

# *Calculator for Estimating Peak Water Demand in Residential Dwellings*

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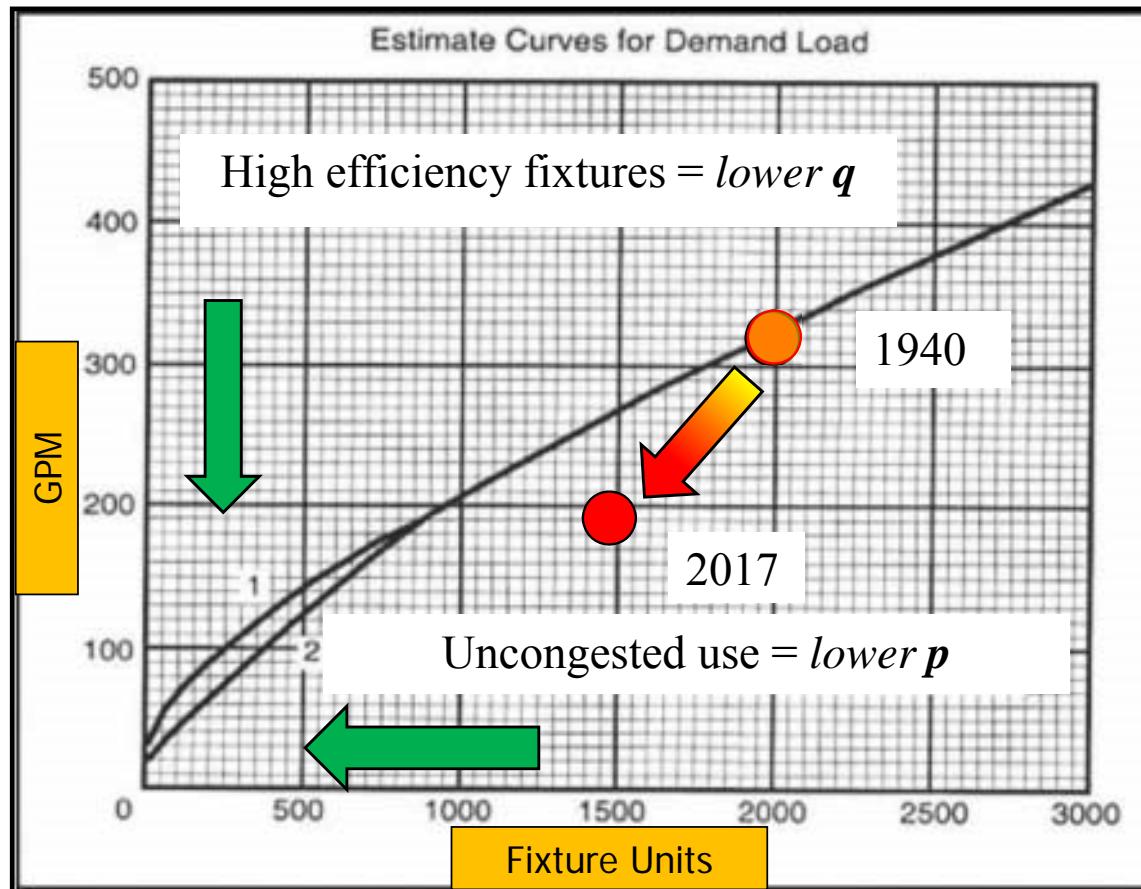
TIMOTHY WOLFE

JASON HEWITT

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2017 CIB W062 SYMPOSIUM

# The Hunter Problem



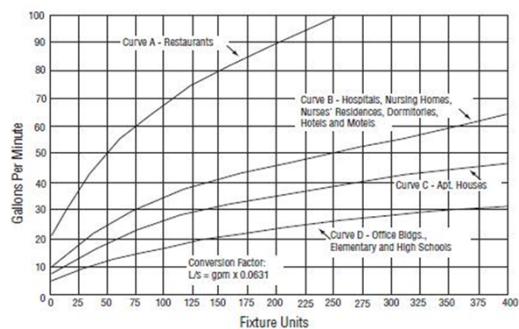
Today, **Hunter's curve** is often faulted for giving overly conservative designs....Why?

# Resolving the Hunter Problem

**Modifying The Hunter Method**



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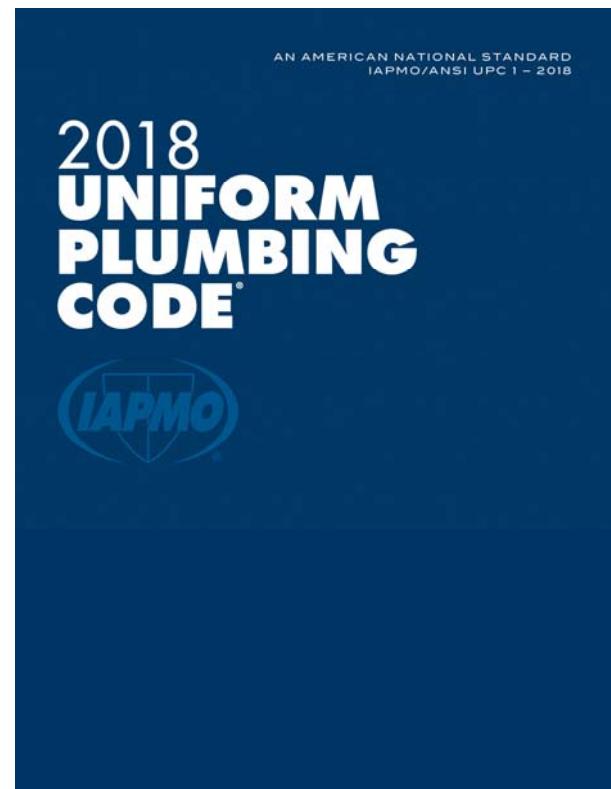
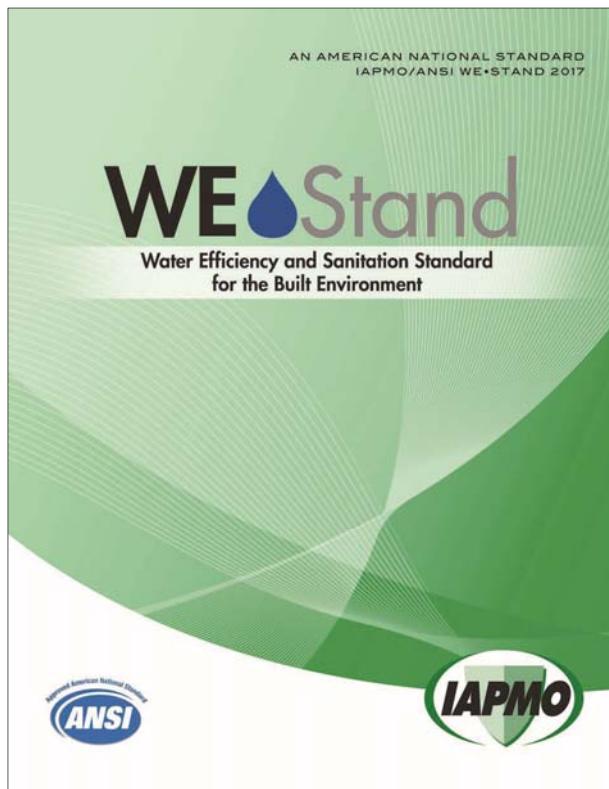
## A NEW LOOK AT DETERMINING WATER DEMAND IN BUILDINGS: ASPE DIRECT ANALYTICAL METHOD

Robert A. Wistort, PE, CPE  
[ASPE Research Founder]



# American National Standards

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# 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 ↑

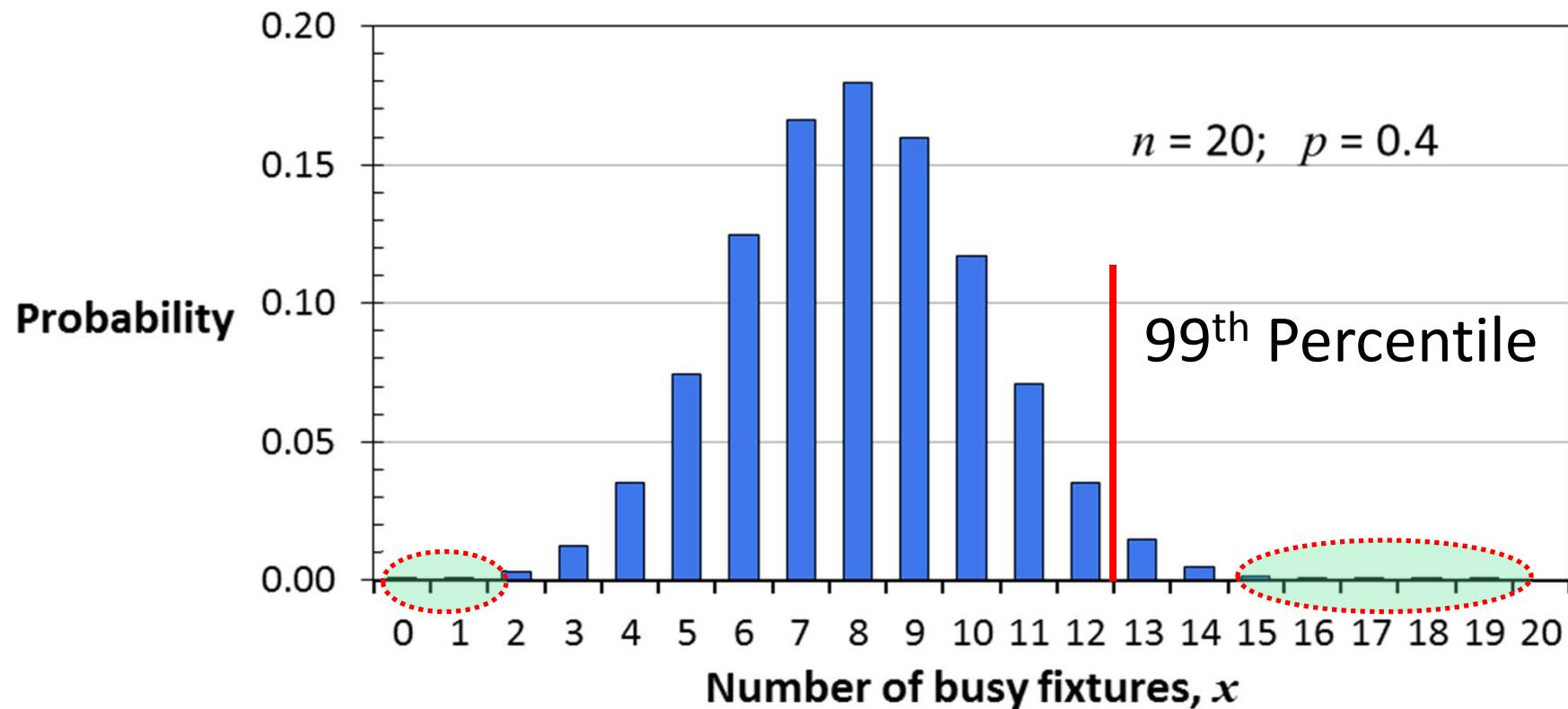
The image shows a Microsoft Word document window with a title bar containing 'Title Page', 'Key', 'DemandEstimate', and a small icon. The main content area displays a 'Basic Template' for a 'Water Demand Calculator'. This template consists of a table for listing fixtures, input fields for total fixtures and flow rate, and a button to run the calculator. A blue callout box with the text 'Basic Template' points to the fixture list table.

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# (PEAK) WATER USE MODEL

# Binomial Model

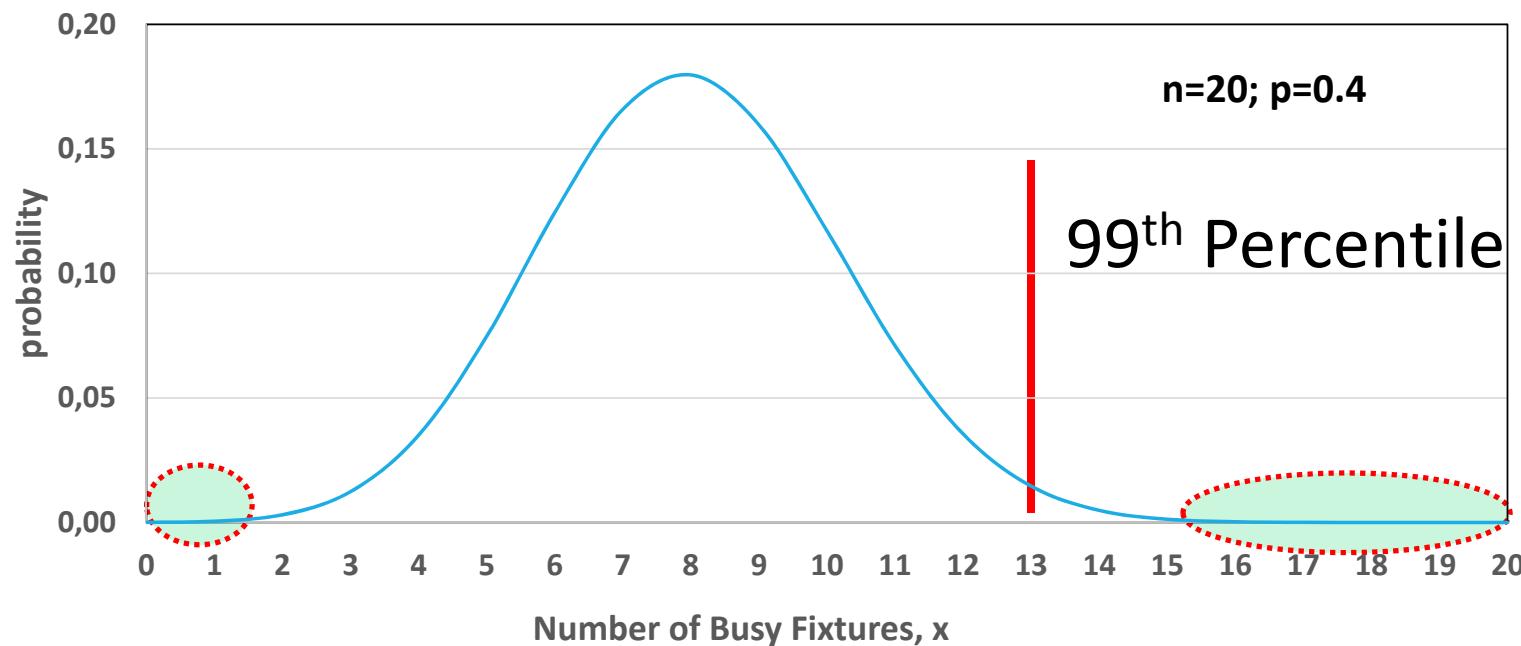
$$\Pr \left( \begin{array}{l} \text{exactly } x \text{ busy} \\ \text{out of } n \text{ fixtures} \end{array} \right) = \binom{n}{x} p^x (1-p)^{n-x}$$



# Normal Approximation Model

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



# [1] Wistort Model (1995)

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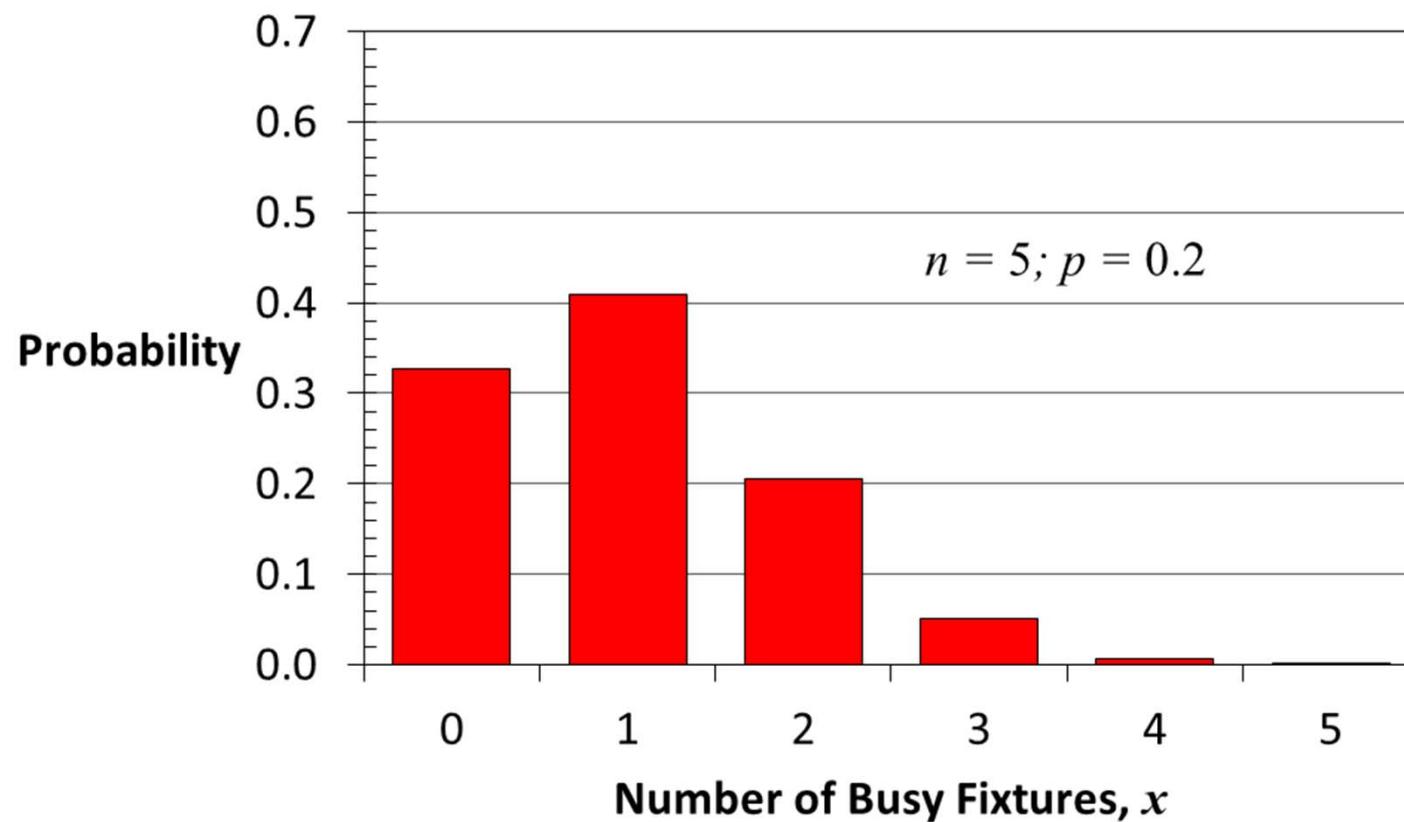
$$Q_{0.99} = \mu_q + (z_{0.99})\sigma_q$$

Adding the q-value

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

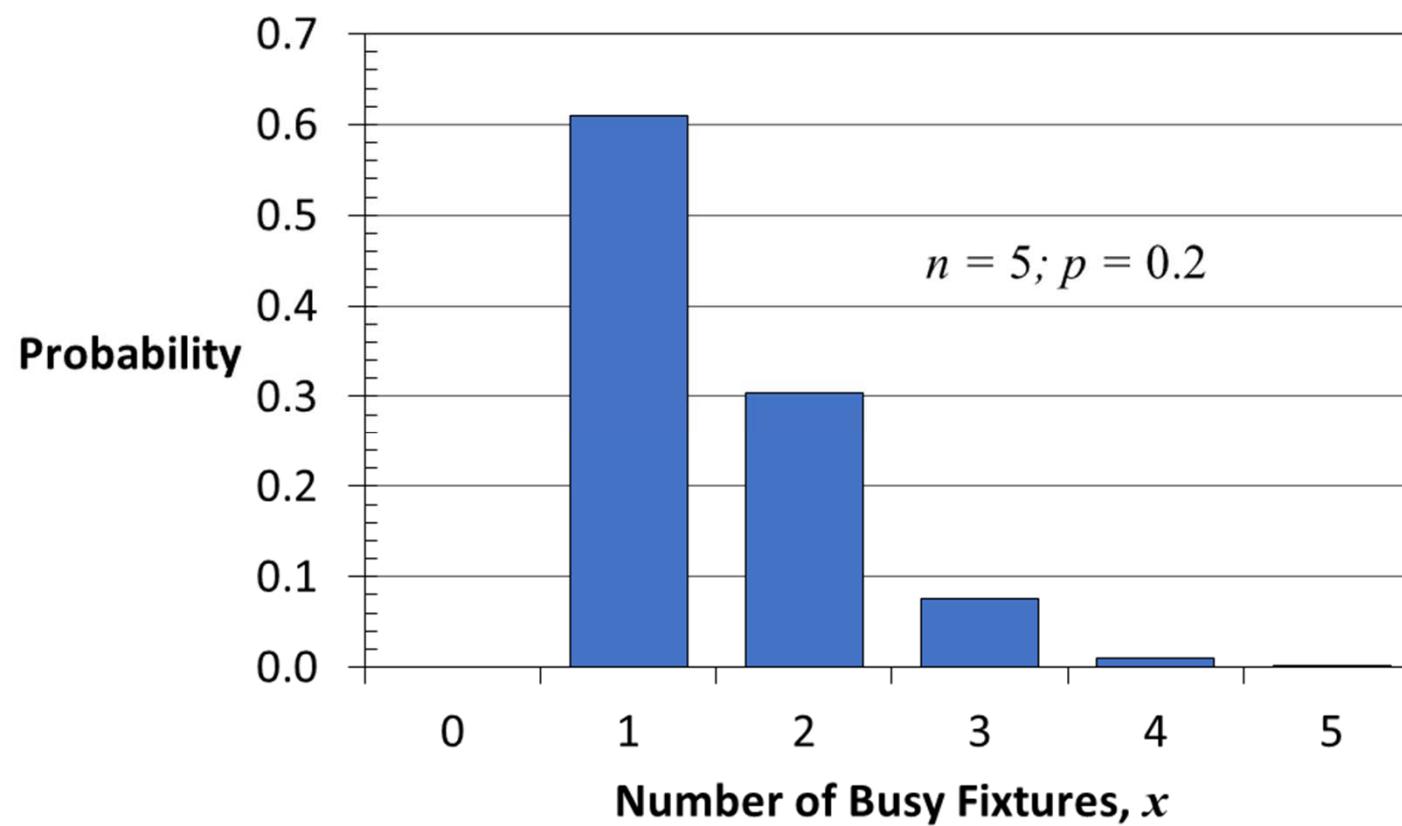
# Binomial Distribution (small building)

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# Zero Truncated Binomial Distribution

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## [2] Modified Wistort's Model

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

❖ Note:

❖  $P_0 = \prod_{k=1}^K (1-p_k)^{n_k}$  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

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[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Case	CW	DW	KF	LF	P <sub>CW</sub>	P <sub>DW</sub>	P <sub>KF</sub>	P <sub>LF</sub>	Q (gpm)	T.T. Probability	Q Ranked	B.T. Probability	B.T. CDF
1	o	o	o	o	0.945	0.995	0.980	0.980	0.0	0.9030401	0.0		0.000
2	•	o	o	o	0.055	0.995	0.980	0.980	3.5	0.0525579	1.3	0.046802	0.047
3	o	•	o	o	0.945	0.005	0.980	0.980	1.3	0.0045379	2.0	0.190072	0.237
4	o	o	•	o	0.945	0.995	0.020	0.980	2.2	0.0184294	2.2	0.190072	0.427
5	o	o	o	•	0.945	0.995	0.980	0.020	2.0	0.0184294	3.3	0.000955	0.428
6	•	•	o	o	0.055	0.005	0.980	0.980	4.8	0.0002641	3.5	0.542058	0.970
7	•	o	•	o	0.055	0.995	0.020	0.980	5.7	0.0010726	3.5	0.000955	0.971
8	•	o	o	•	0.055	0.995	0.980	0.020	5.5	0.0010726	4.2	0.003879	0.975
9	o	•	•	o	0.945	0.005	0.020	0.980	3.5	0.0000926	4.8	0.002724	0.978
10	o	•	o	•	0.945	0.005	0.980	0.020	3.3	0.0000926	5.5	0.011062	0.989
11	o	o	•	•	0.945	0.995	0.020	0.020	4.2	0.0003761	5.5	0.000019	0.989
12	•	•	•	o	0.055	0.005	0.020	0.980	7.0	0.0000054	5.7	0.011062	1.000
13	•	•	o	•	0.055	0.005	0.980	0.020	6.8	0.0000054	6.8	0.000056	1.000
14	•	o	•	•	0.055	0.995	0.020	0.020	7.7	0.0000219	7.0	0.000056	1.000
15	o	•	•	•	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	

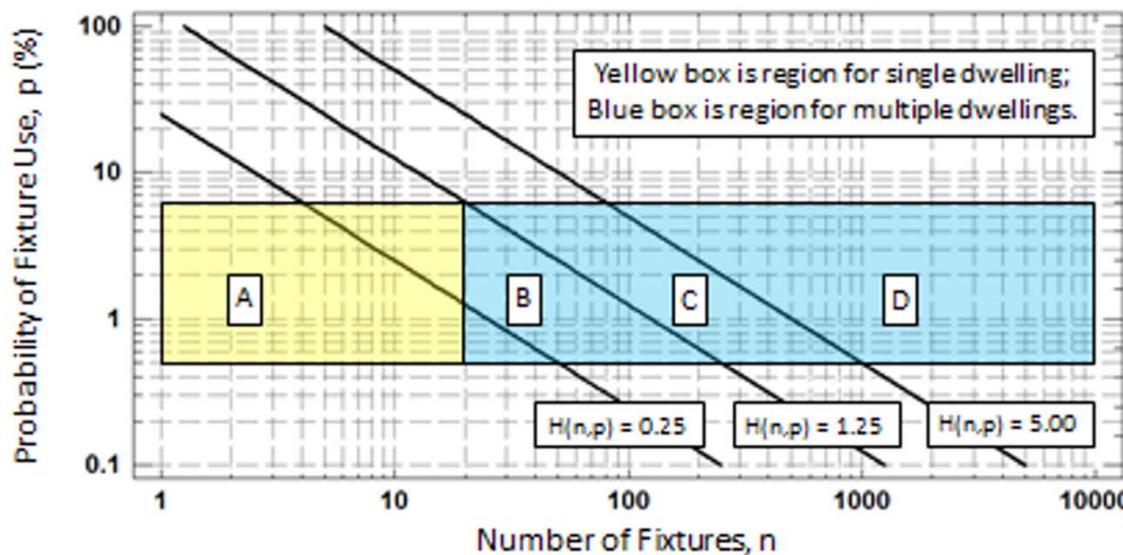
# [4] Q1+Q3

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Number of Fixtures	Number of Combinations	Fixture Demand (gpm)	Design Flow (giving 95 <sup>th</sup> to 99 <sup>th</sup> 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; $q_1+q_3$
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

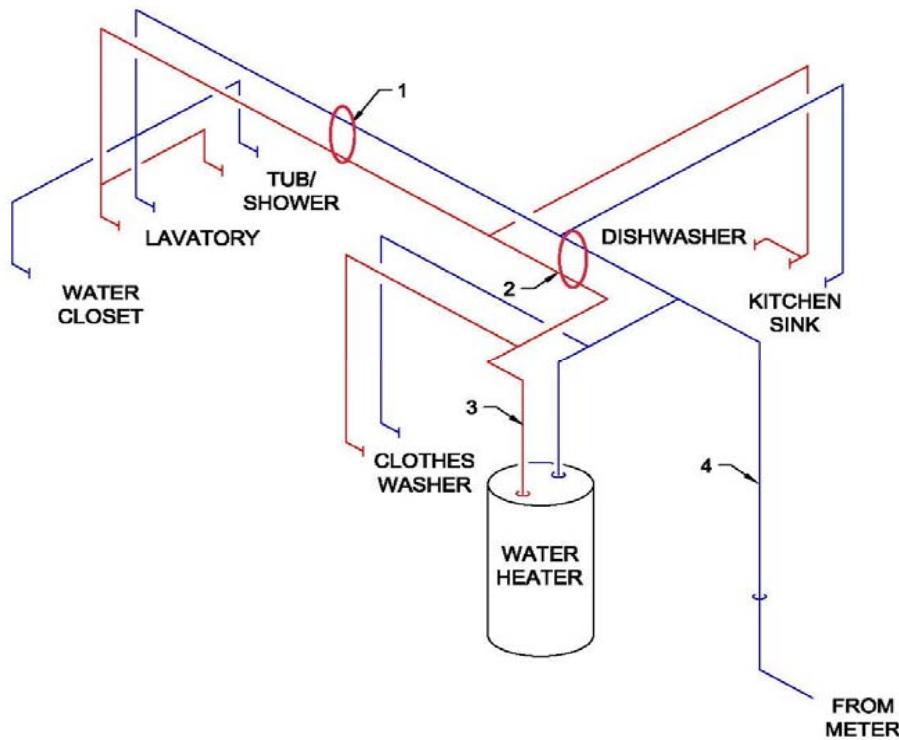


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# APPLICATION

# Small Residential Building Pipe Layout

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# Peak Flow Building Supply

	<b>[A] Fixture</b>	<b>[B] Enter Number of Fixtures</b>	<b>[C] Probability of Use (%)</b>	<b>[D] Enter Fixture Flow Rate (GPM)</b>	<b>[E] Maximum Recommended Fixture Flow Rate (GPM)</b>
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

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# 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/WESStand/Pages/DocumentInformation.aspx>

The screenshot shows the IAPMO website's navigation bar with various services like Product Certification, Product Testing, ISO Registrar, Code Development, and more. Below the bar, the breadcrumb path "IAPMO > WESStand > Document Information" is visible. A sidebar on the left lists "Document Information", "Technical Committee", "Articles/Community", and "Green Plumbing and Mechanical Code Supplement". The main content area is titled "Document Information" and discusses the 2017 WE•Stand standard. It includes links for the development timeline, report on proposals, monograph, draft document, comments deadline, regulations governing consensus development, copyright consent form, manual of style, water demand calculator, and peak water demand study.

IAPMO > WESStand > Document Information

**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.

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