This presentation premiered at WaterSmart Innovations

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The Implications of Reduced Flows in Building Drains

PERC Phase 2.0

Plumbing Efficiency Research Coalition

Alliance for Water Efficiency

ASPE American Society of Plumbing Engineers™

IAPMO®

ICC INTERNATIONAL CODE COUNCIL®

PHCC PLUMBING-HEATING-COOLING CONTRACTORS ASSOCIATION

pmi PLUMBING MANUFACTURERS INTERNATIONAL

What is PERC ?

- Formed in December of 2008
- MoU Signed at EPA HQ
- First Project: Drainline Transport
- MoU with AS-Flow in 2010

Why Drainline Transport?

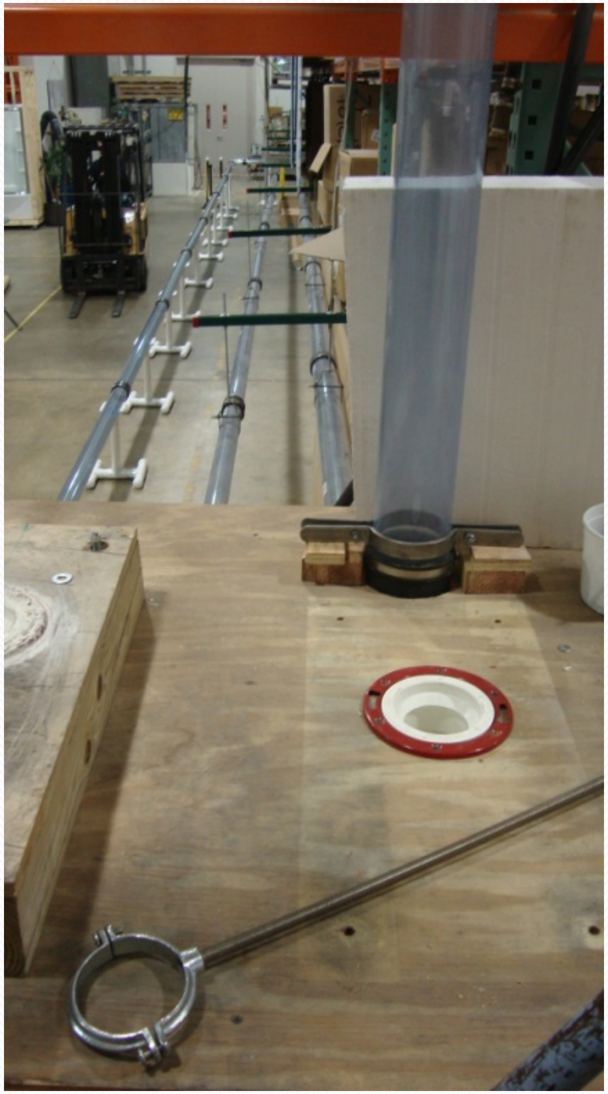
- Toilet consumption reduced 3.5 gpf → 1.6 gpf →1.28 gpf → ?
- Commercial installations
  - Isolated bathrooms
  - Long horizontal run building drains
  - Non-water consuming urinals, ultra low flow faucets (0.5 gpm)
  - Proliferation of other water efficient technologies; medical, food service, industrial and commercial processes
  - Toilets increasingly stressed
- Domestic installations
  - Reduced flow showerheads and appliances
  - Graywater reuse systems – long term potential to eliminate long duration flows

The PERC Approach

- PERC Design of Experiment
  - The "Real World": Too Variable to Duplicate / Characterize
  - Need to Understand What's Really Important
  - Build a Perfect Drainline
- The Test Apparatus
  - 4" Clear PVC, (3" Clear PVC added in Phase 2)
  - 135 feet long (~41 M)
  - Slope Adjustable

The PERC Approach

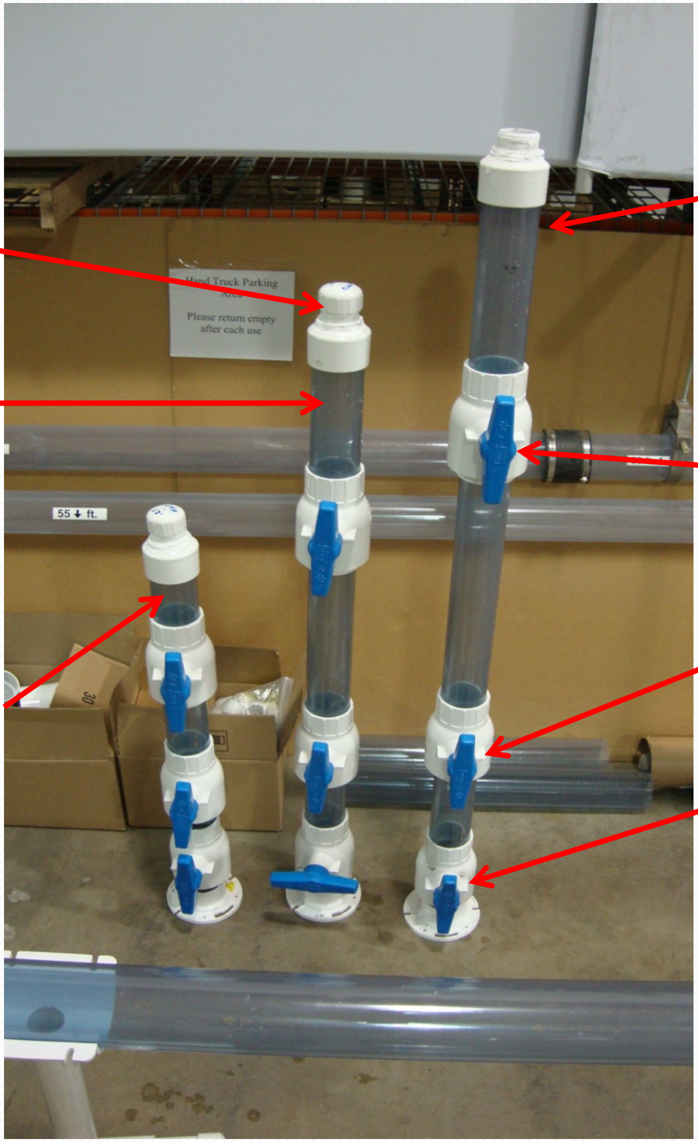
Test Apparatus viewed from Flush Stand



Two 90° Wide Sweep Bends at Far End

The PERC Approach

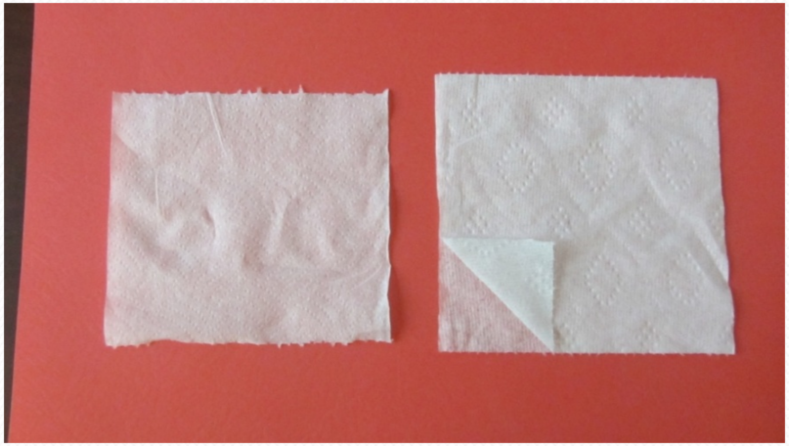
- Surge Injectors
  - More Accurate than Toilets
  - Control Flush Rate (2)
    - Threaded cap orifice
    - 2500 ml/sec
    - 3500 ml/sec
  - Control % Trailing Water (2)
    - 75%
    - 25%
  - Test Volumes (3)
    - 1.6, 1.28, 0.8 gpf
    - (6.0, 4.8, 3.0 Lpf)



Test Media

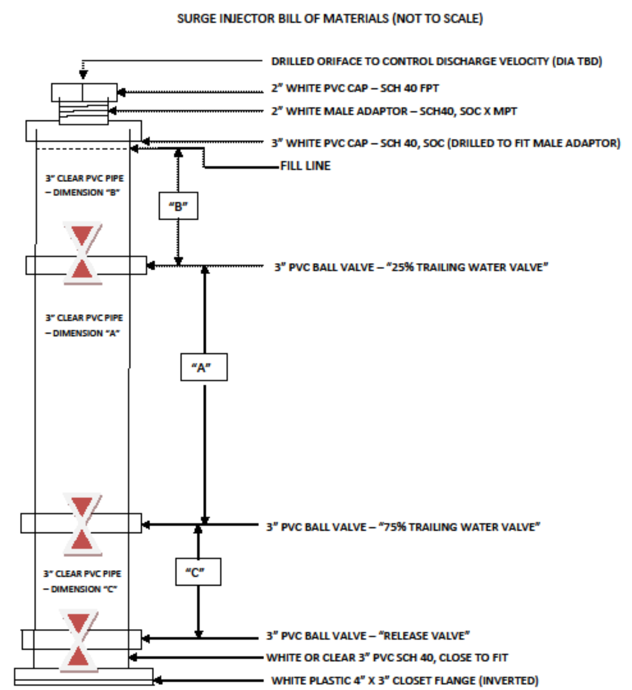
- Uncased "MaP" Test Media
  - Proven "Realistic" in Toilet Testing
  - Deformable, "breaks down"

- Toilet Paper
  - Two common US Brands
    - Low Tensile Strength
    - High Tensile Strength



Test Media – How much to use?

- Assumptions:
  - Commercial Office Building
    - Non-water consuming urinals and 0.5 gpm faucets
  - All males use urinals for liquid waste
  - Males: use toilet 33.3 % of the time for solid waste, urinals 66.7 % of the time.
  - Females: use the toilet 100% of the time, 33.3 percent for solid waste, 66.7 percent of the time for liquid waste and toilet paper only.



SURGE INJECTORS (3)	~1.6 GPF / 6.0 LPF	~1.28 GPF / 4.8 LPF	~0.8 GPF / 3.0 LPF
PART "A" (INCHES)	25.2	20.2	12.6
PART "B" (INCHES)	12.6	10.1	6.3
PART "C" (INCHES)	12.6	10.1	6.3

Illustration: Schematic – Elevation view of Surge Injector

Test Media – How much to use?

- Assumptions (continued):
- 50 percent of the flushes: solid waste and toilet paper
- 50 percent having liquid waste and paper only.
- 100 percent of the flushes contain toilet paper.
- Solid waste loadings vary randomly and evenly @ 300, 200 and 100 grams
- *Note: Amounts of solid waste are consistent with past medical studies*

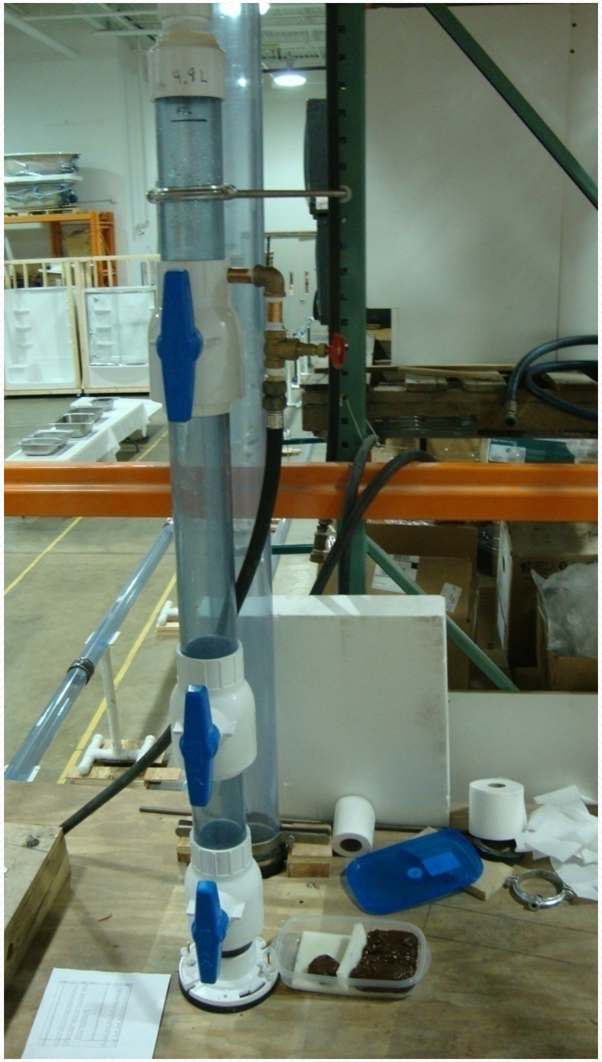


Photo: Surge Injector installed on apparatus flush stand

Test Media – How much to use?

- Toilet Paper Amounts
  - Different tensile strengths – different use amounts
  - Double the amount of low tensile strength paper to normalize

The PERC Test Plan

- The Designed Experiment (DOE)
  - What is a designed experiment?
    - Groups test variables
    - Assigns random test sequence
    - Determine the relative significance of the test variables
    - Uses pre-determined statistical model to analyze data
    - Able to differentiate between "signal" (impact of the variables on the system) and "noise" (random occurrences in the system not attributed to the test variables)
  - Analysis of Variance "ANOVA"
    - Statistical model best suited to rank test variables
    - Significance determined by low "P-value"

The PERC Test Plan – Phase 1

The test variables

- ✓ *1 Diameter: 4-inch / ~100* mm
- ✓ *2 Pitches: 1.00%; 2.00%*
- ✓ *3 Flush Volumes: 6.0/1.6; 4.8/1.3; 3.0/0.8 (Lpf / gpf)*
- ✓ *2 Flush Rates: 3500; 2500 (ml/sec –peak flow)*
- ✓ *2 Percent Trailing Water Levels: 75%; 25%*
- ✓ *2 Toilet Paper Tensile Strengths: High; Low*

The PERC Test Plan

- Execution of the DOE
  - Test Sequence
    - 100 cycle ***Test Runs*** that capture the test variables
    - Random test sequence determined by computer
  - How do we measure?
  - ***Flushes to Out (FO)***: *the number of flushes it took for an individual injection of test media to run the 135 foot Test Apparatus course of in a Test Run*
  - ***Average Flushes to Out (AFO):*** *the average Flushes to Out value in a Test Run after 100 flush cycles*
  - **IMPORTANT** - The AFO scores were used to calculate all results

Test Procedure

- Example: Injection with 75 percent trailing water
  1. Remove threaded cap with drilled orifice at the top of the Surge Injector.
  2. Fill Surge Injector with water until water flows past the height of the 75 percent ball valve.
  3. Close the 75 percent ball valve and place the required amount of test media and toilet paper into the injector.
  4. Fill the surge injector to the marked ‘fill line’.
  5. Replace the threaded cap on the Surge Injector
  6. Open the 75 percent trailing water valve and immediately open the discharge valve allowing water and test media to flow into the test apparatus.
  7. Record (on the data sheet) the distance that the test media travels on the first flush.
  8. Repeat steps 1 through 7 as per the Test Plan.
  9. Record the distance that the test media travels on each subsequent flush until the test media exits the apparatus.

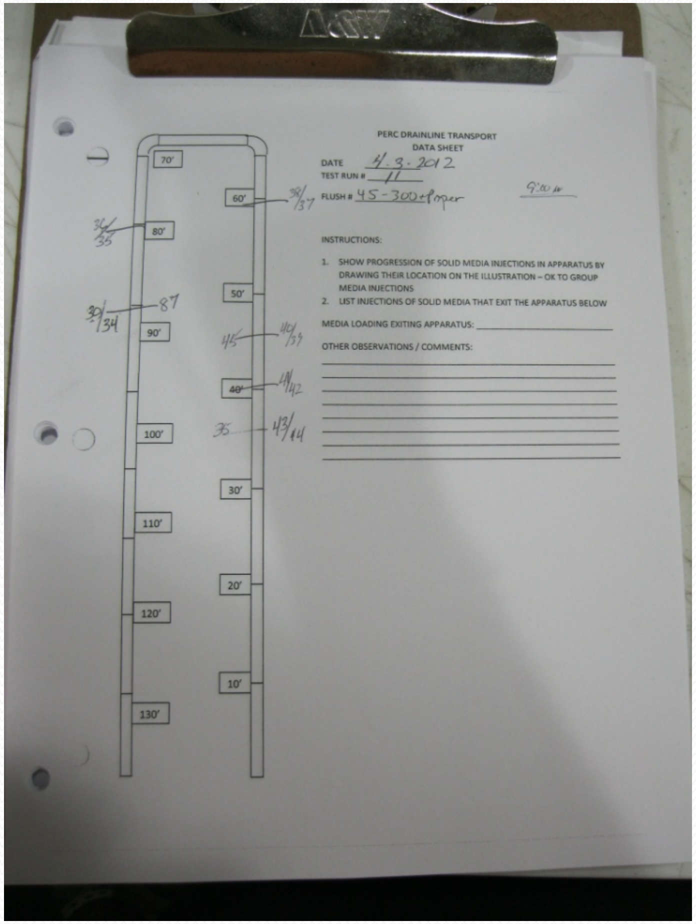
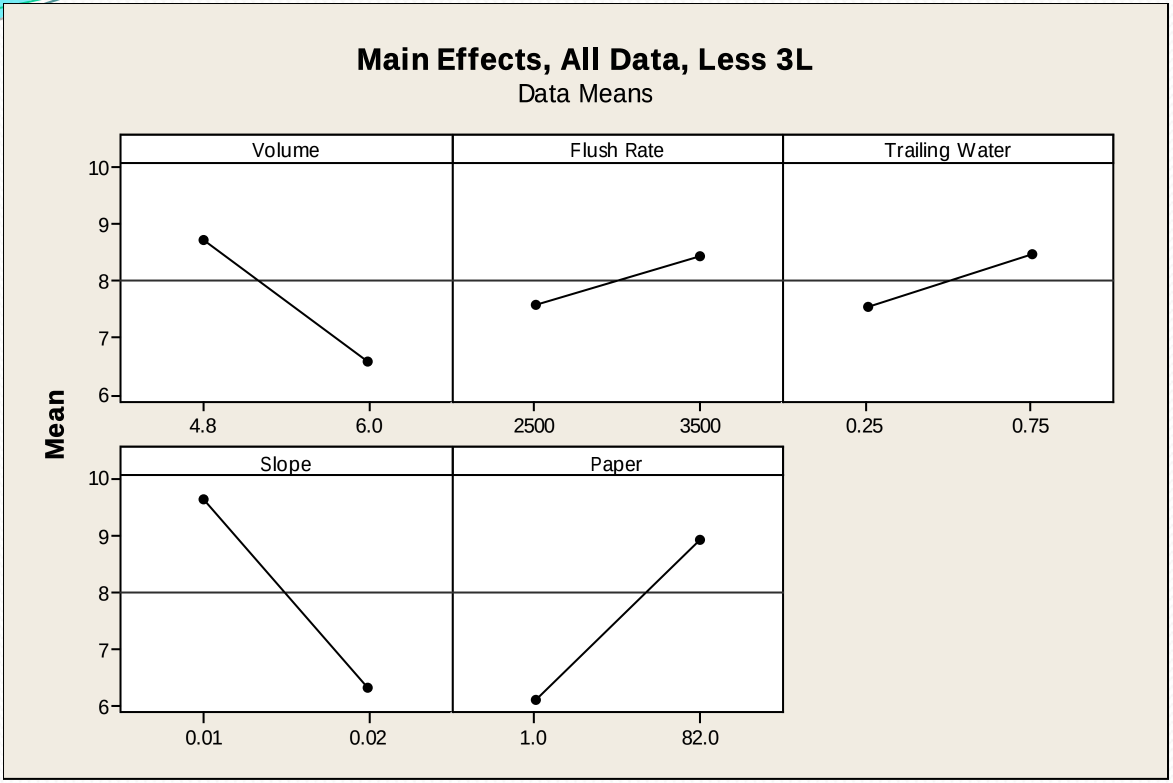


Photo: Completed data sheet

Phase 1 Findings



Variable	P Value
Volume	0.000*
Flush Rate	0.216
Trailing Water	0.185
Slope	0.000*
Paper	0.000*

- P-values below 0.05 indicate significance of the test variable
- R-Sq = 81.61percent

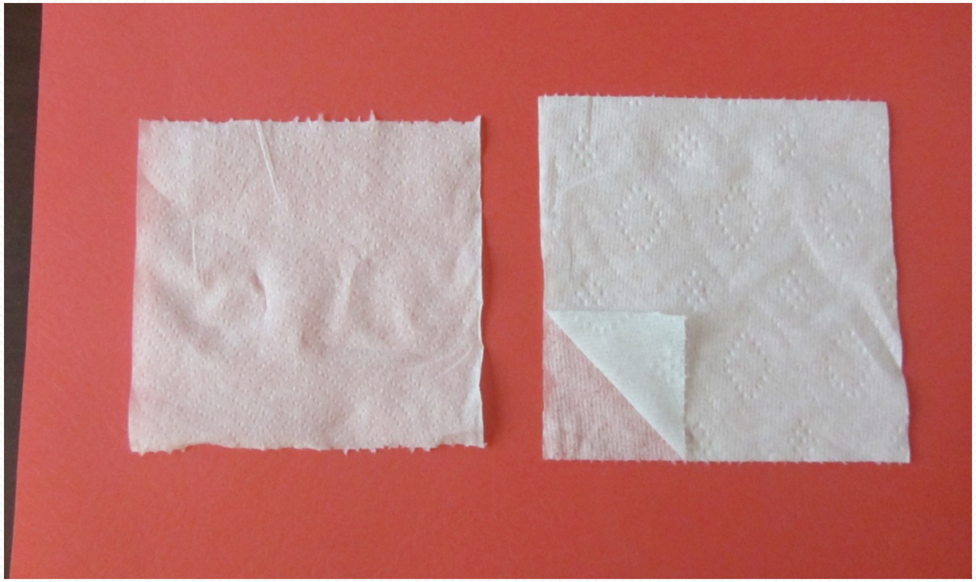
Level	Volume	Flush Rate	%Trailing Water	Slope	Paper
1	8.710	7.567	7.535	9.671	6.104
2	6.554	8.416	8.448	6.311	8.935
Delta	2.156	0.849	0.913	3.360	2.831
Rank	**3**	**5**	**4**	**1**	**2**

Phase 1 Additional Findings

- 0.8 gpf / 3.0 Lpf Toilets: Chaotic conditions resulted in the test apparatus at this discharge volume. Further study needed on commercial installations w/ long horizontal runs to sewer and little or no additional long duration flows.
- 1.28 gpf / 4.8 Lpf HET's: The behavior of the Test Apparatus at this volume level indicates satisfactory performance at this discharge volume.
- Impact of Toilet Flush Characteristics: *Not significant factors in drain line performance in this study* **(further study required)**.

Phase 1 Additional Findings

- Significance of Toilet Paper: *Toilet paper characteristics have the potential to drastically impact DLT distances*
  - Strong inverse correlation between wet tensile strength and DLT distances
  - Caution: Potential demonstrated in the PERC DOE characterizes the <u>extremes</u> of toilet paper influence
  - Easy test to determine relative wet tensile strength developed
  - Possible low-cost solution to mitigate DLT related blockages



PERC Phase 2.0

Primary PERC Phase 2 Focus Areas

- **Pipe Size Reduction** – Topic of debate at code hearings:
  - Will reduced pipe size improve drainline transport distances?
  - 3-inch test apparatus used in addition to the 4-inch diameter apparatus employed in Phase 1 to determine impact
- **Additional Flush Volume Level –**
  - Phase 1: behavioral shift and a chaotic drainline performance condition at 3.0 Lpf / 0.8 gpf consumption level.
  - Phase 2: investigate drainline transport performance at the 3.8 Lpf (1.0 gpf) volume level.
  - Many U.S. manufacturers already producing toilets that flush at this consumption level for both commercial and residential applications.

PERC Phase 2 - Deliverables

- **Deliverable 1 – Pipe Size Reduction**
  - Show how a commonly suggested pipe size reduction (going from 4-inch diameter pipe to 3-inch pipe) will impact drainline transport in a long horizontal run.
  - Rank the significance of reducing pipe diameter to flush consumption level reductions, slope, toilet paper wet tensile strength, and toilet discharge characteristics of flush rate and percent trailing water.
  - Provide needed data on implications of pipe size reductions
  - Advise future code considerations of pipe sizing requirements

PERC Phase 2 - Deliverables

- **Deliverable 2 – Added 1.0 gpf discharge level**
  - Provide a better understanding of how the drainline performs at the critical consumption level between 4.8 Lpf (1.28 gpf) and 3.0 Lpf (0.8 gpf)
  - Provide insight into the "tipping point" flush volume level, below which chronic blockage problems are more likely to occur.

PERC Phase 2.0

- Same test apparatus, same surge injector design, same test media, same test methods, same data collection, same data analysis
  - Added:
    - 3” Pipe Diameter
    - 3.8 Lpf / 1.0 gpf surge injector
  - Phase 1 = 40 test runs
  - Phase 2 = 88 test runs
  - Total = 128 test runs, 12,800 individual “flushes”

Additional PERC Phase 2 Focus Areas

- **Toilet Paper Characteristics**
  - Phase 1 indicated a very strong significance for the wet tensile strength of toilet paper to impact drainline transport performance
  - We cannot assume the results achieved related to toilet paper when using the 3-inch diameter pipe.
- **Toilet Flush Characteristics**
  - Phase 1 results indicated non-significance of the toilet flush characteristics Percent Trailing Water and Flush Rate
  - Before these characteristics can be dismissed, results must be confirmed in Phase 2

The PERC Test Plan – Phase 1

The test variables

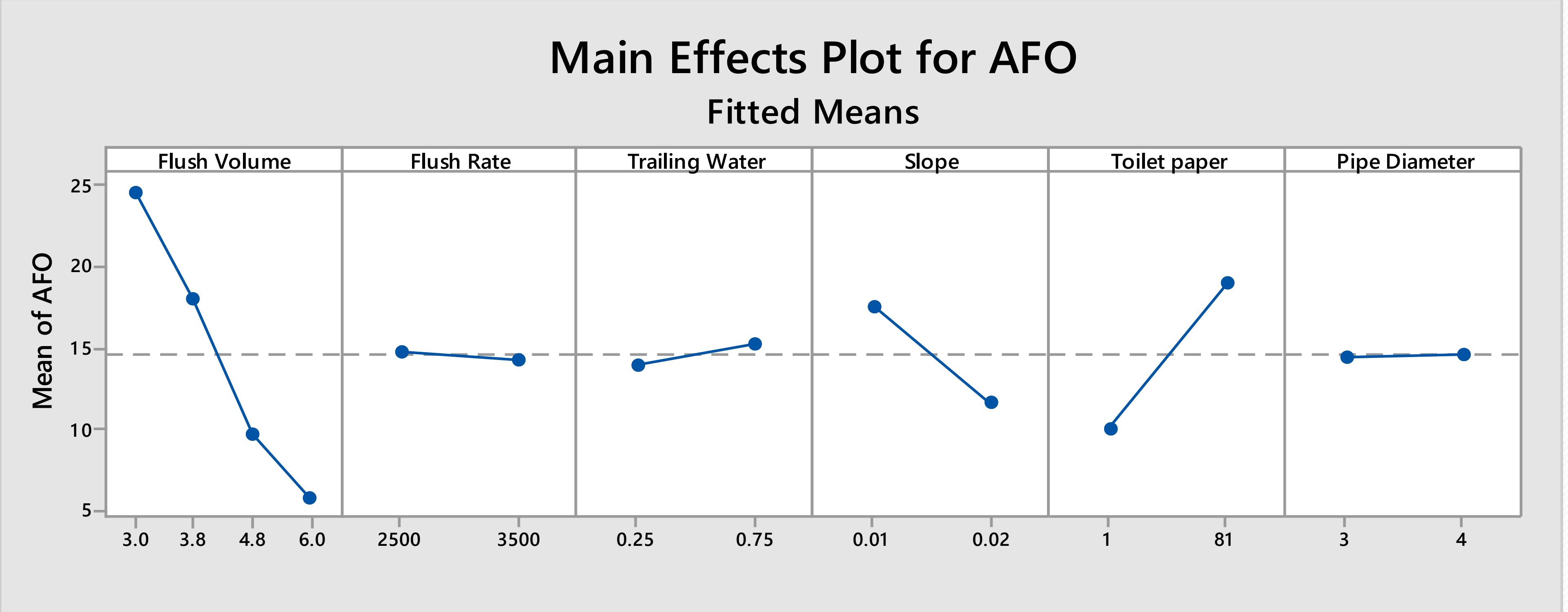
- ✓ *1 Diameter: 4-inch / ~100* mm
- ✓ *2 Pitches: 1.00%; 2.00%*
- ✓ *3 Flush Volumes: 6.0/1.6; 4.8/1.3; 3.0/0.8 (Lpf / gpf)*
- ✓ *2 Flush Rates: 3500; 2500 (ml/sec –peak flow)*
- ✓ *2 Percent Trailing Water Levels: 75%; 25%*
- ✓ *2 Toilet Paper Tensile Strengths: High; Low*

The PERC Test Plan – Phase 2

The test variables

- 1 *Diameter:* *4-inch / ~100* mm; **3-inch / ~75 mm**
- 2 *Pitches: 1.00%; 2.00%*
- 3 *Flush Volumes: 6.0/1.6; 4.8/1.3;* **3.8 / 1.0**; *3.0/0.8 (Lpf / gpf)*
- 2 *Flush Rates: 3500; 2500 (ml/sec –peak flow)*
- 2 *Percent Trailing Water Levels: 75%; 25%*
- 2 *Toilet Paper Tensile Strengths: High; Low*

Phase 2 Findings



Variable	P Value
Volume	0.000*
Flush Rate	
Trailing Water	
Slope	0.000*
Paper	0.000*
Pipe Diameter	0.533

P-values below 0.05 indicate significance

R-Sq = 84.6 percent

Response Table for Means

Volume: 4.8 Lpf (1.28 gpf) to 6.0 Lpf (1.6 gpf)

Level	Volume	Flush Rate	%Trailing Water	Slope	Paper	Pipe Diameter
1 (4.8 Lpf)	9.56	14.77	13.93	17.45	9.94	14.44
2 (6.0 Lpf)	5.75	14.28	15.11	11.59	19.10	14.60
Delta	3.81	0.49	1.18	5.86	9.16	0.16
Significance Rank	**3**	**5**	**4**	**2**	**1**	**6**

Response Table for Means

Volume: 3.8 Lpf (1.0 gpf) to 4.8 Lpf (1.28 gpf)

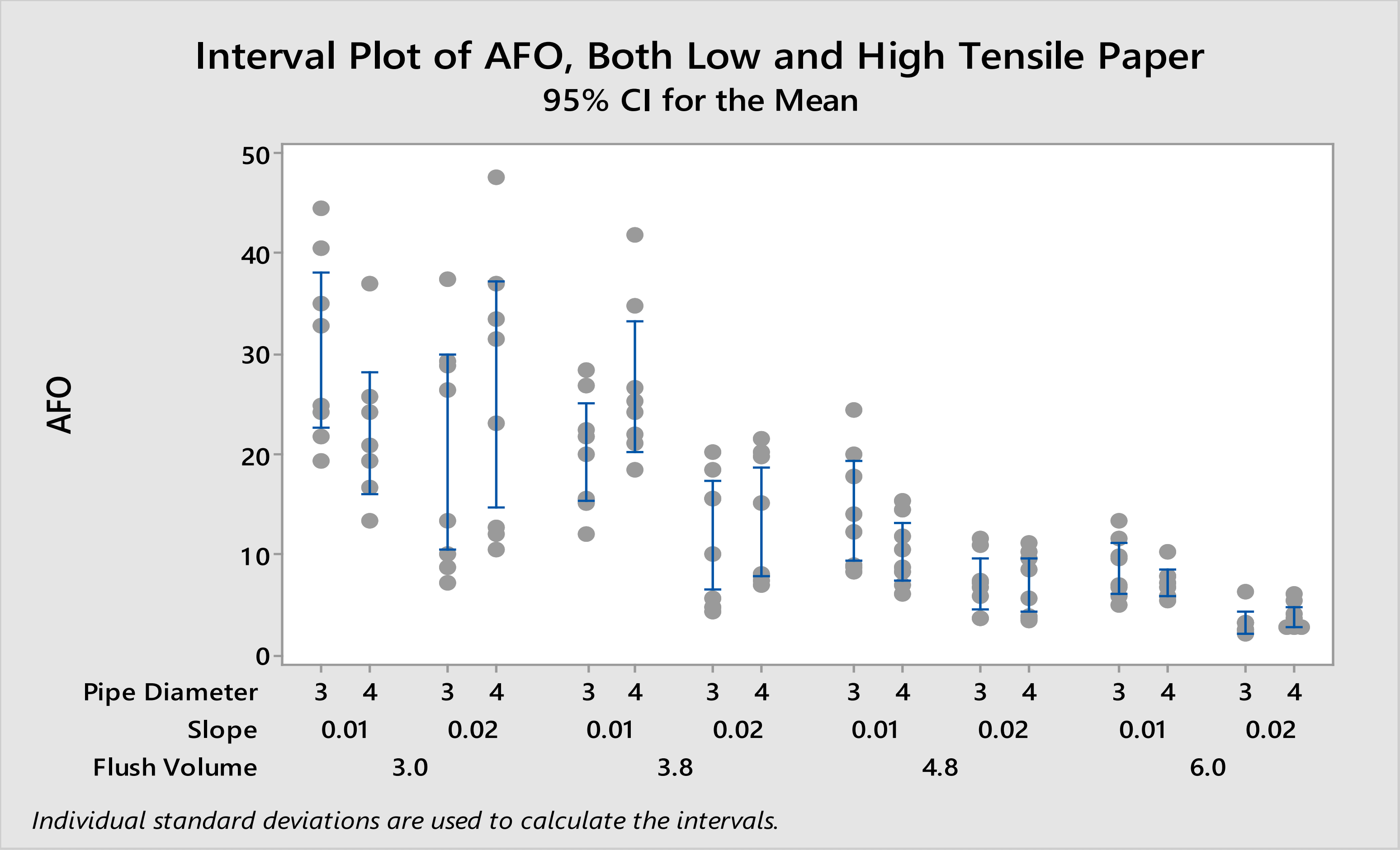
Level	Volume	Flush Rate	%Trailing Water	Slope	Paper	Pipe Diameter
1 (3.8 Lpf)	18.11	14.77	13.93	17.45	9.94	14.44
2 (4.8 Lpf)	9.56	14.28	15.11	11.59	19.10	14.60
Delta	8.55	0.49	1.18	5.86	9.16	0.16
Significance Rank	**2**	**5**	**4**	**3**	**1**	**6**

Response Table for Means

Volume: 3.0 Lpf (0.8 gpf) to 3.8 Lpf (1.0 gpf)

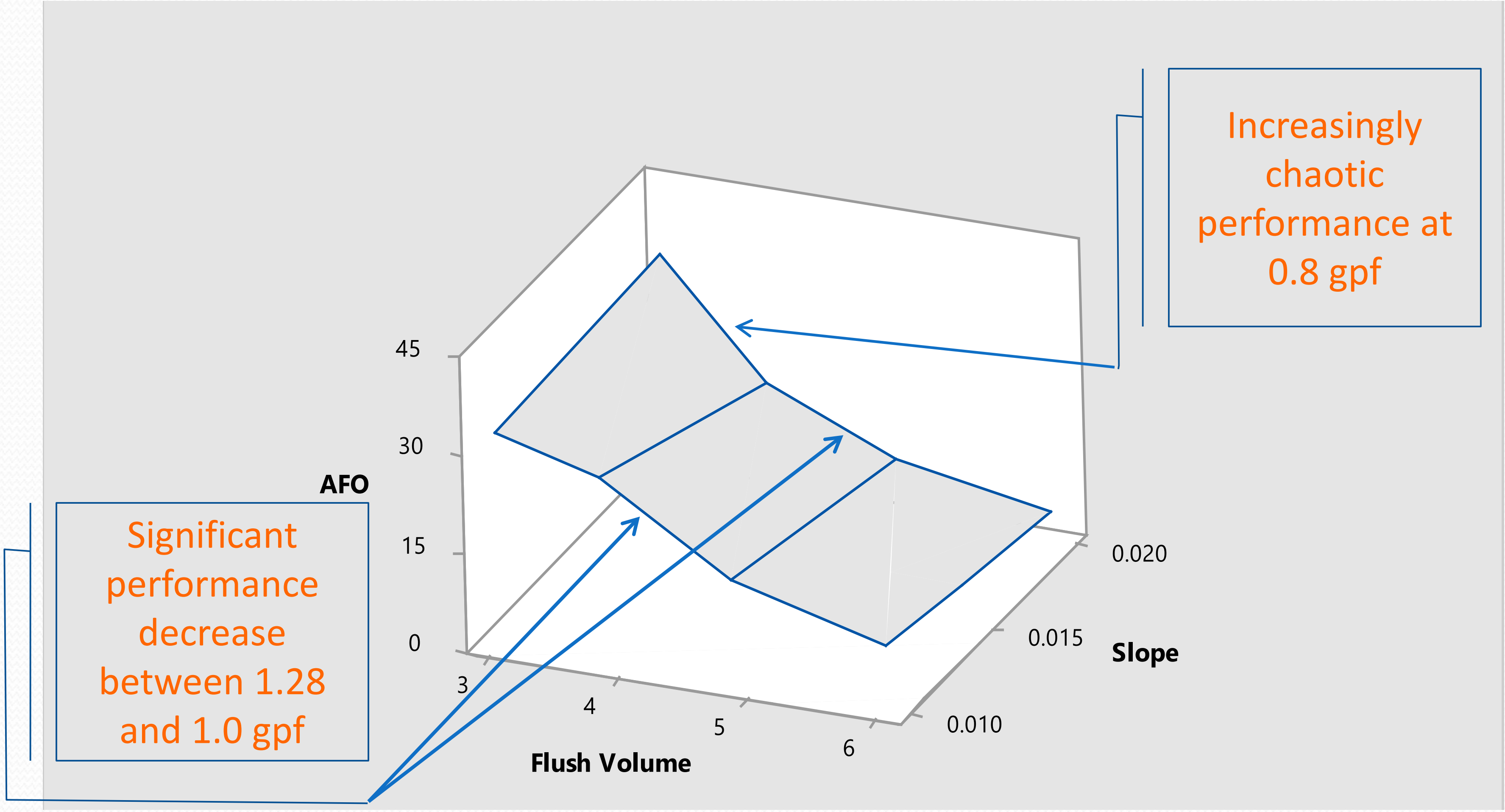
Level	Volume	Flush Rate	%Trailing Water	Slope	Paper	Pipe Diameter
1 (3.0 Lpf)	24.68	14.77	13.93	17.45	9.94	14.44
2 (3.8 Lpf)	18.11	14.28	15.11	11.59	19.10	14.60
Delta	6.57	0.49	1.18	5.86	9.16	0.16
Significance Rank	**2**	**5**	**4**	**3**	**1**	**6**

PERC 2 Finding: Pipe Diameter – Deliverable 1

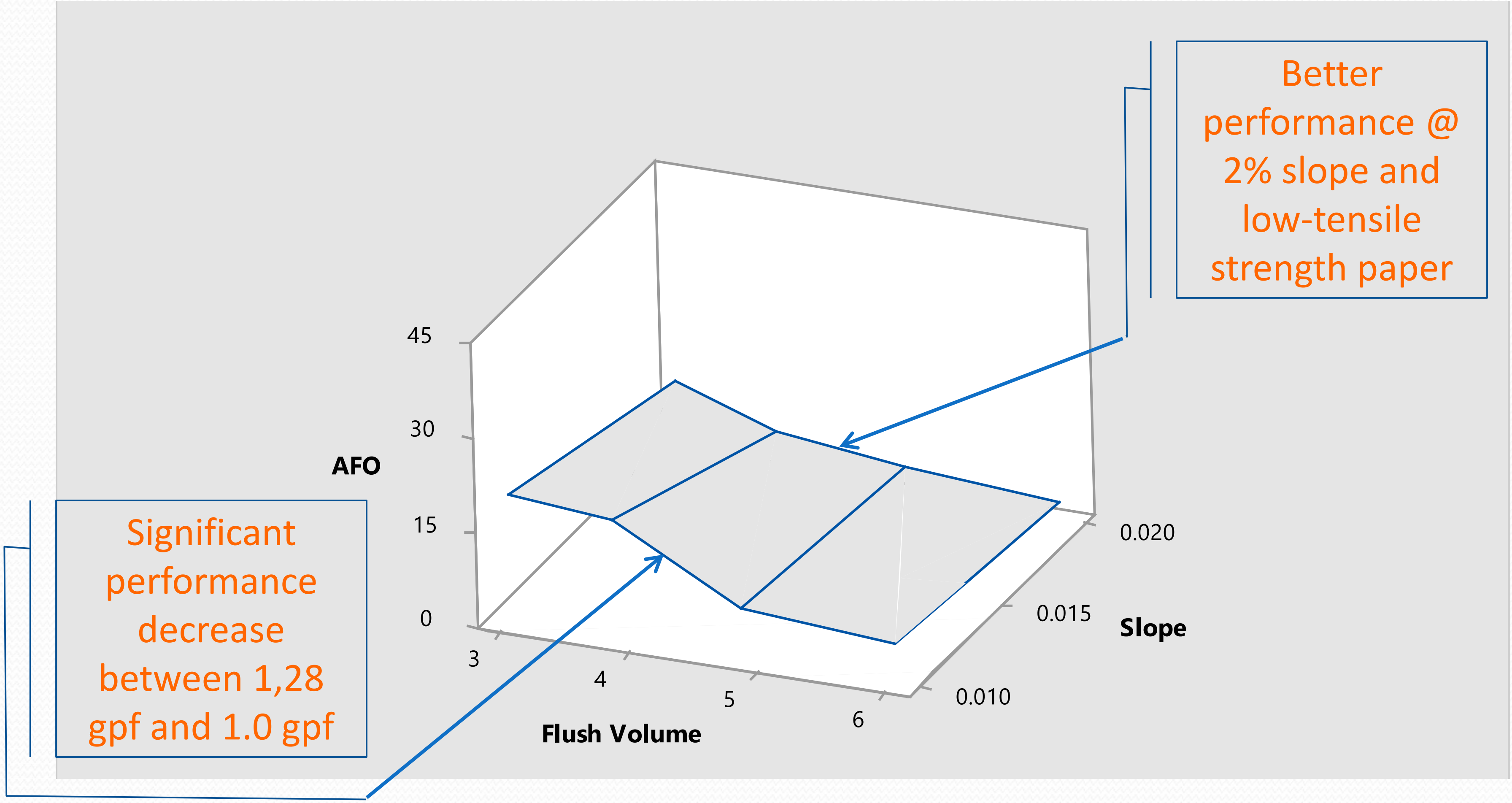


Pipe diameter reduction does <u>not</u> reliably improve drainline transport in long building drains.

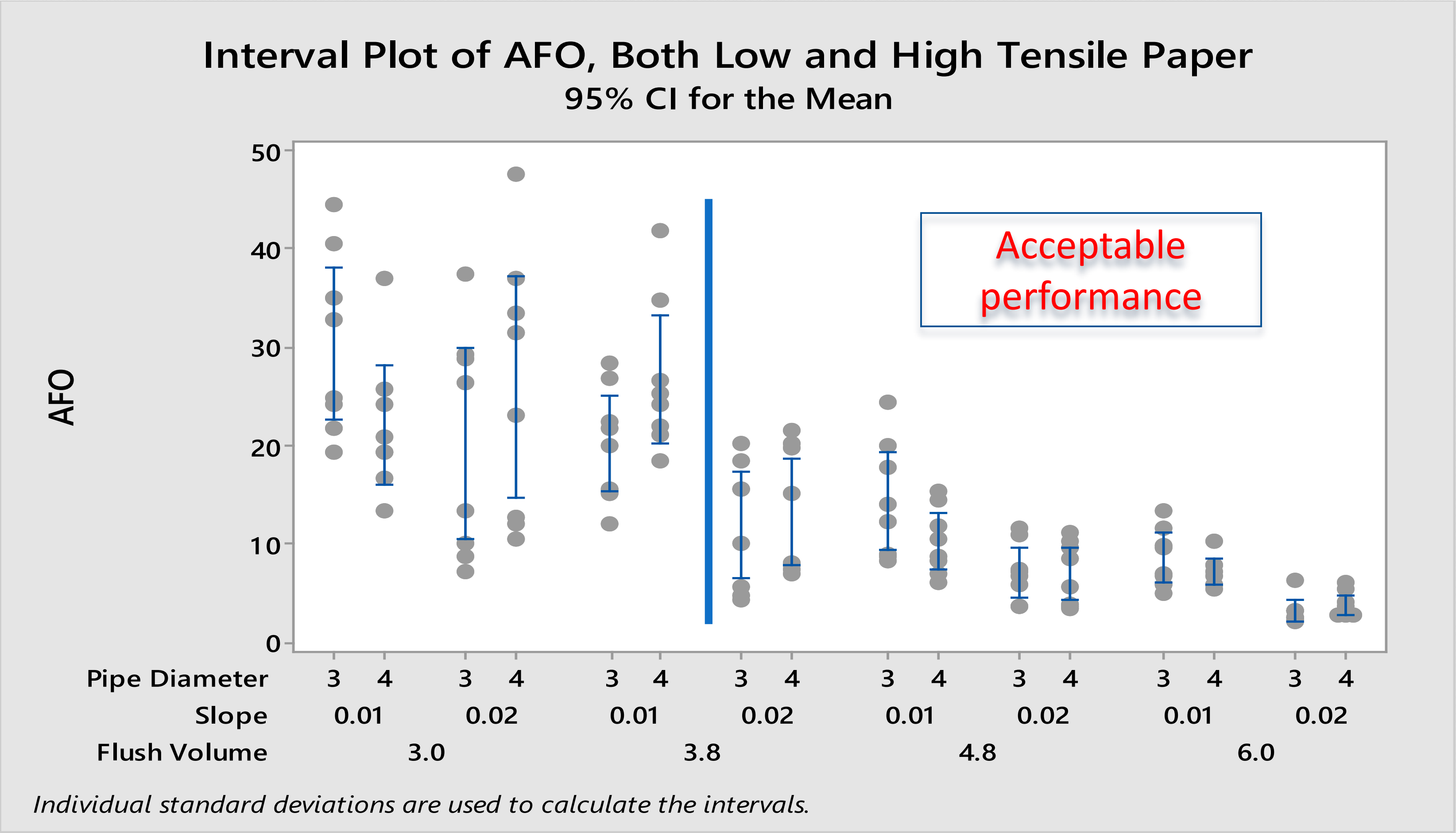
Surface Plot for AFO, High Tensile Strength Paper Data Only



Surface Plot for AFO, Low Tensile Strength Paper Data Only



PERC 2 Finding: The "Tipping Point" – Deliverable #2



The tipping point lies <u>within</u> the 1.0 gpf data set.
PERC does not recommend 1.0 gpf in long drains.

Phase 2 Additional Findings

- Confirmed: Significance of Toilet Paper: *Toilet paper characteristics have the potential to drastically impact DLT distances*
  - Toilet paper wet-tensile strength was the #1 significant variable in the combined PERC 1 and PERC 2 studies
- Confirmed: Satisfactory performance of 4.8 Lpf / 1.28 gpf HETs
- Confirmed: The non-significance of toilet attributes in long drainlines

What's Next?

- PERC 2.1 – Report to publish in early 2016
  - PERC will conduct additional testing using Phase 2 funds
- 2 Focus Areas
  - Impact of dual flush discharge patterns on DLT
    - Does a dual flush toilet really provide the same DLT as a single flush toilet?
    - What happens as flush volumes are reduced?
  - Impact of slope deviations on DLT
    - Do slope deviations manifest more severely as flush volumes are reduced?
- Stay tuned!

Recognition of Phase 2 Contributors

American Standard

- Without American Standard Brands contributions, this study would not have been possible
  - Allowing PERC to conduct study at Product Development Center in NJ
  - Allowing access by PERC Personnel
  - Expanding their DLT Test Apparatus to PERC specifications
  - In-kind Contributions, $ saving labor
- Mr. C.J. Lagan – Senior Manager of Testing and Compliance - Many hours of work
  - Assistance in obtaining experienced technicians
  - Assistance with the DOE development and data analysis
  - Day to day supervision of PERC Technicians

Recognition of Phase 2 Contributors

East Bay Municipal Utility District

ASHRAE

FluidMaster

The IAPMO Group

Kohler Company

Metropolitan Water District of Southern California

Natural Resources Defense Council

Region of Peel, Ontario, Canada

TOTO USA, Inc.

The United Association

Recognition of Phase 2 Contributors

City of Calgary, Alberta, Canada
Cast Iron Soil Pipe Institute
Plastic Pipe and Fittings Association

San Francisco Public Utilities Commission

Seattle Public Utilities
Delta Faucet Company

Indian Plumbing Association

Southern Nevada Water Authority

World Plumbing Council

Portland Water Bureau

Gauley Associates, Ltd.

Vitra, USA

THANKS FOR YOUR KIND ATTENTION

QUESTIONS?

Plumbing Efficiency Research Coalition

The PERC Technical Committee:
Milt Burgess, P.E., ASPE
John Koeller, P.E., AWE
Pete DeMarco, IAPMO / PERC Technical Director
Lee Clifton, ICC
Chuck White - PHCC
Matt Sigler, PMI

The PERC Executive Committee:
Billy Smith, ASPE
Mary Ann Dickinson, AWE
Pete DeMarco, IAPMO
Lee Clifton, ICC
Dr. Gerry Kennedy- PHCC
Barbara Higgens, PMI

Please submit questions to: pete.demarco@iapmo.org