al. (2014) as part of a classification study. A general schematic of the system is shown below. The system has one reservoir, two pumps, four elevated storage tanks, and 162 miles of pipe. Water loss within the system is estimated to be 12%.

NETWORK SCHEMATIC:



HISTORY OF THE NETWORK FILE

The KY 4 system was originally created by Matthew Jolly and Amanda Lothes in 2012 as part of an article “Research Database of Water Distribution System Models” which was published in 2014 in the *Journal of Water Resources Planning & Management*. It was updated by Stacy Schal in 2013 and updated again by Steven Hoagland in 2014.

ORIGINAL REFERENCE:

Jolly, M. D., Lothes, A. D., Bryson, L. S., & Ormsbee, L. (2014). Research Database of Water Distribution System Models. *Journal of Water Resources Planning and Management*, 410-416. [10.1061/\(ASCE\)WR.1943-5452.0000352](https://doi.org/10.1061/(ASCE)WR.1943-5452.0000352)

ABSTRACT: Since the 1960s, researchers have continued to develop new methodologies and algorithms in support of the planning, design, and management of water distribution systems. While initial research focused on modeling the hydraulics of such systems, the 1980s gave rise to additional research focused on water quality issues. More recent research has expanded into issues of system reliability and resilience, energy management, and sensor and chlorine booster station placement. In most cases, researchers have relied on either hypothetical water distribution systems or a handful of actual systems for use as benchmark test systems. Some of the more widely used actual systems include the New York tunnel system and the Hanoi water distribution system. This paper describes the development of a database of several water distribution systems synthesized from a statewide database of systems originally developed by the Kentucky Infrastructure Authority. The developed models include both small and medium networks, as well a range of system characteristics (i.e., system configuration-grid, looped, and branched systems-and system components-number of tanks, pump stations, and supply sources). The development of the database is described, as well as how to gain access to the developed models. All models have been developed to support use by water distribution system modeling software.

ADDITIONAL CITATIONS:

The original publication of Jolly et. al. (2014) and by inference the KY 4 system have been cited by 78 additional authors. These may be accessed by moving your cursor over the following link while simultaneously depressing the CTRL key on your keyboard:

[78 Citations](#)

AVAILABLE INFORMATION

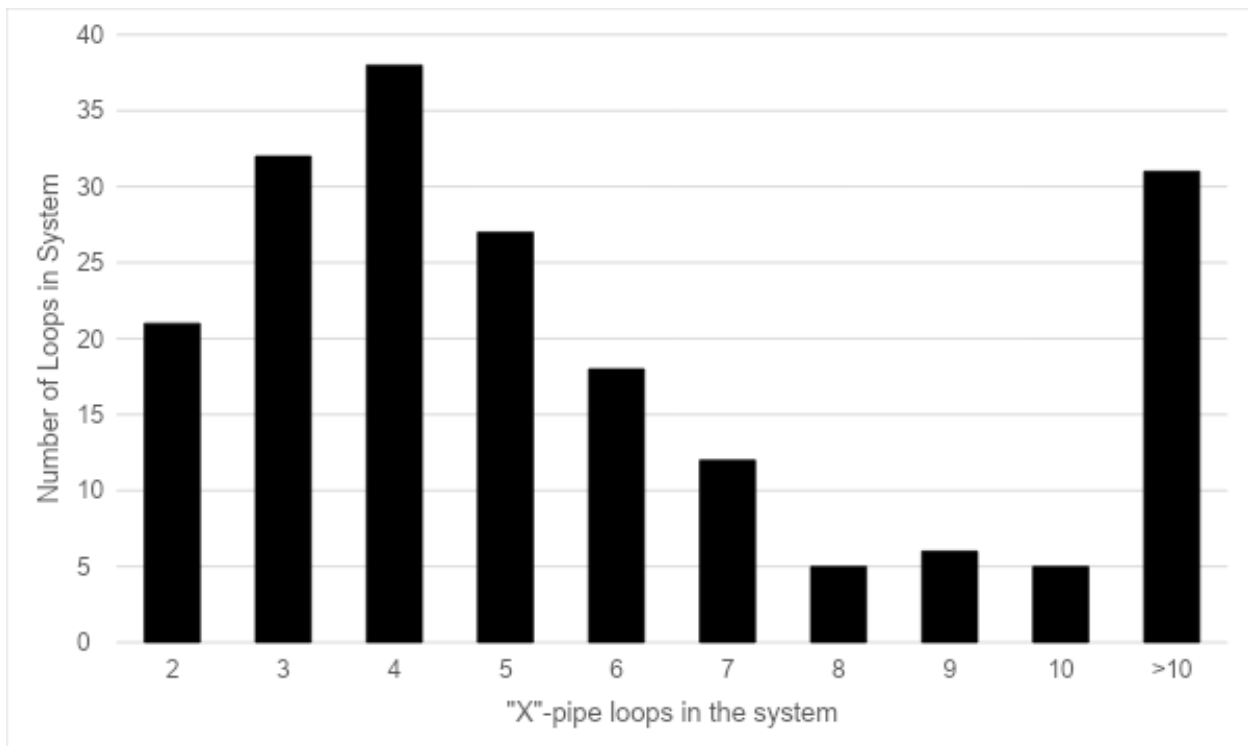
Physical attributes	Yes
Schematic diagram	Yes
Network geometry data	Yes
GIS data file	Yes
Background map	Yes
Elevation data	Yes
Pipe data	Yes
<i>Pipe material</i>	Yes
<i>Pipe age</i>	Yes
<i>Pipe pressure class</i>	No
<i>Nominal or actual diameters</i>	Nominal
Pump data	Yes
<i>Useful horsepower</i>	Yes
<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	No
<i>SCADA datasets</i>	
<i>Operational rules</i>	

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 4 system is provided below. Using this information, Hoagland et al., classified this system as being a LOOPED system.

# Total Pipes:	1156
# Branch Pipes:	368
Ratio (Branch Pipes / Total Pipes):	0.318



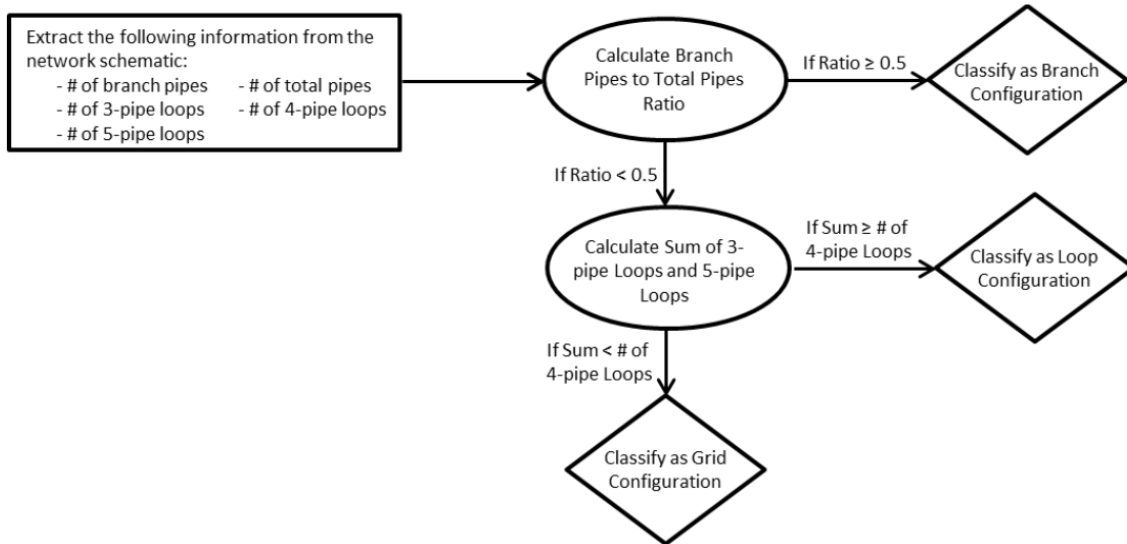


Figure 3.4. Classification Algorithm (Hoagland et al., 2015)

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	1158
Pipes	1156
Nodes	964
Average Diameter	7
Reduced Nodes	534
Reduced Edges	728
Branched Edges	329
Branched Index	0.3
Meshed Connectedness	0.1
Reduced Meshed Connectedness	0.18
Link Density	0
Average Node Degree	2.4
Hwang & Lansey Classification	Distribution Sparse-Grid

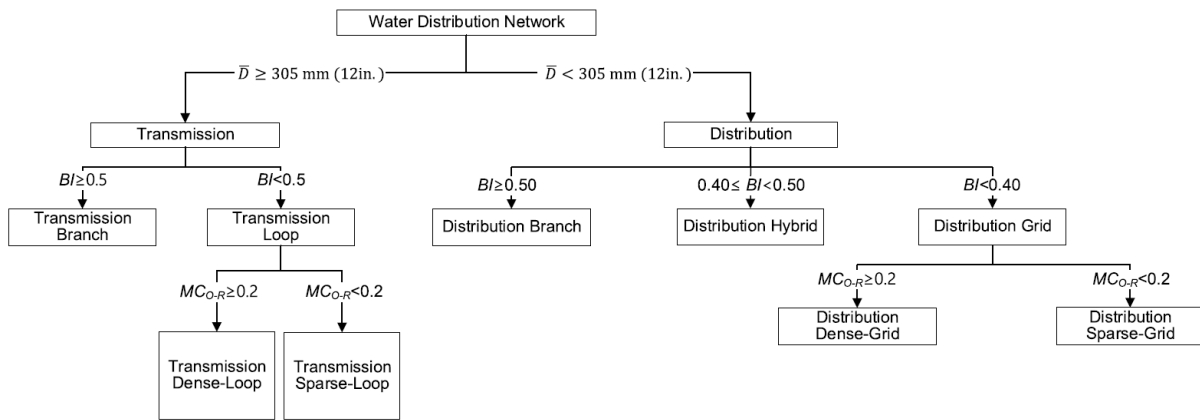


Figure 7. Water Distribution System Classification Flowchart (Hwang & Lansey, 2017)

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	4
Pumps	2
Water Sources	1

NETWORK CHARACTERISTICS:

# Total Pipes:	1156
# Junctions	962
# Reservoirs	1
# Tanks	4
# Regulating Valves	0
# Isolation Values	Unknown
# Hydrants	Unknown
Elevation Data	YES

PIPE DATA:

Diameter (in)	Length (ft)
3	27,581
4	171,782
6	223,167
8	331,387
10	1376
12	88,627
16	9,890

PUMP DATA:

Pump Horsepower	YES
Pump Curves:	NO

DEMAND STATISTICS:

Demographic Type	Population	Households
Directly Serviceable:	19,320	7,681
Indirectly Serviceable:		
Total Serviceable:	19,320	7,681

Production Statistics	
Total Annual Volume Produced (MG):	
Total Annual Volume Purchased (MG):	627.760
Total Annual Volume Provided (MG):	627.760
Estimated Annual Water Loss:	12%

Water Costs	
Customer Type	Cost per 1000 gallons
Customers within the municipality	\$6.46
Customers outside the municipality	\$7.65

CUSTOMERS AND USAGE:

Customer Type	Customer Count	Average Demand (MG)
Wholesale:		
Residential:	8,621	482.980
Commercial:	399	68.612
Institutional:		
Industrial:		
Other:		
Total Customers:	9,020	
Flushing, Maintenance & Fire Protection:		
Total Water Usage:		551.592

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	X	GPD
Pump Data	X	HP