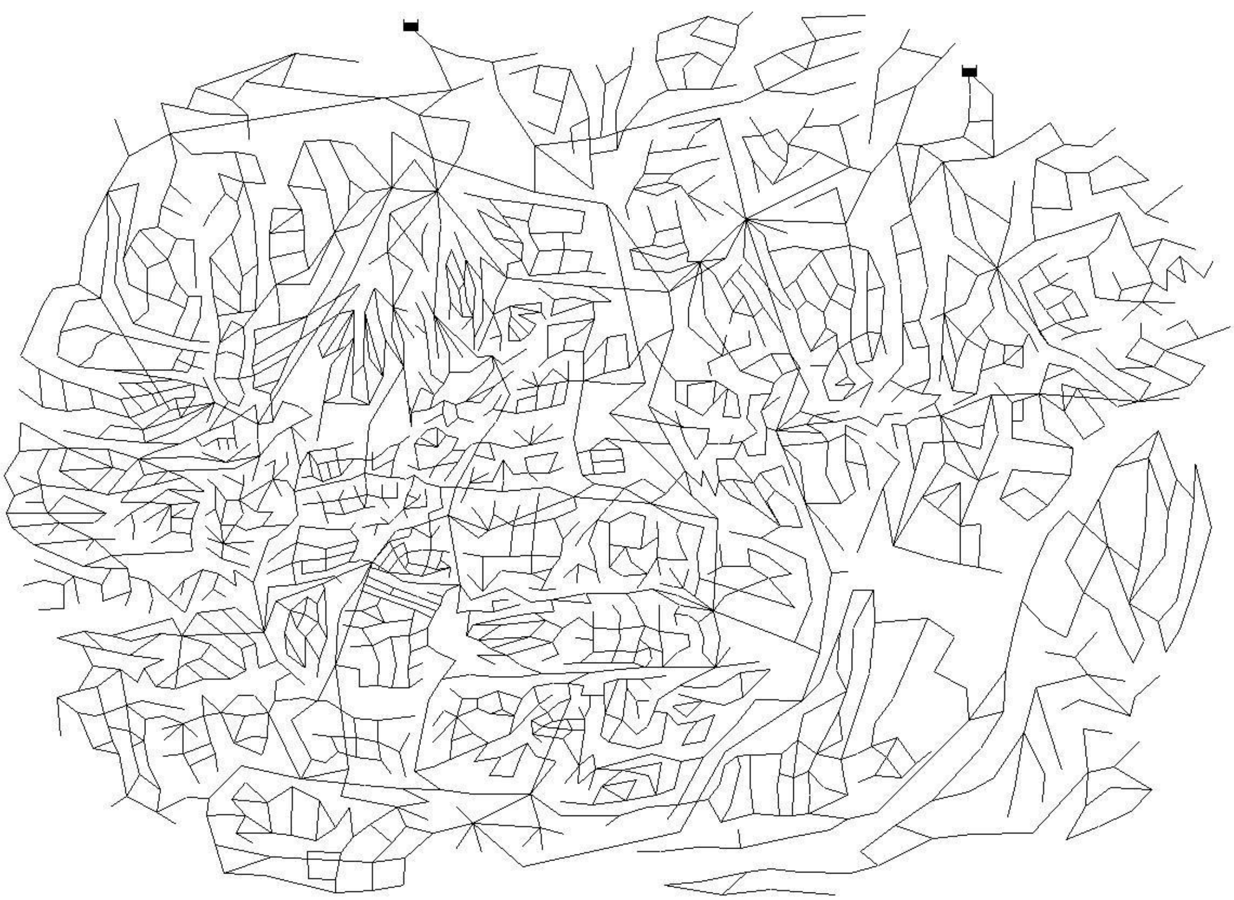
SYSTEM ID: Exnet

NARRATIVE DESCRIPTION

The Exnet system is a synthetic system that is a benchmark model for the Centre for Water Systems of Exeter University. It serves 400,000 customers with an average demand of 82,000 CMD. The network was first presented by Farmani et al. (2004) to establish the Exnet benchmark problem. A general schematic of the system is shown below. The system has two reservoirs and 594 kilometers of pipe.

NETWORK SCHEMATIC:



HISTORY OF THE NETWORK FILE

The Exnet system was originally developed by Farmani et al. (2004) to be used as a benchmark in multi-objective optimization problems. It has since been used in many optimization studies to compare results between methods.

ORIGINAL REFERENCE:
Farmani, R., Savic, D.A., Walters, G.A., 2004. "EXNET" Benchmark Problem for Multi-Objective Optimization of Large Water Systems, Modelling and Control for Participatory Planning and Managing Water Systems, IFAC workshop: Venice, Italy.

ABSTRACT: In this paper, a large realistic water distribution system (EXNET) is constructed as a challenging benchmark for optimization models that are able to consider many real system features, such as tank sizing and operation schedules and pipe rehabilitation decisions. Design of distribution storage facilities involves solving numerous issues and trade-offs such as levels and volume and requires consideration of water system operation over the demand pattern. Design variables for rehabilitation problems are the pipe locations and diameters and tank sizing. The application of multi-objective evolutionary algorithms is investigated in the identification of the pay-off characteristic between different criteria for rehabilitation of the large water distribution system. The optimal rehabilitation of EXNET water distribution systems is a complex process requiring systematic examination and evaluation of the design alternatives. Rather than searching for a single solution with the best fitness value, the target in these multi-objective problems is to find a set of diverse solutions which together define a multi-objective trade-off surface. Results are presented for the pay-off characteristics between cost and benefit, for 24 hour design conditions.

ADDITIONAL CITATIONS:
The original publication of Farmani (2004) and by inference the Exnet system have been cited by 36 additional authors. These may be accessed by moving your cursor over the following link while simultaneously depressing the CTRL key on your keyboard: 36 Citations.

AVAILABLE INFORMATION

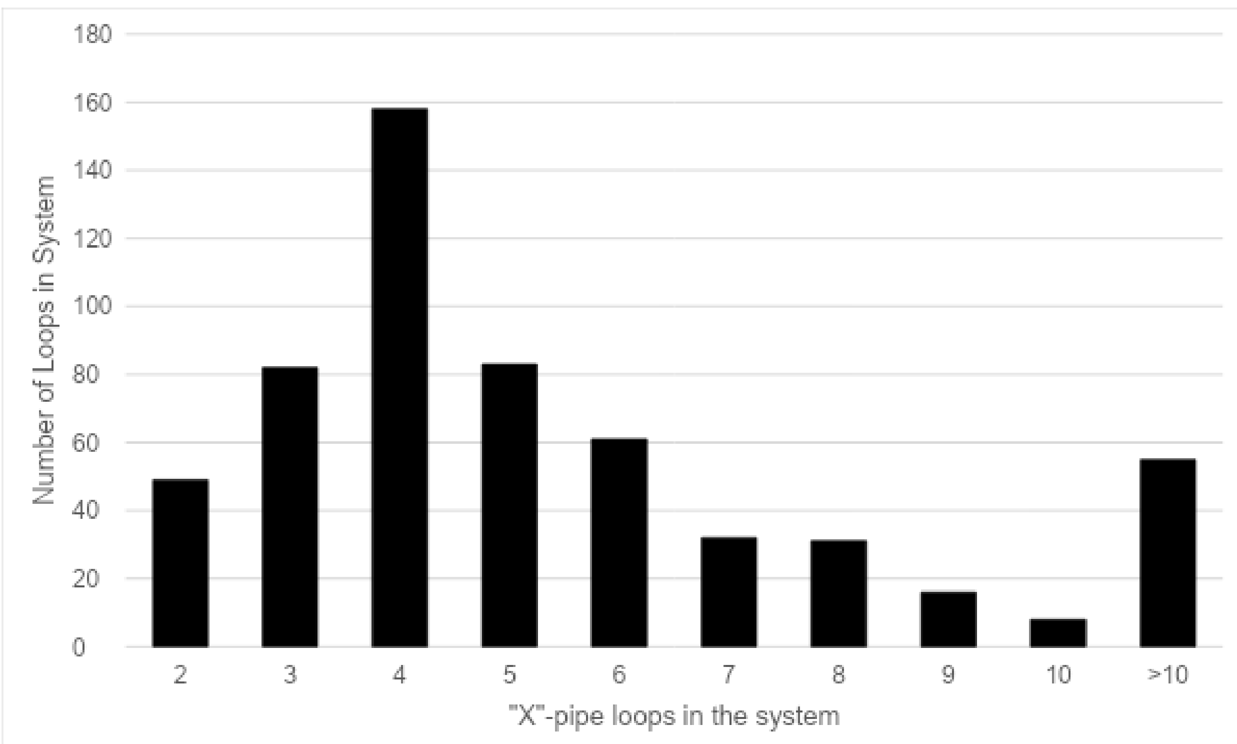
Physical attributes	Yes
Schematic diagram	Yes
Network geometry data	Yes
GIS data file	No
Background map	No
Elevation data	Yes
Pipe data	Yes
Pipe material	No
Pipe age	No
Pipe pressure class	No
Nominal or actual diameters	Nominal
Pump data	NA
Useful horsepower	
Pump operating curves	
Tank data	NA
Elevation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

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

# Total Pipes:	2469
# Branch Pipes:	490
Ratio (Branch Pipes / Total Pipes):	0.2



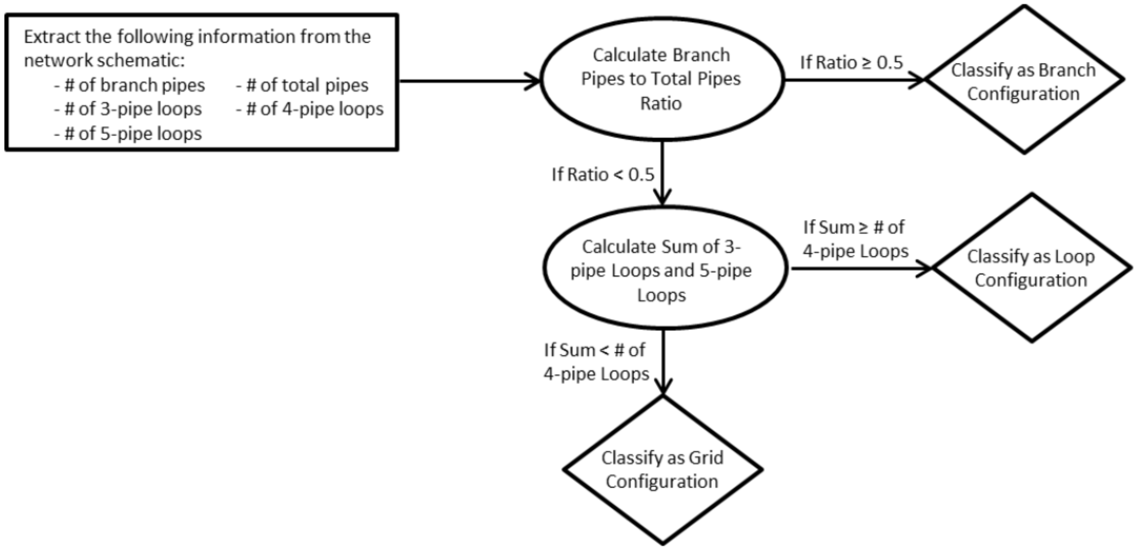


Figure 3.4. Classification Algorithm (Hoagland et al., 2015)

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	2467
Pipes	2462
Nodes	1893
Average Diameter	231
Reduced Nodes	1465
Reduced Edges	2039
Branched Edges	428
Branched Index	0.17
Meshed Connectedness	0
Reduced Meshed Connectedness	0.197
Link Density	0
Average Node Degree	3
Hwang & Lansey Classification	Distribution Sparse-Grid

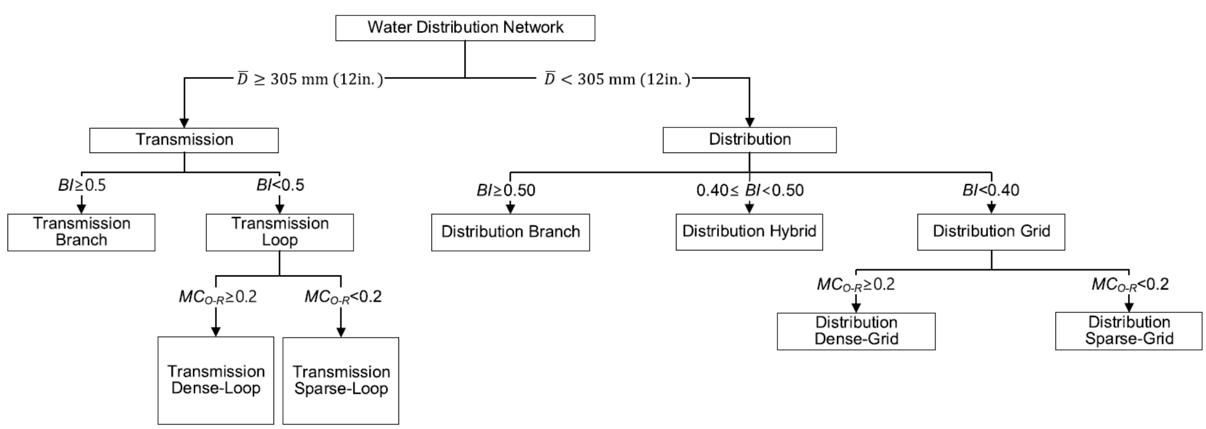


Figure 7. Water Distribution System Classification Flowchart (Hwang & Lansey, 2017)

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

DETAILED DATA SUMMARIES

PHYSICAL ASSETS:

Asset Type:	# of Assets
Master Meters	0
Tanks	0
Pumps	0
Water Sources	2

NETWORK CHARACTERISTICS:

# Total Pipes:	2469
# Junctions	1891
# Reservoirs	2
# Tanks	0
# Regulating Valves	1
# Isolation Values	1
# Hydrants	Unknown
Elevation Data	YES

PIPE DATA:

Diameter (mm)	Length (m)
50	1
76	151
80	2
81	90
97	4211
100	6
101	4867
102	110868
103	320
106	38809
110	4240
127	240
144	10474
146	2762
150	3673
152	183310
154	374

159	23092
178	590
195	77
197	260
200	11
202	100
209	81
221	126
229	36652
236	12193
250	1503
254	1739
262	2040
288	3255
296	4628
300	3705
310	26189
314	816
319	14749
360	210
361	2260
387	17181
391	1142
397	740
400	3912
423	590
464	9510
474	12900
491	2649
495	928
500	6978
522	1080
540	4102
541	650
552	2020
600	269
629	120
690	80
691	2120
745	1931

765	8884
890	2400
900	2636
917	691
918	4961
1000	2
1073	6740

PUMP DATA:

Pump Horsepower	NO
Pump Curves:	NO

DATA FILE ATTRIBUTES:

ATTRIBUTE		UNITS
Pipe Length & Diameter	X	Meters and Millimeters
Pipe Age		
Node Elevation	X	Meters
Node Demand	X	LPS
Valves		
Hydrants		
Tank Levels		
Tank Volume		
PRVs		
WTP		
WTP Capacity		
Pump Data		