Calculator for Estimating Peak Water Demand in Residential Dwellings

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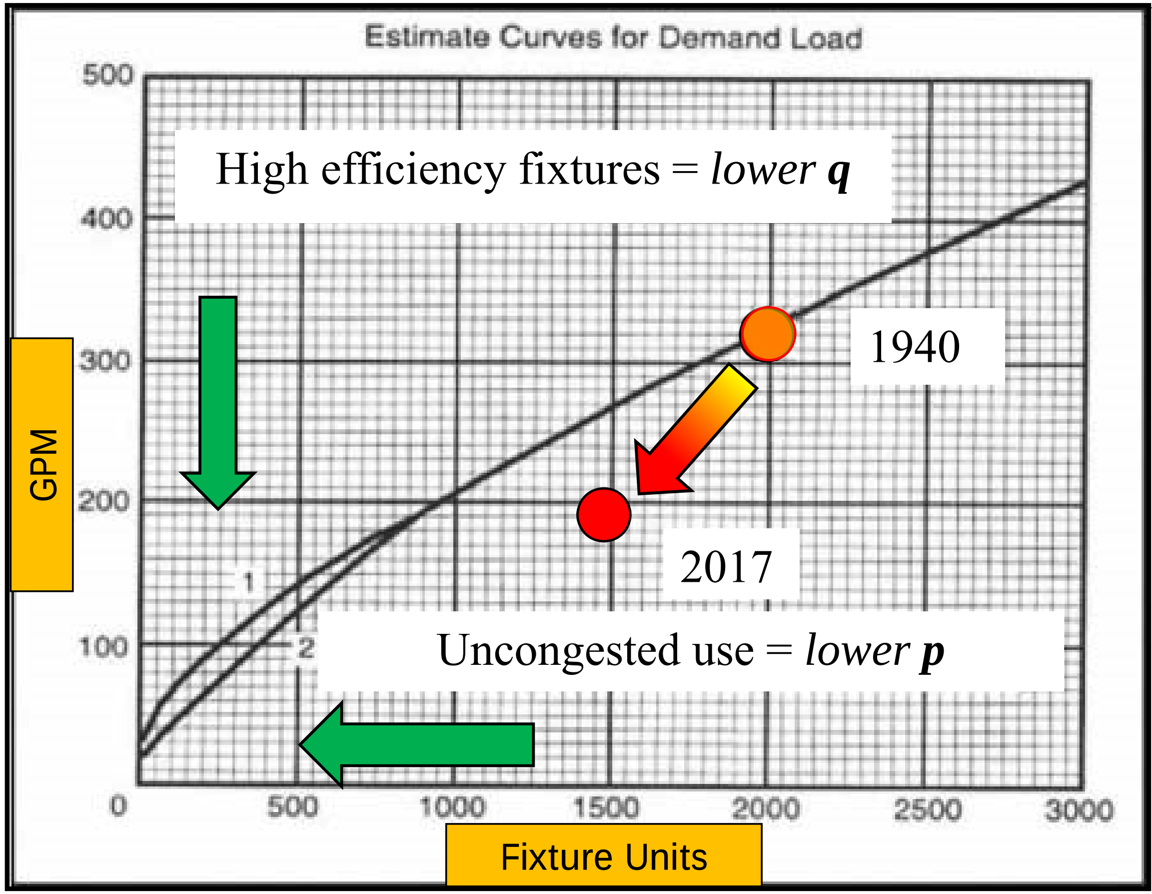
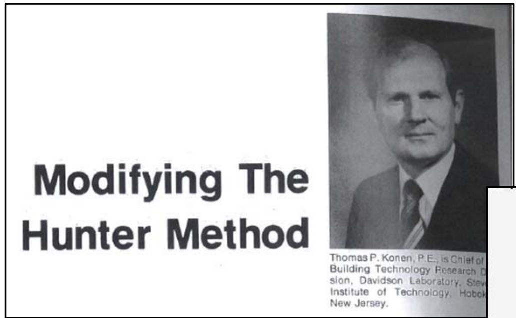
2017 CIB W062 SYMPOSIUM

The Hunter Problem



Today, **Hunter's curve** is often faulted for giving overly conservative designs….Why?

Resolving the Hunter Problem



International Council
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Simulation model of design flow rate in water submetering systems using fuzzy logic and Monte Carlo method

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ASPE 1994 Convention
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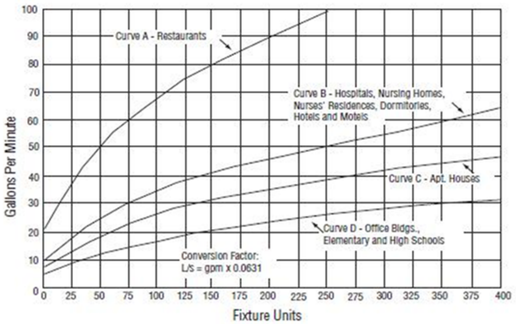
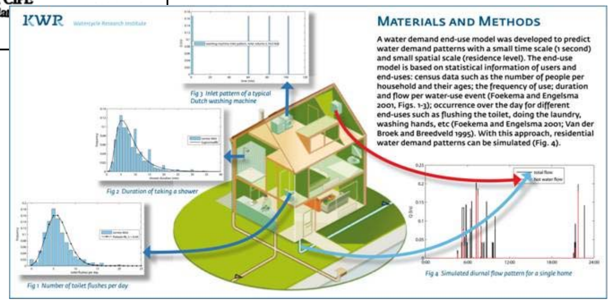
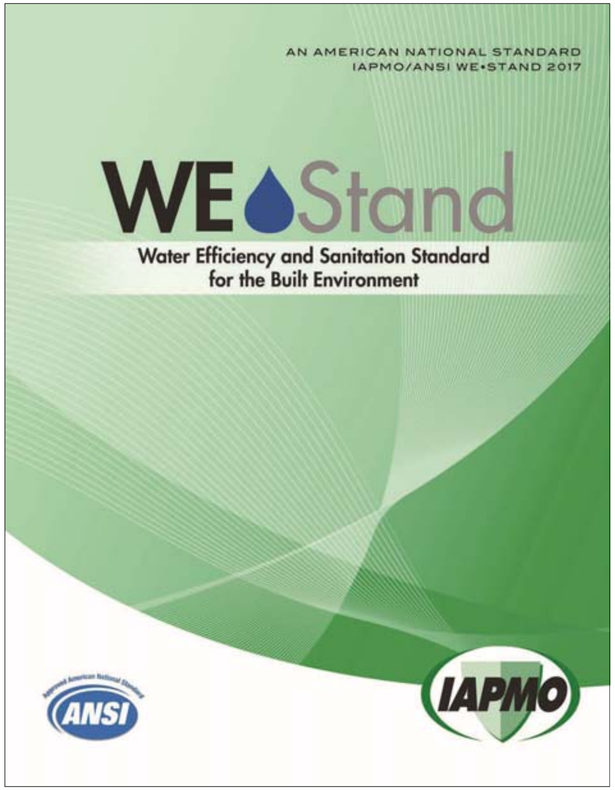
A NEW LOOK AT DETERMINING WATER DEMAND IN BUILDINGS: ASPE DIRECT ANALYTICAL METHOD

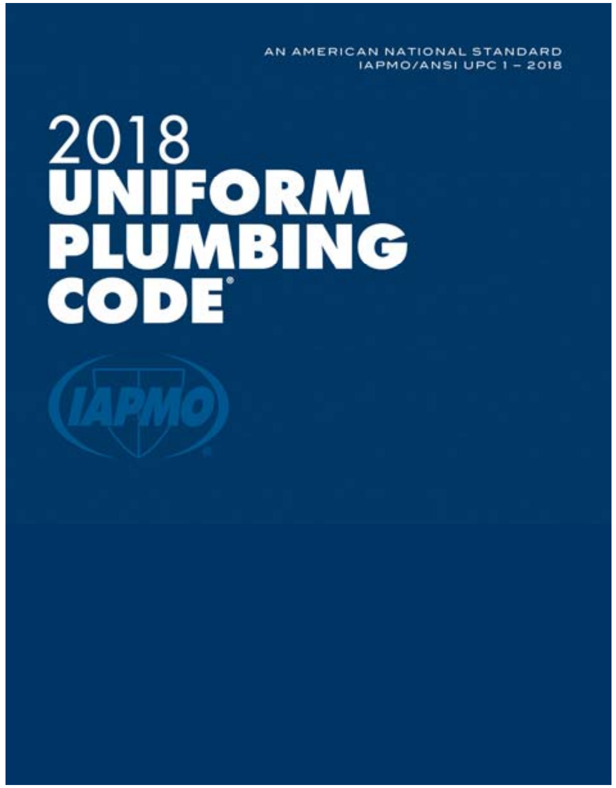
Robert A. Wistort , PE, CIPE
[ASPE Research Foundat





American National Standards





Water Demand Calculator

	[A] FIXTURE	[B] ENTER NUMBER OF FIXTURES	[C] PROBABILITY OF USE (%)	[D] ENTER FIXTURE FLOW RATE (GPM)	[E] MAXIMUM RECOMMENDED FIXTURE FLOW RATE (GPM)
1	Bar Sink	0	2.0	1.5	1.5
2	Bathtub	0	1.0	5.5	5.5
3	Bidet	0	1.0	2.0	2.0
4	Clothes Washer	0	5.5	3.5	3.5
5	Combination Bath/Shower	0	5.5	5.5	5.5
6	Dishwasher	0	0.5	1.3	1.3
7	Kitchen Faucet	0	2.0	2.2	2.2
8	Laundry Faucet	0	2.0	2.0	2.0
9	Lavatory Faucet	0	2.0	1.5	1.5
10	Shower, per head	0	4.5	2.0	2.0
11	Water Closet, 1.28 GPF Gravity Tank	0	1.0	3.0	3.0
12	Other Fixture 1	0	0.0	0.0	6.0
13	Other Fixture 2	0	0.0	0.0	6.0
14	Other Fixture 3	0	0.0	0.0	6.0

Total Number of Fixtures 0

99th PERCENTILE DEMAND FLOW = GPM

RESET

RUN WATER DEMAND CALCULATOR

↑ CLICK BUTTON ↑

Title Page | Key | DemandEstimate

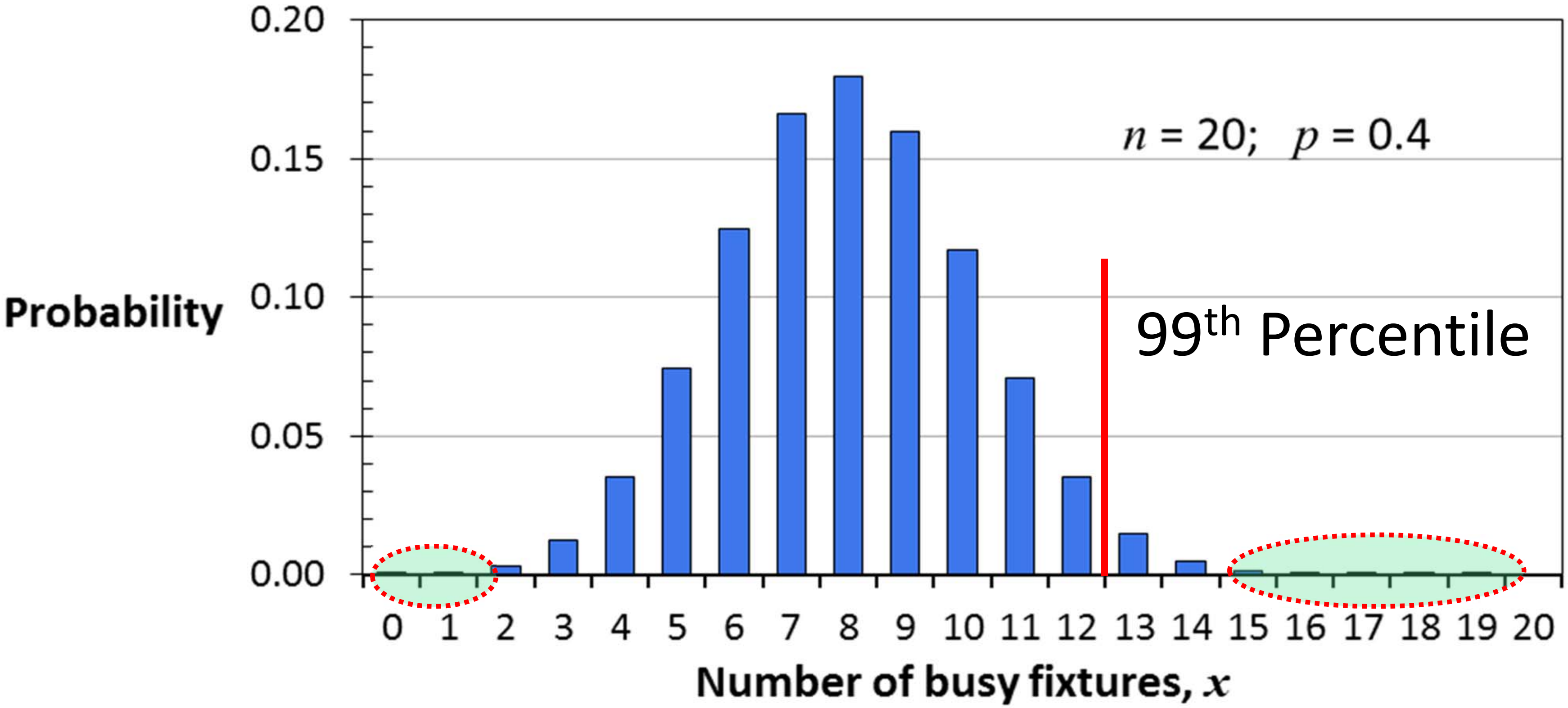
Ready 70%

Basic Template

(PEAK) WATER USE MODEL

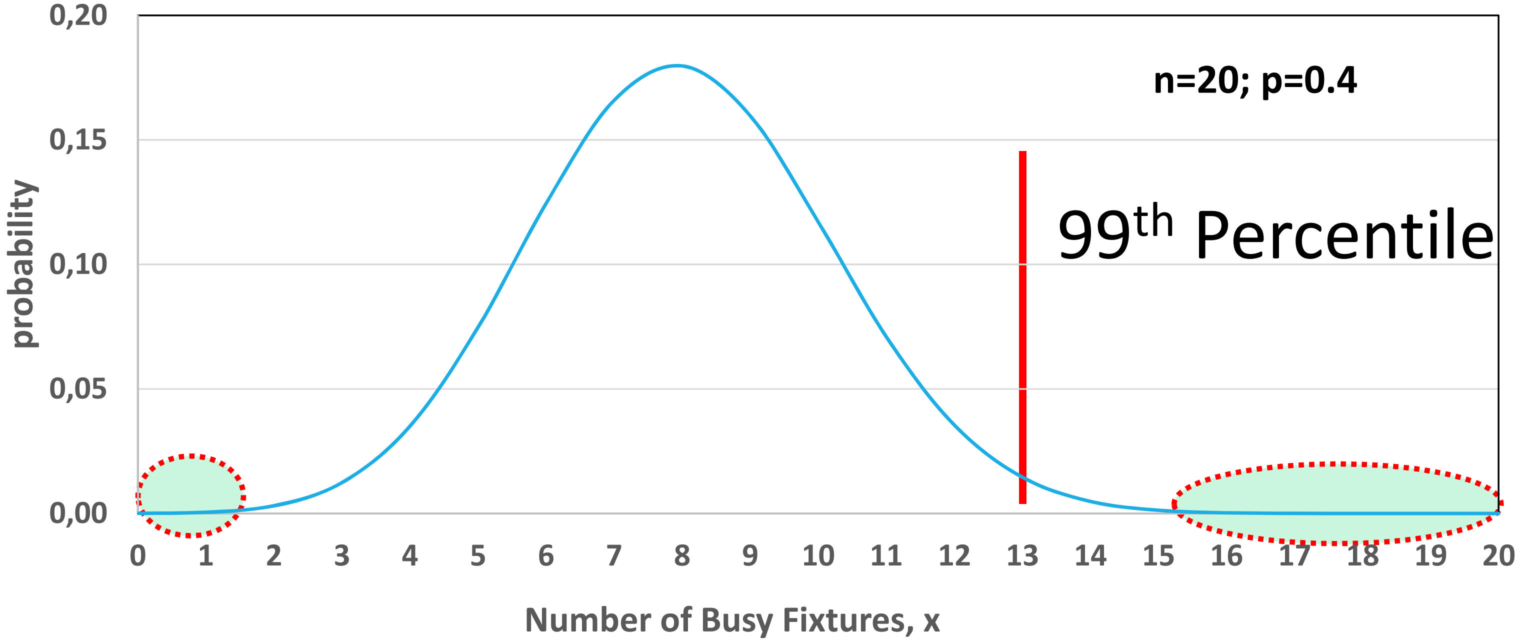
Binomial Model

$$\Pr\begin{pmatrix}\text{exactly } x \text{ busy} \\ \text{out of } n \text{ fixtures}\end{pmatrix} = \binom{n}{x} p^x (1-p)^{n-x}$$



Normal Approximation Model

$$X \quad = Mean + \left(z_{0.99}\right) Standard\ Deviation$$



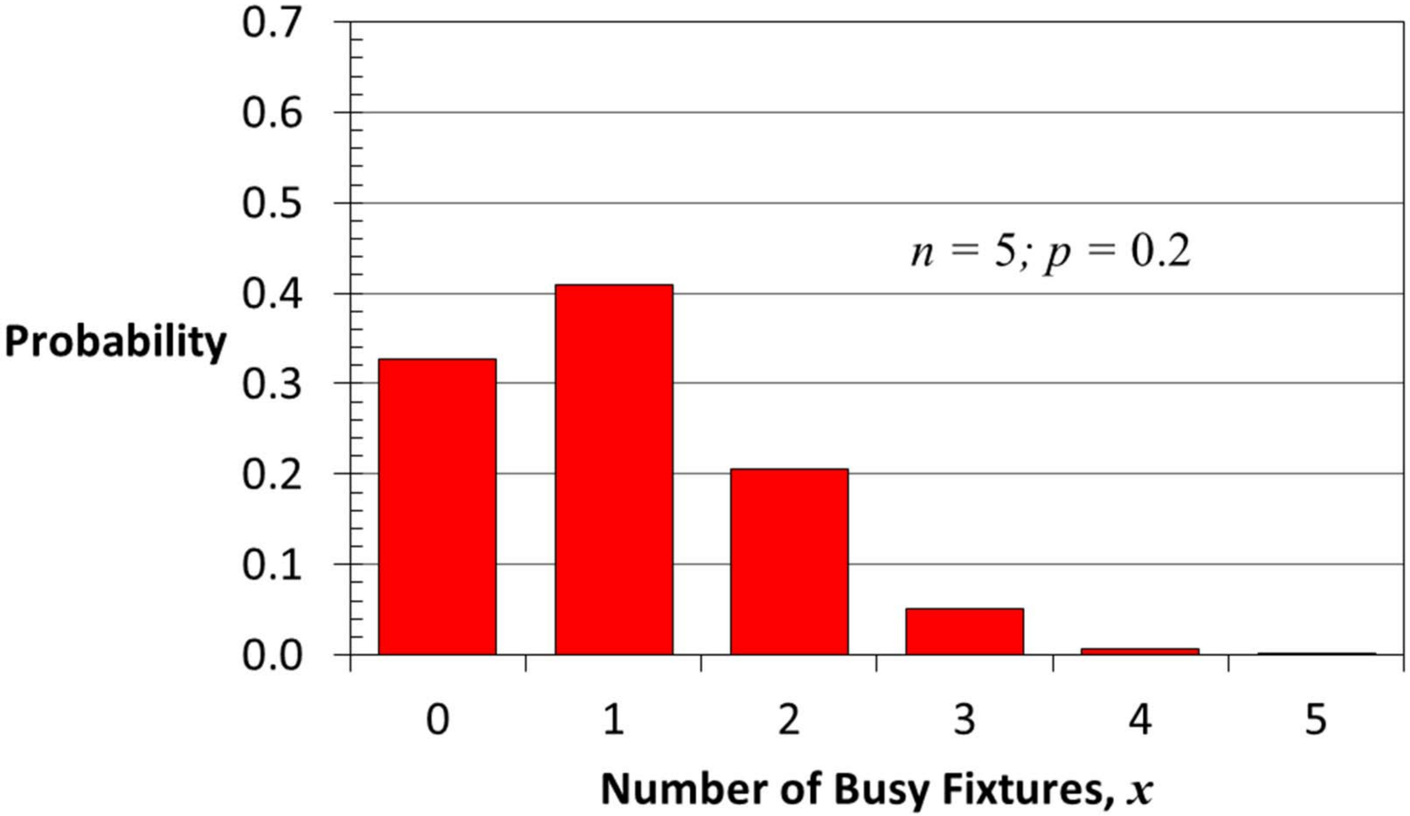
[1] Wistort Model (1995)

$$Q_{0.99} = \mu_q + (z_{0.99})\sigma_q$$

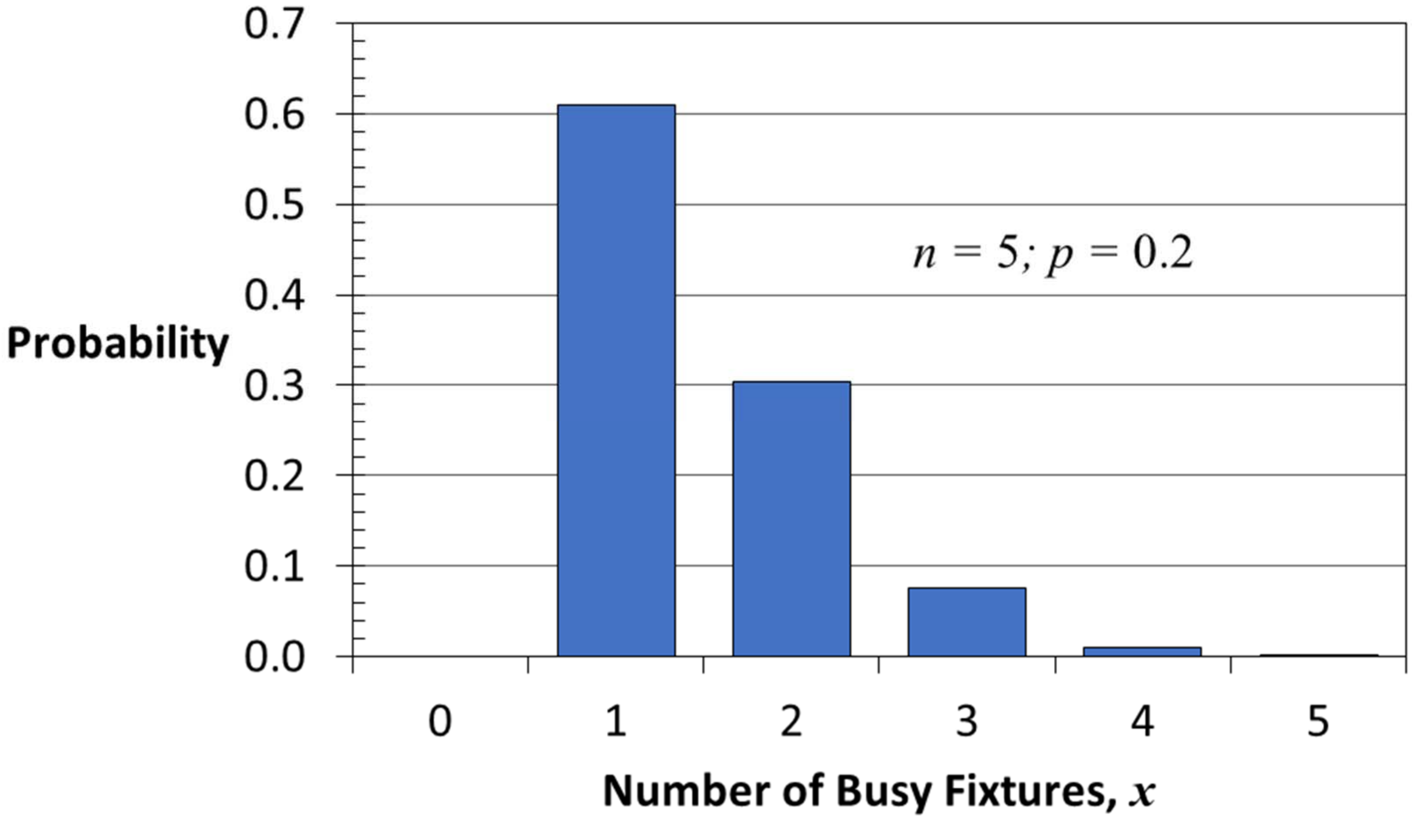
Adding the q-value

$$Q_{0.99} = \sum_{k=1}^{K} n_k p_k q_k + (z_{0.99})\sqrt{\sum_{k=1}^{K} n_k p_k (1 - p_k) q_k^2}$$

Binomial Distribution (small building)



Zero Truncated Binomial Distribution



[2] Modified Wistort's Model

$$Q_{0.99} = \sum_{k=1}^{K} n_k p_k q_k + (z_{0.99}) \sqrt{\sum_{k=1}^{K} n_k p_k (1 - p_k) q_k^2}$$

$$Q_{0.99} = \frac{1}{1 - P_0} \left[\sum_{k=1}^{K} n_k p_k q_k + (z_{0.99}) \sqrt{\left[(1 - P_0) \sum_{k=1}^{K} n_k p_k (1 - p_k) q_k^2 \right] - P_0 \left(\sum_{k=1}^{K} n_k p_k q_k \right)^2} \right]$$

- Note:
  - $P_0 = \prod_{1}^{k} (1 - p_k)^{n_k}$ is probability of stagnation in a home (i.e. no water use)
  - Addresses water demand in single family homes with high P_0
  - Transitions back to Wistort's model as P_0 approaches 0

[3] Exhaustive Enumeration

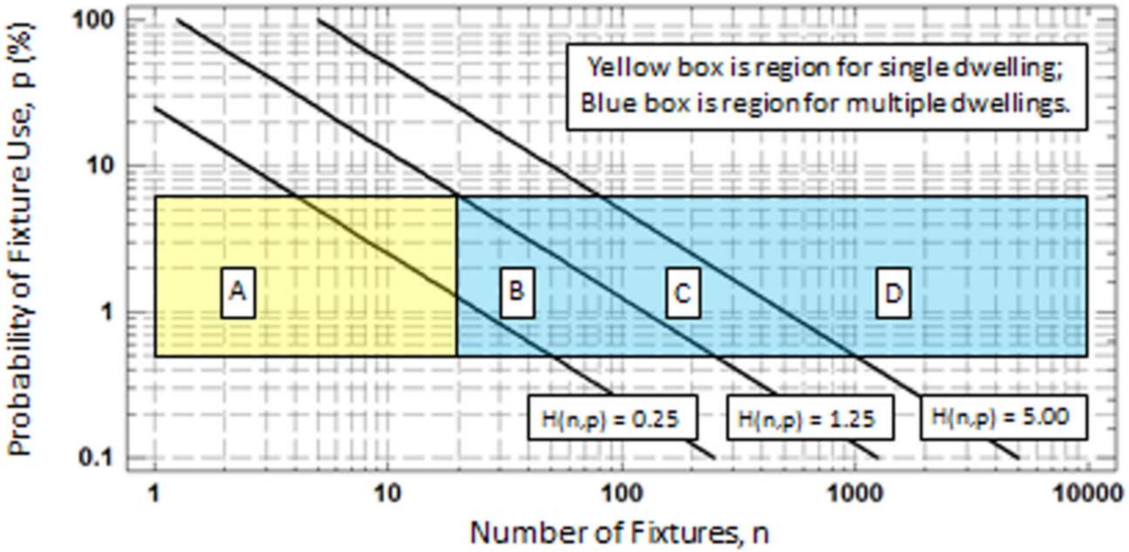
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Case	CW	DW	KF	LF	P_{CW}	P_{DW}	P_{KF}	P_{LF}	Q (gpm)	T.T. Probability	Q Ranked	B.T. Probability	B.T. CDF
1	○	○	○	○	0.945	0.995	0.980	0.980	0.0	0.9030401	0.0		0.000
2	●	○	○	○	0.055	0.995	0.980	0.980	3.5	0.0525579	1.3	0.046802	0.047
3	○	●	○	○	0.945	0.005	0.980	0.980	1.3	0.0045379	2.0	0.190072	0.237
4	○	○	●	○	0.945	0.995	0.020	0.980	2.2	0.0184294	2.2	0.190072	0.427
5	○	○	○	●	0.945	0.995	0.980	0.020	2.0	0.0184294	3.3	0.000955	0.428
6	●	●	○	○	0.055	0.005	0.980	0.980	4.8	0.0002641	3.5	0.542058	0.970
7	●	○	●	○	0.055	0.995	0.020	0.980	5.7	0.0010726	3.5	0.000955	0.971
8	●	○	○	●	0.055	0.995	0.980	0.020	5.5	0.0010726	4.2	0.003879	0.975
9	○	●	●	○	0.945	0.005	0.020	0.980	3.5	0.0000926	4.8	0.002724	0.978
10	○	●	○	●	0.945	0.005	0.980	0.020	3.3	0.0000926	**5.5**	0.011062	**0.989**
11	○	○	●	●	0.945	0.995	0.020	0.020	4.2	0.0003761	**5.5**	0.000019	**0.989**
12	●	●	●	○	0.055	0.005	0.020	0.980	7.0	0.0000054	5.7	0.011062	1.000
13	●	●	○	●	0.055	0.005	0.980	0.020	6.8	0.0000054	6.8	0.000056	1.000
14	●	○	●	●	0.055	0.995	0.020	0.020	7.7	0.0000219	7.0	0.000056	1.000
15	○	●	●	●	0.945	0.005	0.020	0.020	5.5	0.0000019	7.7	0.000226	1.000
16	●	●	●	●	0.055	0.005	0.020	0.020	9.0	0.0000001	9.0	0.000001	1.000
									Sum	1.0000000	Sum	1.000000	

[4] Q1+Q3

Number of Fixtures	Number of Combinations	Fixture Demand (gpm)	Design Flow (giving 95th to 99th percentile)
1	2	q_1	q_1
2	4	$q_2 \leq q_1$	q_1
3	8	$q_3 \leq q_2 \leq q_1$	$q_1 + q_3$
4	16	$q_4 \leq q_3 \leq q_2 \leq q_1$	$q_1 + q_3$
5	32	$q_5 \leq q_4 \leq q_3 \leq q_2 \leq q_1$	$q_1 + q_3$
6	64	$q_6 \leq q_5 \leq q_4 \leq q_3 \leq q_2 \leq q_1$	$q_1 + q_3$

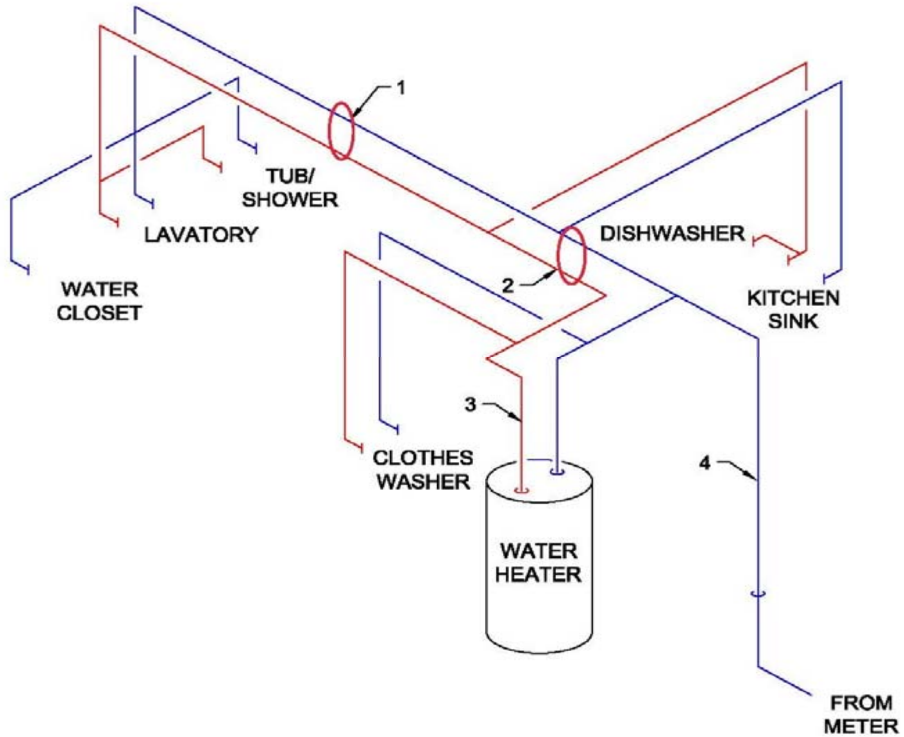
Summary of Methods

Region	Spatial Scale	Range for $H(n,p)$	Method
A	Small	$0 < H(n,p) < 0.25$	Exhaustive Enumeration; q1+q3
B	Small to Intermediate	$0.25 \leq H(n,p) < 1.25$	Exhaustive Enumeration
C	Intermediate to Large	$1.25 \leq H(n,p) < 5.00$	Modified Wistort Method
D	Large	$H(n,p) \geq 5.00$	Wistort Method



APPLICATION

Small Residential Building Pipe Layout



Peak Flow Building Supply

	[A] FIXTURE	[B] ENTER NUMBER OF FIXTURES	[C] PROBABILITY OF USE (%)	[D] ENTER FIXTURE FLOW RATE (GPM)	[E] MAXIMUM RECOMMENDED FIXTURE FLOW RATE (GPM)
1	Bar Sink	0	2.0	1.5	1.5
2	Bathtub	0	1.0	5.5	5.5
3	Bidet	0	1.0	2.0	2.0
4	Clothes Washer	1	5.5	3.5	3.5
5	Combination Bath/Shower	1	5.5	5.5	5.5
6	Dishwasher	1	0.5	1.3	1.3
7	Kitchen Faucet	1	2.0	2.2	2.2
8	Laundry Faucet	0	2.0	2.0	2.0
9	Lavatory Faucet	1	2.0	1.5	1.5
10	Shower, per head	0	4.5	2.0	2.0
11	Water Closet, 1.28 GPF Gravity Tank	1	1.0	3.0	3.0
12	Other Fixture 1	0	0.0	0.0	6.0
13	Other Fixture 2	0	0.0	0.0	6.0
14	Other Fixture 3	0	0.0	0.0	6.0

Total Number of Fixtures **6**

99th PERCENTILE DEMAND FLOW = 8.5 GPM

RESET

RUN WATER DEMAND CALCULATOR

6 Fixtures

UPC with Hunter's Curve gives 10gpm

15% Reduction

Large Residential Apartment

Peak Flow Building Supply

	[A] FIXTURE	[B] ENTER NUMBER OF FIXTURES	[C] PROBABILITY OF USE (%)	[D] ENTER FIXTURE FLOW RATE (GPM)	[E] MAXIMUM RECOMMENDED FIXTURE FLOW RATE (GPM)
1	Bar Sink	0	2.0	1.5	1.5
2	Bathtub	0	1.0	5.5	5.5
3	Bidet	0	1.0	2.0	2.0
4	Clothes Washer	100	5.5	3.5	3.5
5	Combination Bath/Shower	200	5.5	5.5	5.5
6	Dishwasher	100	0.5	1.3	1.3
7	Kitchen Faucet	100	2.0	2.2	2.2
8	Laundry Faucet	100	2.0	2.0	2.0
9	Lavatory Faucet	300	2.0	1.5	1.5
10	Shower, per head	0	4.5	2.0	2.0
11	Water Closet, 1.28 GPF Gravity Tank	300	1.0	3.0	3.0
12	Other Fixture 1	0	0.0	0.0	6.0
13	Other Fixture 2	0	0.0	0.0	6.0
14	Other Fixture 3	0	0.0	0.0	6.0

Total Number of Fixtures **1200**

99th PERCENTILE DEMAND FLOW = 155.4 GPM

RESET

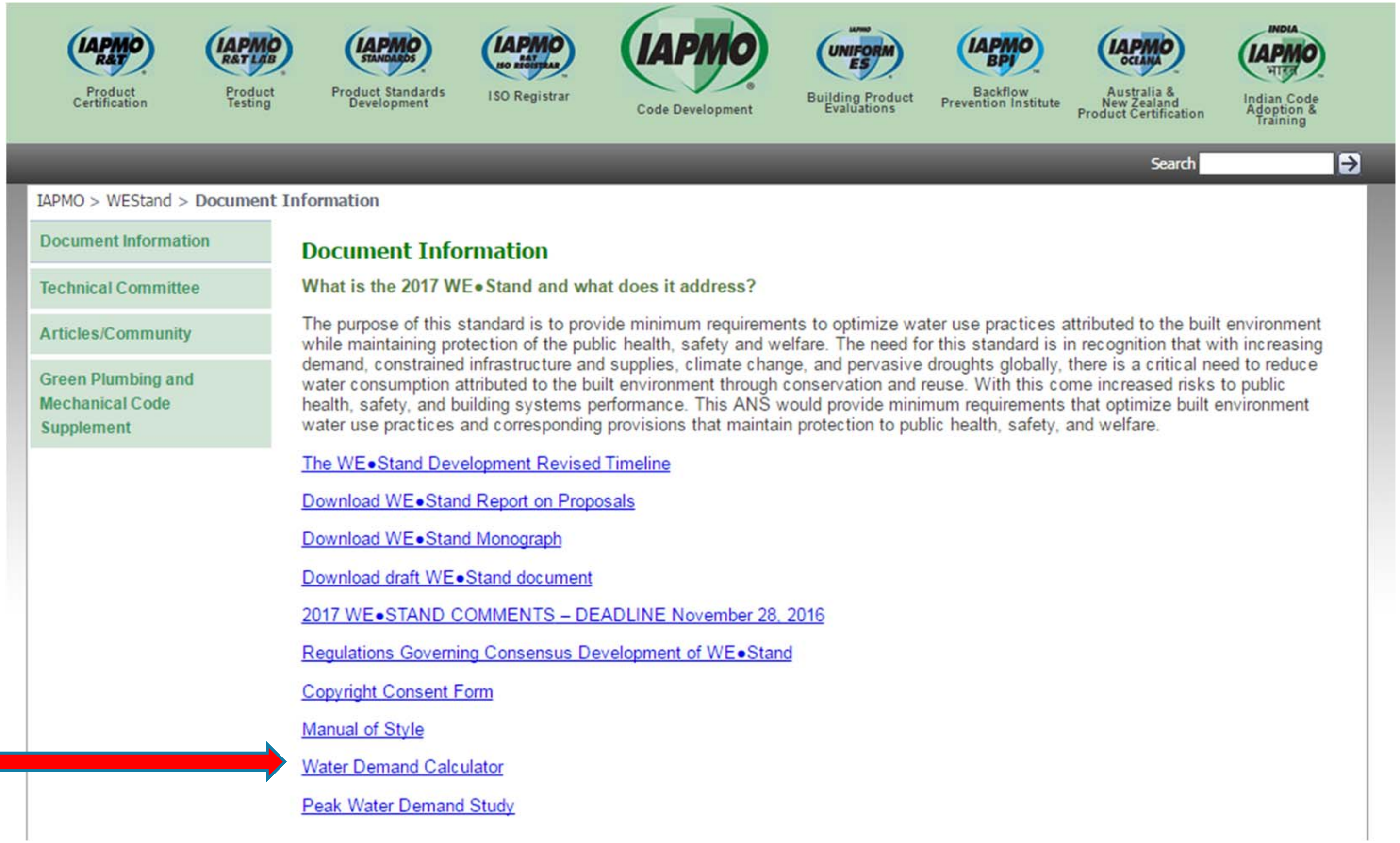
RUN WATER DEMAND CALCULATOR

1200 Fixtures

UPC with Hunter's Curve gives 402gpm

61% Reduction

http://www.iapmo.org/WEStand/Pages/DocumentInformation.aspx



To Download the Calculator