This presentation premiered at WaterSmart Innovations

watersmartinnovations.com

watersmart
INNOVATIONS

Calculator for Estimating Peak Water Demand in Residential Dwellings

DAN COLE

WATERSMART INNOVATIONS

OCTOBER 5, 2017

IAPMO Task Group Sponsors and Members

Daniel Cole, Chair , IAPMO, Mokena, IL 60448
Jason Hewitt, CB Engineers, San Francisco, CA 94103
Timothy Wolfe, TRC Worldwide Engineering MEP, LLC, Indianapolis, IN 46240
Toritseju Omaghomi, College of Engineering, University of Cincinnati, Cincinnati , OH 45221
Steven Buchberger, College of Engineering, University of Cincinnati, Cincinnati, OH 45221

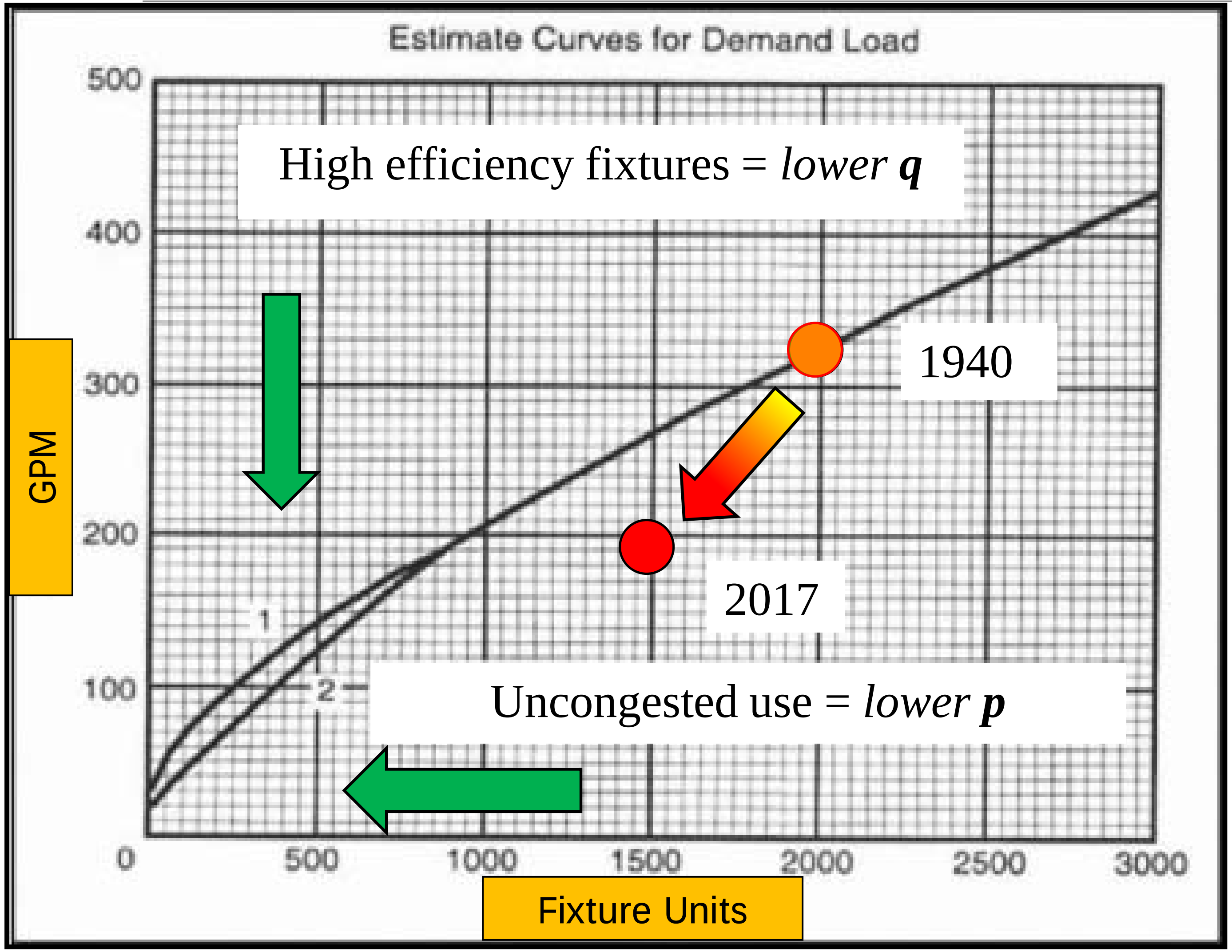
IAPMO Task Group Scope

International Association of Plumbing and Mechanical Officials

"….will work singularly to develop the probability model to predict peak demands based on the number of plumbing fixtures of different kinds installed in one system."

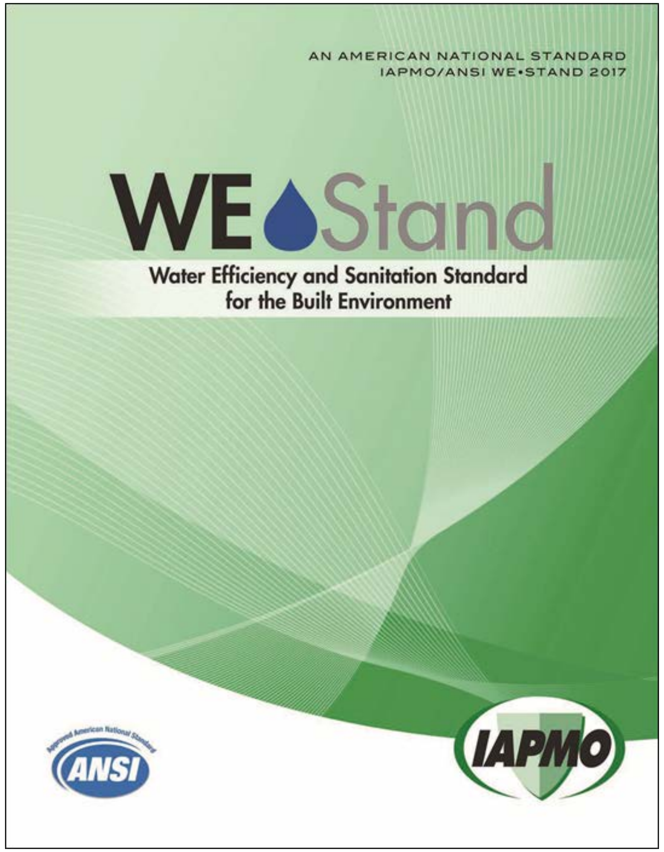
(Bring Hunter into 21st Century)

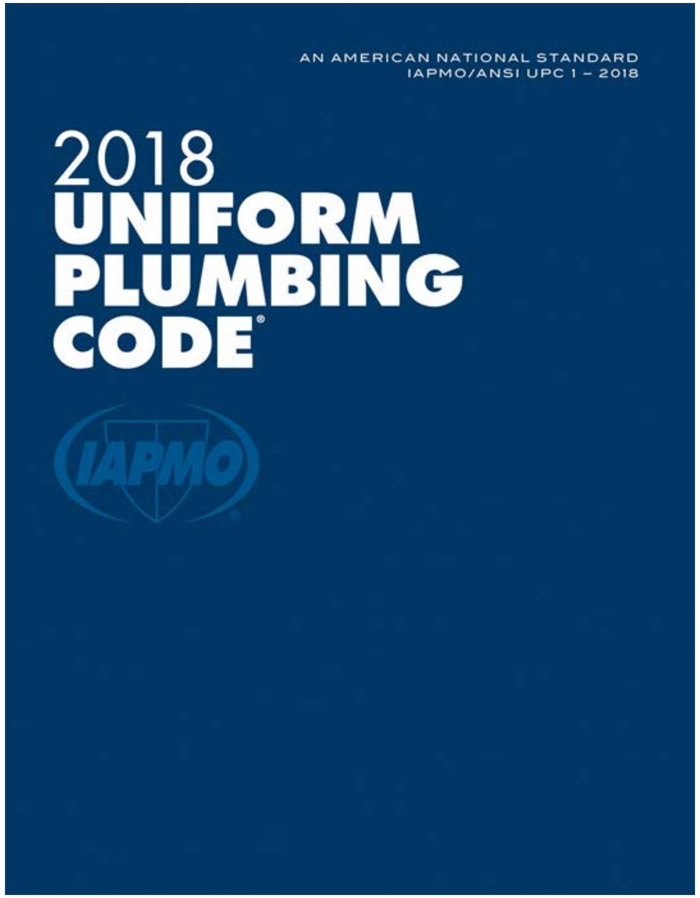
The Hunter Problem



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

Resolving the Hunter Problem for Residential Applications





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

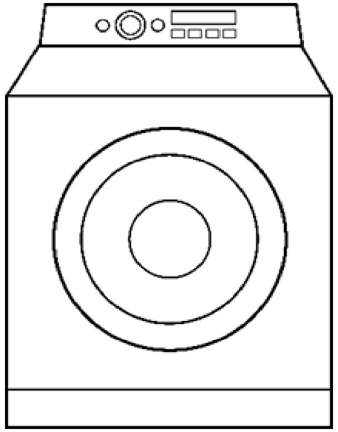
↑ CLICK BUTTON ↑

Title Page | Key | DemandEstimate

Ready 70%

Basic Template

Design Fixture Probability Values

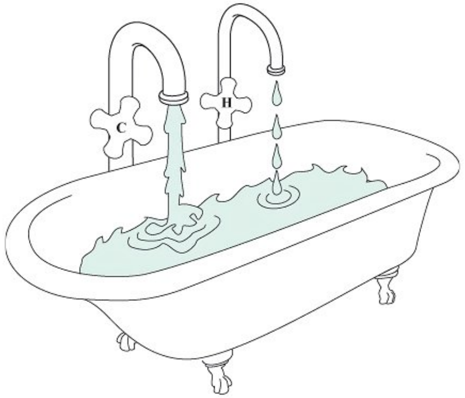


p = 0.055

p = 0.045

p = 0.020

p = 0.010



p = 0.010

p = 0.005

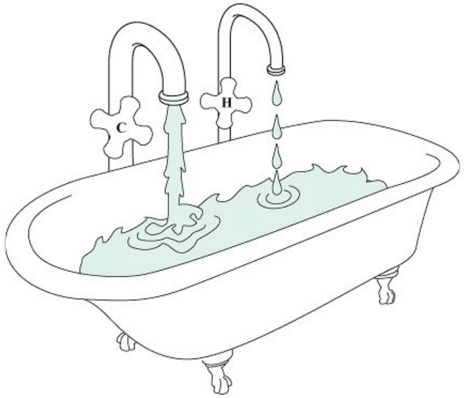
Design Fixture Flow Rate Values

q = 2.0

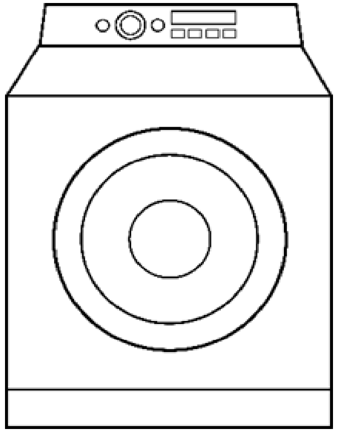
q = 1.5

q = 2.2

q = 3.0



q = 5.5



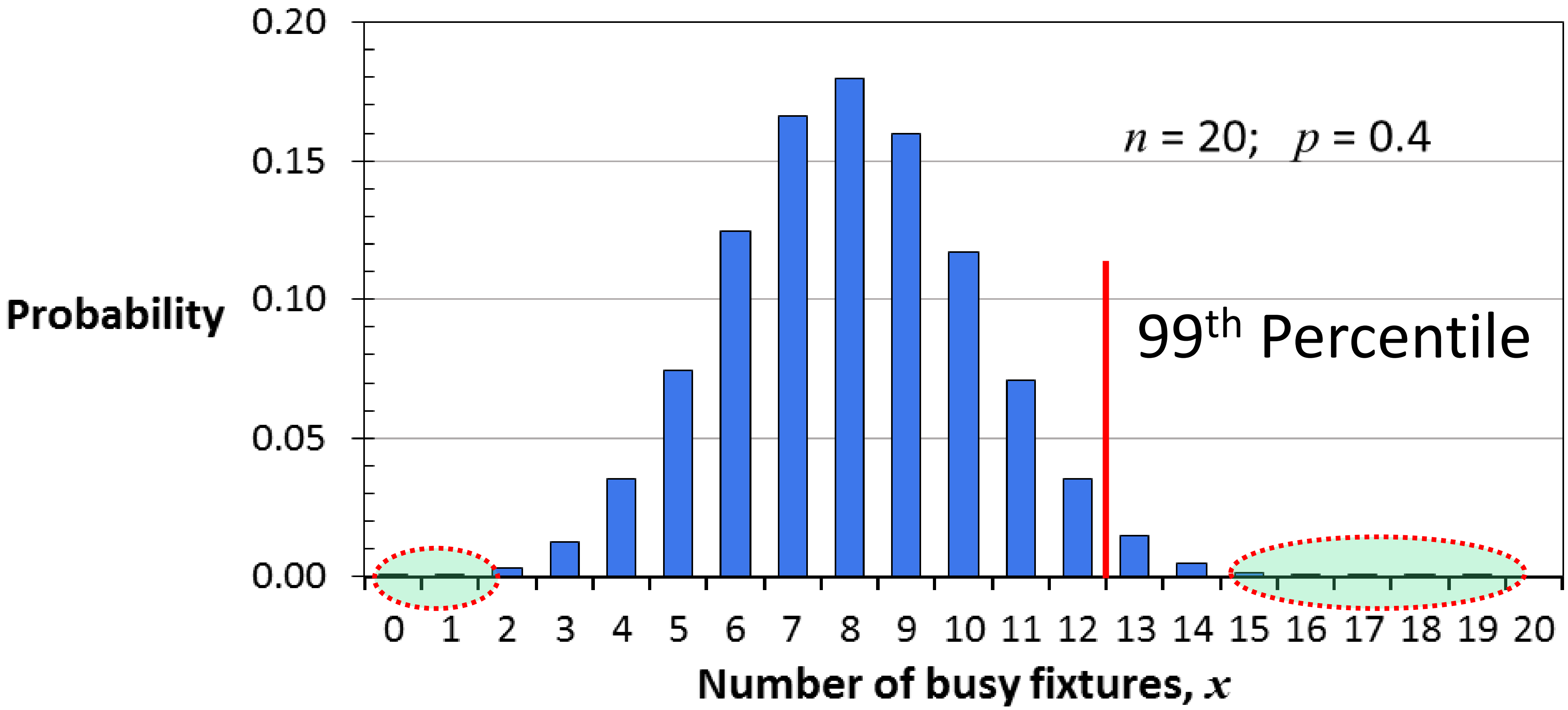
q = 3.5

q = 1.3

(PEAK) WATER USE MODEL

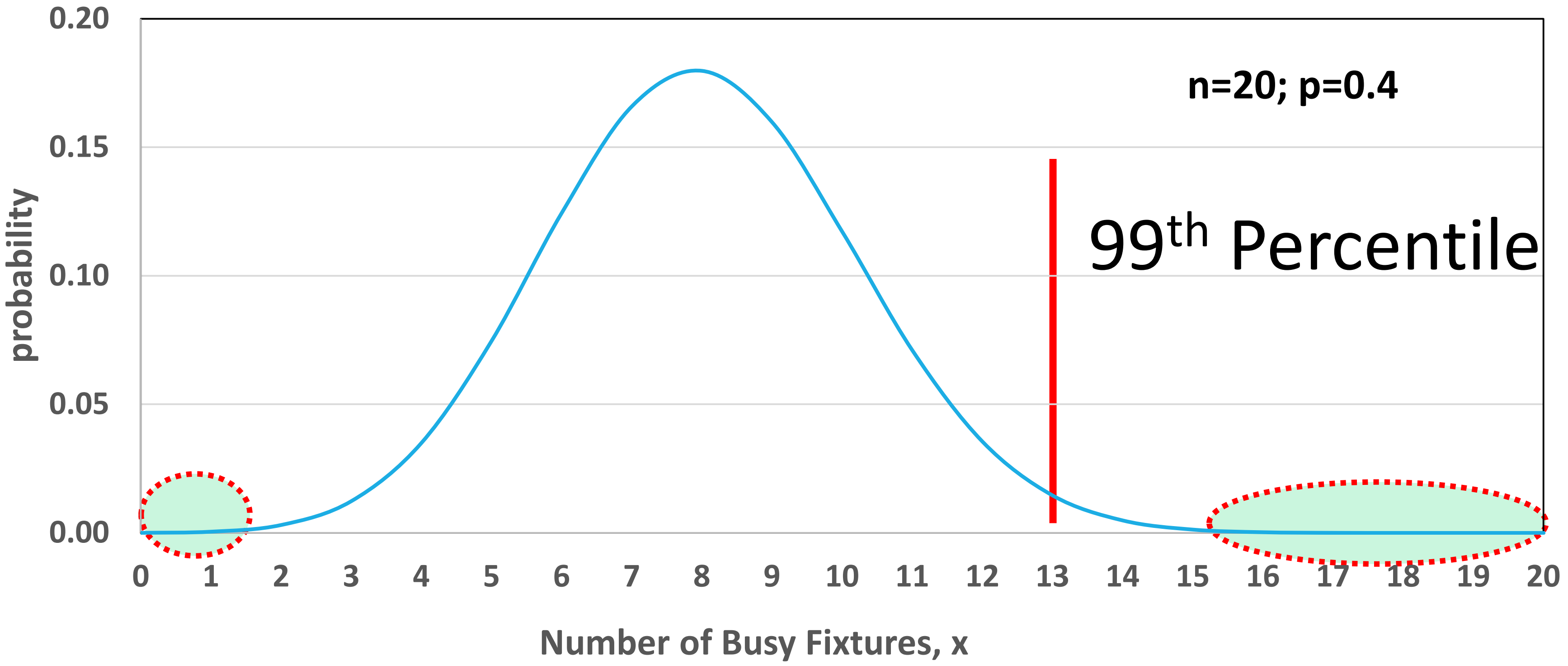
Binomial Model

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



Normal Approximation Model

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



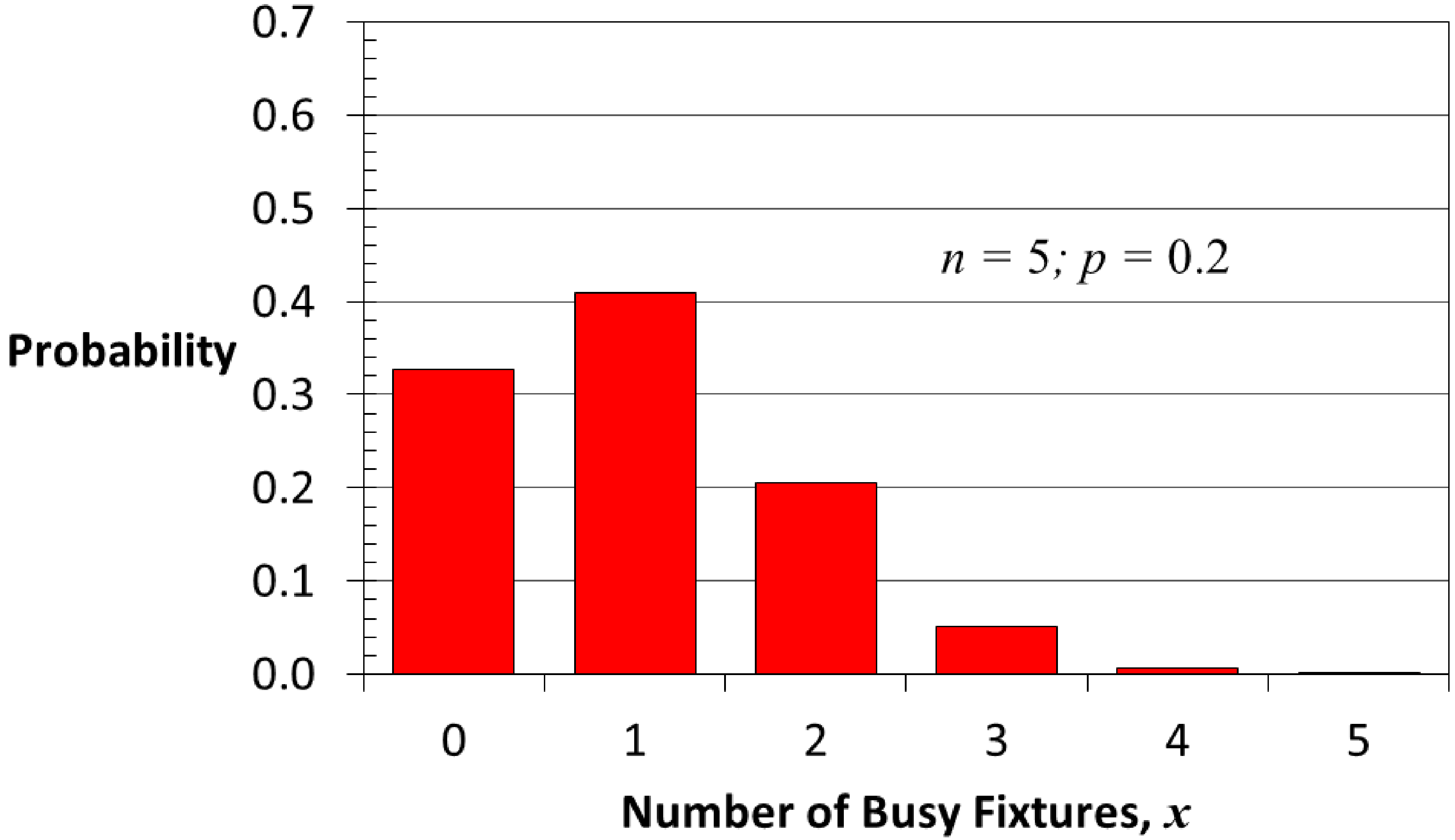
[1] Wistort Model (1995)

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

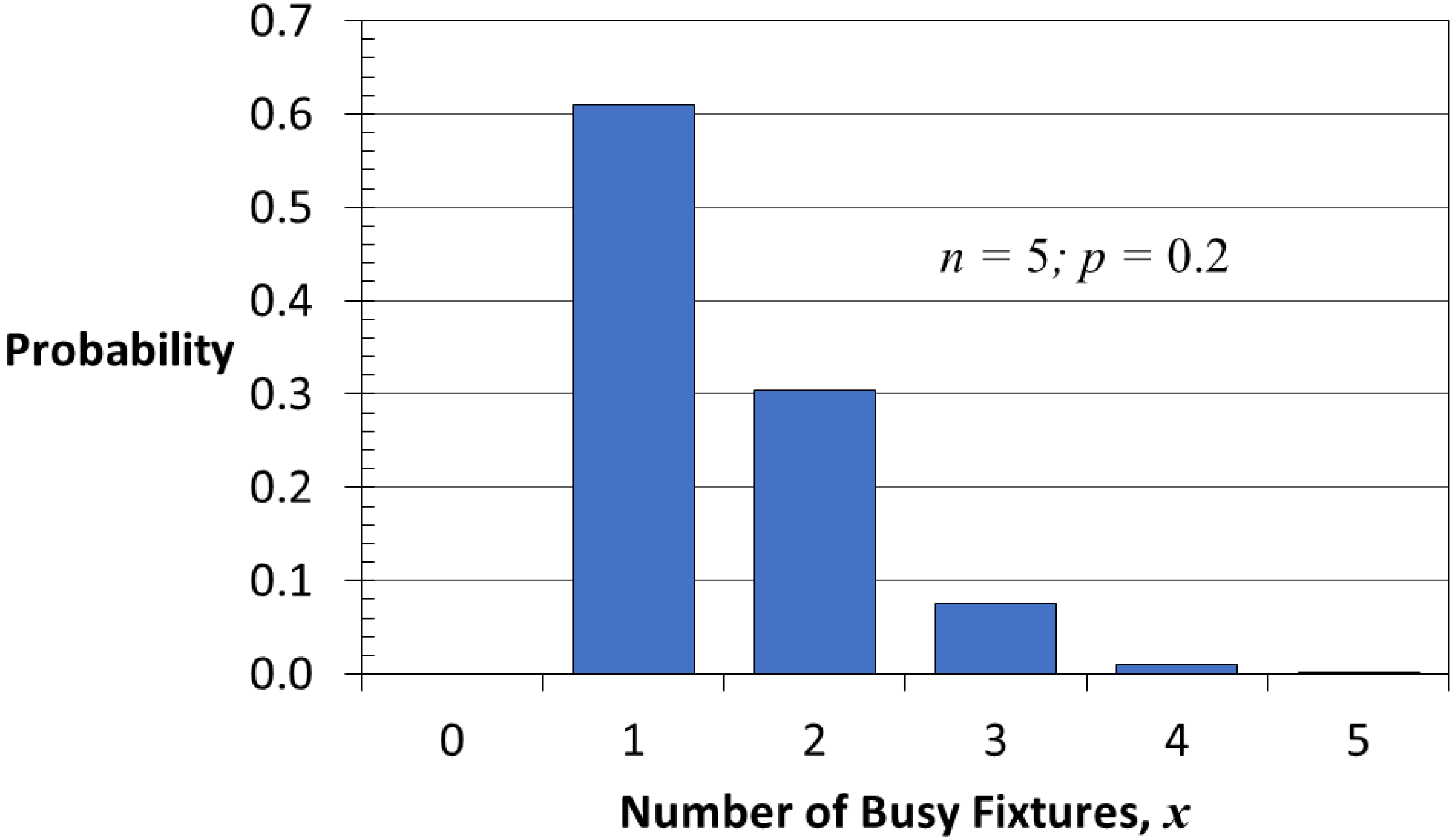
Adding the q-value

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

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

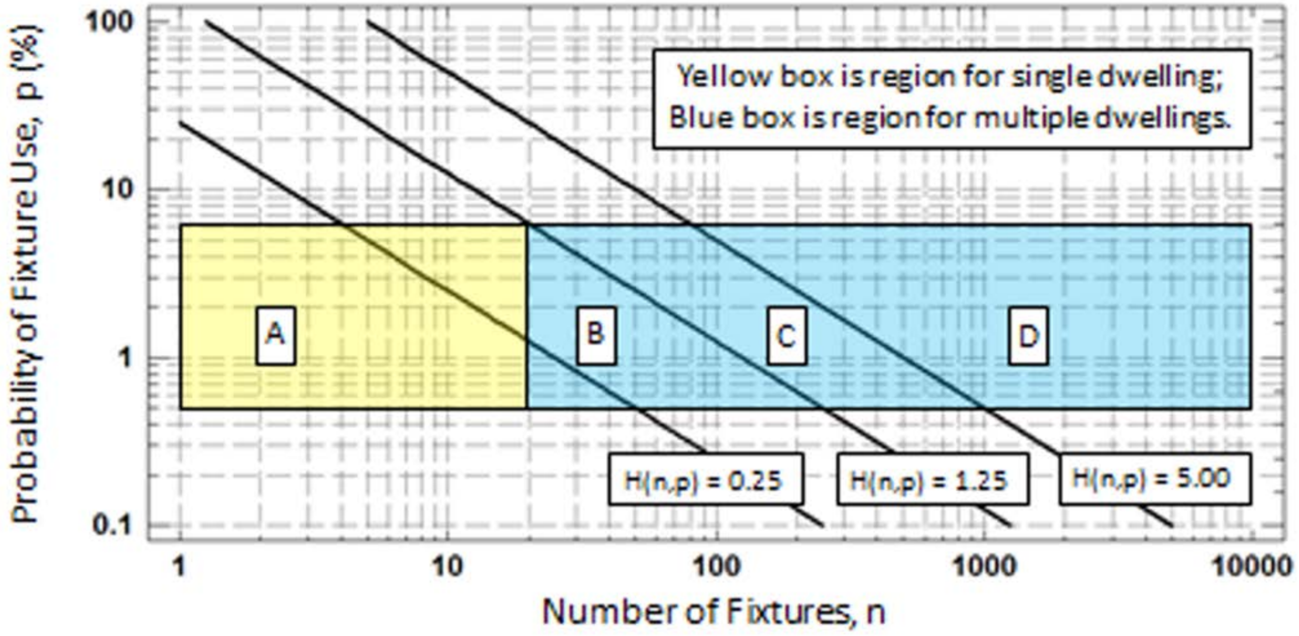
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Case	CW	DW	KF	LF	P_{CW}	P_{DW}	P_{KF}	P_{LF}	Q (gpm)	T.T. Probability	Q Ranked	B.T. Probability	B.T. CDF
1	○	○	○	○	0.945	0.995	0.980	0.980	0.0	0.9030401	0.0		0.000
2	●	○	○	○	0.055	0.995	0.980	0.980	3.5	0.0525579	1.3	0.046802	0.047
3	○	●	○	○	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	$q_6 \leq q_5 \leq q_4 \leq q_3 \leq q_2 \leq q_1$	$q_1 + q_3$

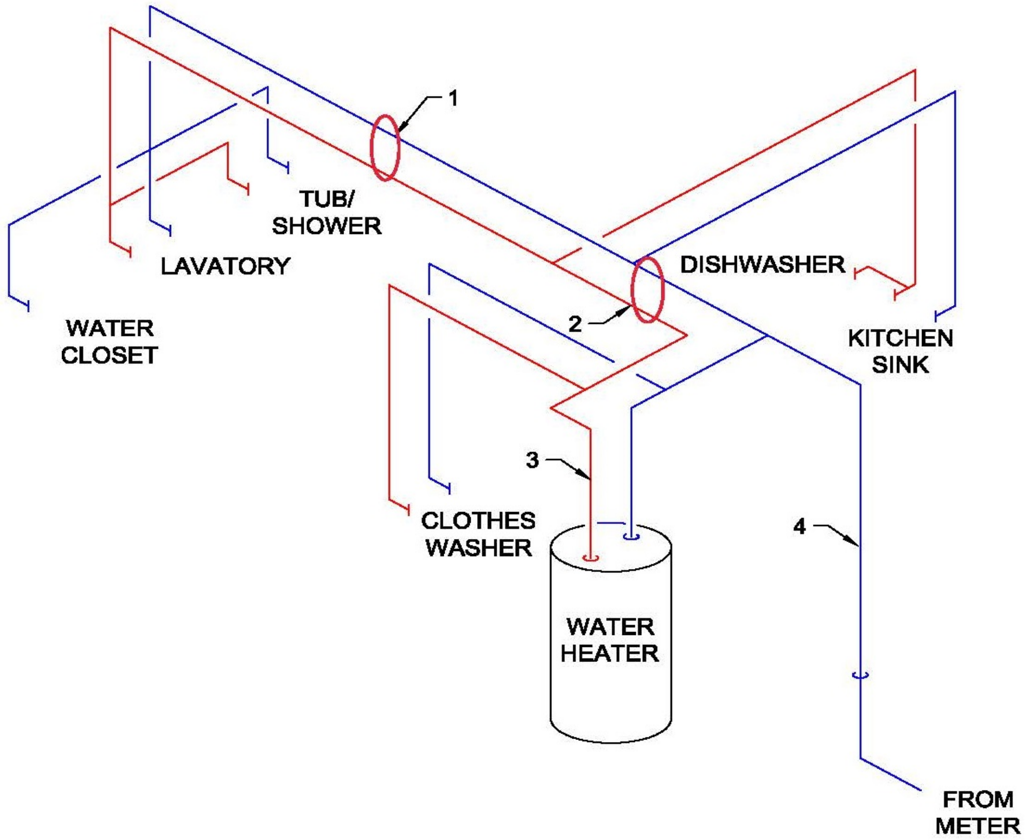
Summary of Methods

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

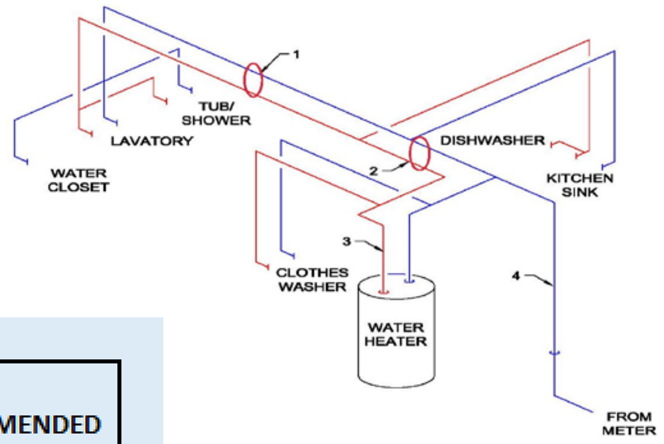


APPLICATION

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

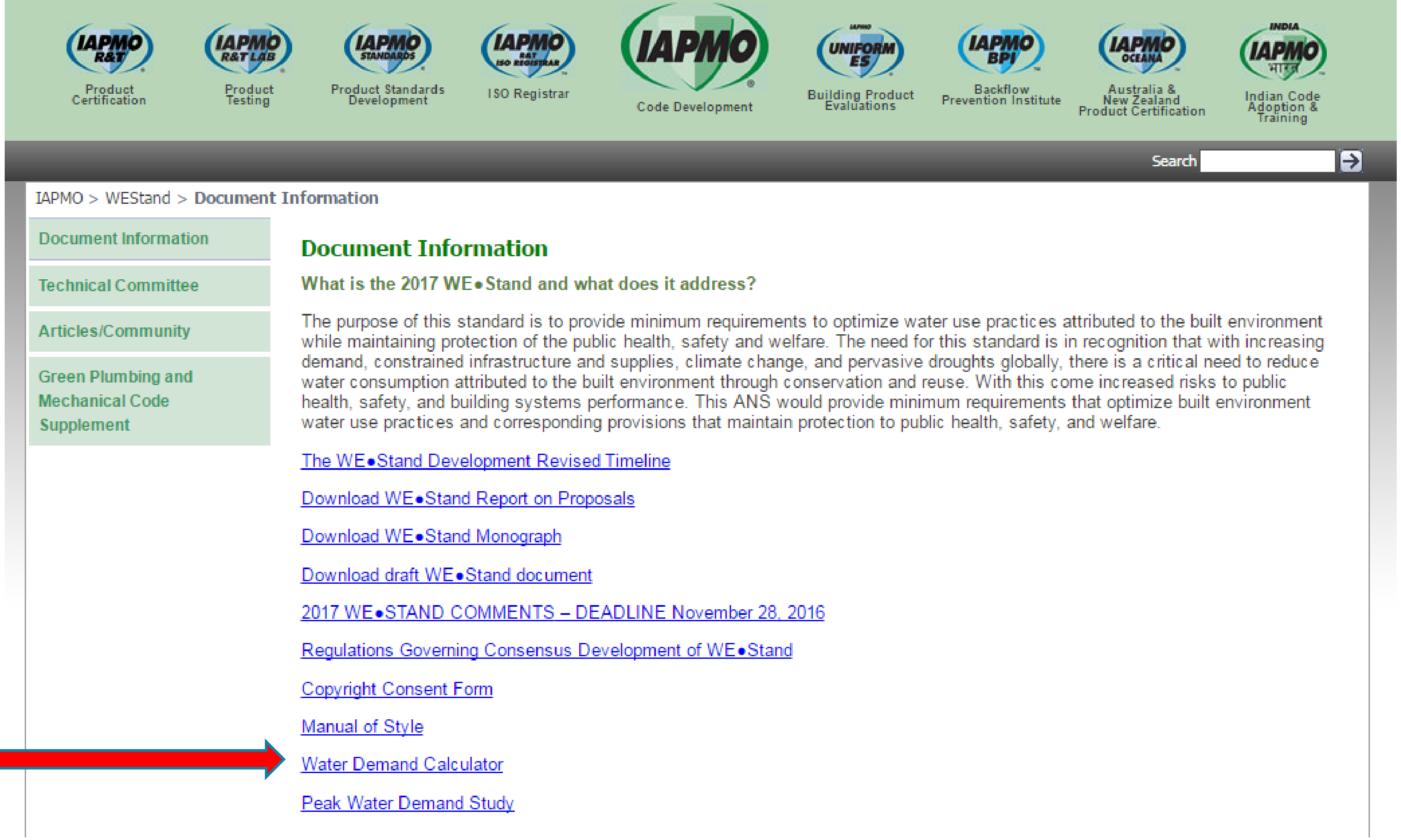
RUN WATER DEMAND CALCULATOR

1200 Fixtures

UPC with Hunter's Curve gives 402gpm

61% Reduction

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



Document Information

What is the 2017 WE•Stand and what does it address?

The purpose of this standard is to provide minimum requirements to optimize water use practices attributed to the built environment while maintaining protection of the public health, safety and welfare. The need for this standard is in recognition that with increasing demand, constrained infrastructure and supplies, climate change, and pervasive droughts globally, there is a critical need to reduce water consumption attributed to the built environment through conservation and reuse. With this come increased risks to public health, safety, and building systems performance. This ANS would provide minimum requirements that optimize built environment water use practices and corresponding provisions that maintain protection to public health, safety, and welfare.

The WE•Stand Development Revised Timeline

Download WE•Stand Report on Proposals

Download WE•Stand Monograph

Download draft WE•Stand document

2017 WE•STAND COMMENTS – DEADLINE November 28, 2016

Regulations Governing Consensus Development of WE•Stand

Copyright Consent Form

Manual of Style

Water Demand Calculator

Peak Water Demand Study

To Download the Calculator

Questions?