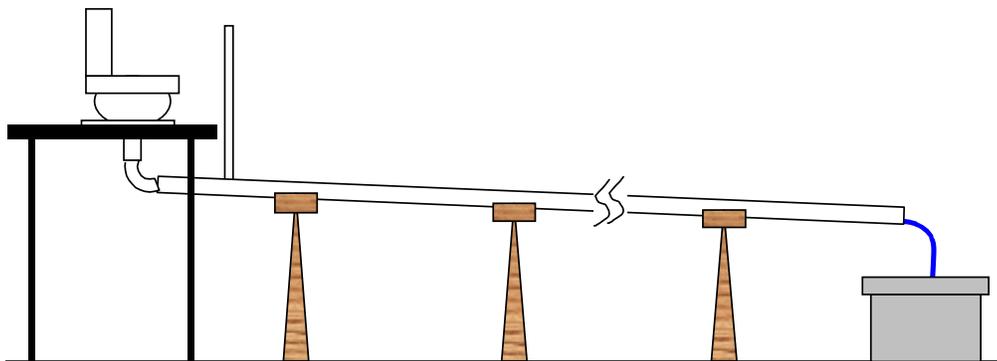


Evaluation of Low-Flush-Volume Toilet Technologies to Carry Waste in Drainlines

A Canada Mortgage and Housing Corporation Project

Final Report



February 2005

by

BILL GAULEY, P.ENG.

Veritec Consulting, Inc. Mississauga, Ontario Canada

AND

JOHN KOELLER, P.E.

Koeller and Company, Yorba Linda, California U.S.A.

Prepared by

Bill Gauley, P.Eng.
Veritec Consulting Inc.
1495 Bonhill Rd., #12
Mississauga, ON L5T 1M2
Canada

Tel (905) 696-9391 x102
Fax (905) 696-9395

bgauley@t5flushmeter.com

John Koeller, P.E.
Koeller and Company
5962 Sandra Drive
Yorba Linda, CA 92886-5337
U.S.A.

Tel (714) 777-2744
Fax (714) 777-2267

koeller@earthlink.net

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CONTRIBUTORS

Initiated by municipalities and other interested organizations in Canada, the Drainline Carry Testing program was a cooperative effort between the Canada Mortgage and Housing Corporation and several Canadian partners, such as:

- CMHC
- City of Calgary
- City of Toronto
- Region of Durham
- Region of Peel
- Region of Waterloo
- Province of Manitoba
- Ontario Ministry of Municipal Affairs and Housing

We gratefully acknowledge the contributions from these participating agencies and municipalities. We would also like to acknowledge the efforts of all those persons that provided a technical review of this document prior to finalization, especially Dr. Larry Galowin who provided many pages of valuable insight.

DISCLAIMERS

Every effort was made to ensure the accuracy of the testing program and the presentation of the project results contained in this report. However, because this testing program was conducted under laboratory conditions these results should not necessarily be considered as fully representative of results that may occur under field conditions.

Although this test project utilized a media whose physical properties closely resembles typical human waste, the reader is reminded that there is an enormous variation in human waste from person to person, and from one day to another.

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Readers are reminded that this report represents a 'snap shot' of drainline transport levels achieved by certain toilet models and flushing technologies at a particular time. As such, changes in the performance of specific flushing technologies may have occurred since the testing was completed.

The selection of toilets included as part of this project is in no way intended to represent all of the various makes and models available, nor is it intended to include a comprehensive list of all toilets that might employ each of the flushing technologies tested.

The results obtained during this testing program are not guarantees of performance.

CONVERSIONS

We expect that this document will be read and reviewed by interested parties in both Canada and the U.S.A.; as such, following are some of the measurement conversions used.

S-I Units	U.S. Units
13.25-litre flush	3.5-gallon flush
6.0-litre flush	1.6-gallon flush
4.0-litre flush	1.1-gallon flush
1 litre	0.264 gallon
3.785 litres	1.0 gallon
1.0 metre	3.28 feet
24.4 metres	80 feet
0.3048 metres	1.0 foot
25.4 mm	1.0 inch
75 mm pipe	3 inch pipe
100 mm pipe	4 inch pipe

DEFINITIONS

ULF: ultra-low-flush

ULFT: ultra-low-flush toilet

HET: High-Efficiency Toilet : effective flush volume of less than 4.8 litres (1.28 gallons), i.e., equal to less than 80% of flush volume of a 6-litre (1.6-gallon) toilet. Typically achieved via the use of dual-flush or pressure-assisted technologies.

Lpf: litres per flush

Gpf: gallons per flush

EXECUTIVE SUMMARY

There continues to be some debate regarding the ability of 6-litres (1.6-gallon) ultra-low-flush (ULF) toilets to transport waste through building drainlines. Do ULF toilets provide enough water to sufficiently carry waste? What's more, new technologies have enabled manufacturers to develop toilets that flush with only 4 litres (1.1 gallons) of water or less. Do these toilets provide enough water to get the waste to the sewer?

Many concerns appear to be based on anecdotal evidence and have little scientific or field-based verification. Most *documented* problems of toilets becoming blocked or plugged involve the toilet itself, poor installation practices, or the flushing of inappropriate materials.

Although some laboratory studies of drainline carry properties have been conducted, they tend to involve a different set of materials, e.g., plastic balls, sponges, water-filled 'sausages', etc. A limited number of field studies have also been completed but, unfortunately, the ability to change and accurately measure variables under field conditions is severely limited, the consequence being that the results are limited in their application.

This study was initiated to answer many of the questions concerning low-flush-volume toilets and their ability to carry waste to the sewer. A realistic media was used for testing (extruded soybean paste and toilet paper¹) and, because this is a lab-based study, most of the variables could be measured and controlled.

This study included testing several drainline variables and evaluating how each one affects drainline carry. Primary variables evaluated in project include:

- Effect of different flushing systems,
- Effect of flush volume,
- Effect of slope,
- Effect of diameter,
- Effect of mass loading,
- Effect of second (water-only) flush.

The results of this study included quantifying the minimum expected carry distance for 6 Lpf (1.6 gpf) toilets in general under variable loading and site conditions, and to predict the effect on carry distance as loading and site conditions are changed.

This study concludes that under expected site conditions (e.g., 3" drainline installed at a 2% slope for a single toilet installation application) virtually all 6-litre (1.6-gallon) toilet models meet drainline carry expectations. Under lab conditions, where pipes are installed straight and true, free from buildup or intrusion, and properly sloped and vented, carry distances of greater than 24 metres (80 feet) were common in 75mm (3 in) pipes².

General study findings (all findings are noted within test limitations):

- Carry distance increases as slope increases
- Carry distance increases as flush volume increases
- Carry distance increases as mass loading decreases
- Carry distance increases as pipe diameter decreases (for 3 inch and 4 inch pipes)

¹ Although no simulated media exactly matches human waste, and although human waste varies from person to person and from day to day, the media used in this study is unarguably more similar to 'average' human waste than test media used in other studies.

² Many contractors, even in Canada, continue to use imperial measurements when discussing construction elements, e.g., drywall and plywood is referred to as a 4x8 sheet (meaning feet rather than metres) and pipes are referred to as half inch or 3 inch (vs. 12 mm or 75mm). As such, in this report, pipe sizes are commonly referred to by their imperial measurement.

- Some flushing systems are more effective at carrying waste materials.

The charts on the following page identify the relationships between flush volume, mass loading, and carry distance for both 3 inch and 4 inch drain pipes. A rectangle identifies ‘normal’ mass loading and flush volume. For example, these charts identify that a mass loading of 300g in a 3 inch pipe installed at 2% would, on average, be carried about 20 m (65 ft), whereas the same loading in a pipe installed at a 1% slope would only be carried about 8.8 metres (29 ft).

It should be noted, however, that these charts indicate expected carry distances when pipes are installed straight and true. These charts do not consider the effects of dips, sags, or bends in the pipes, or tree root intrusion, or mis-aligned pipes, etc.

Possible Further Testing

Budget and time constraints naturally resulted in the following limitations to project testing:

- cast iron pipes were not tested due to insufficient budget and difficulty in observing carry distances without cutting holes in pipe (holes will alter ‘venting’ characteristics)
- waste media failing to clear the entire length of drainline in a single flush was not allowed to dry out completely before the second flush (simulating weekend or vacation drying of media in drain) because of time constraints
- no testing was completed using sanitary napkins
- no testing was completed using increasing loadings of toilet paper
- no testing was completed on old piping removed from demolished buildings
- no testing was completed to assess the effects of supplemental flows from faucets, showers, clothes washers, or dishwashers
- no testing was completed on toilet models that repeatedly fail to clear at least 200g
- testing was completed for only two flange-to-drain conditions (minimum and maximum drop heights); a more circuitous route from flange-to-drain may effect carry distances.
- no testing was completed to compare the various test media and methodologies used for drainline testing by different test agencies or nations.

Importance of Clearing the bowl

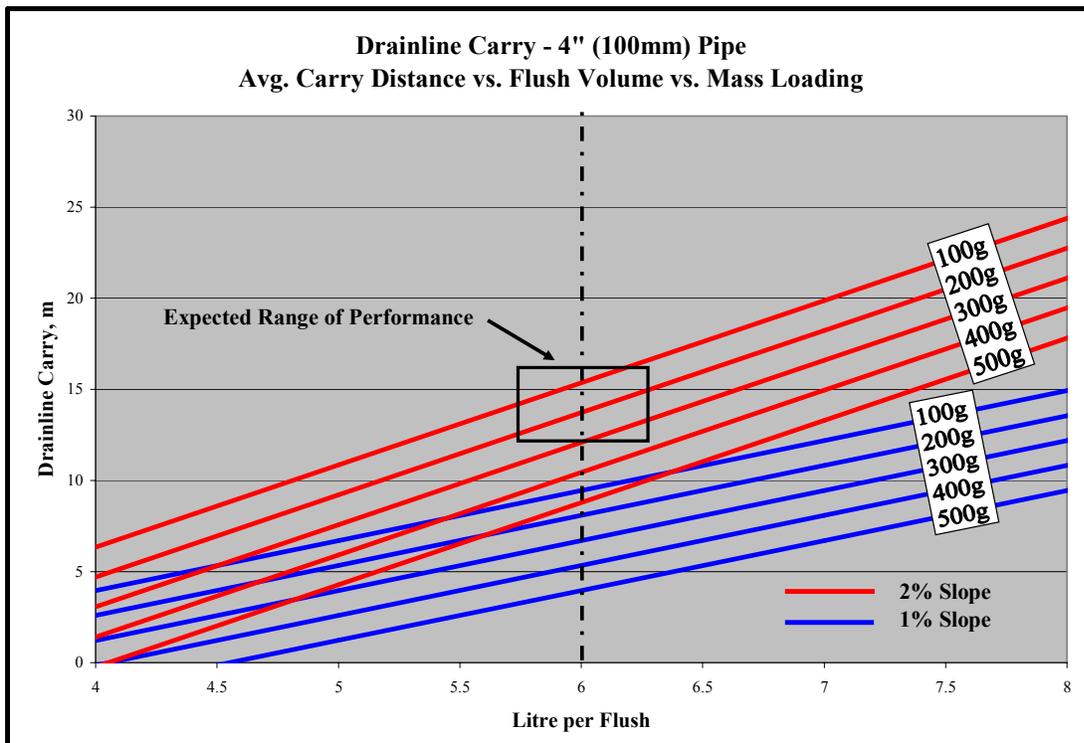
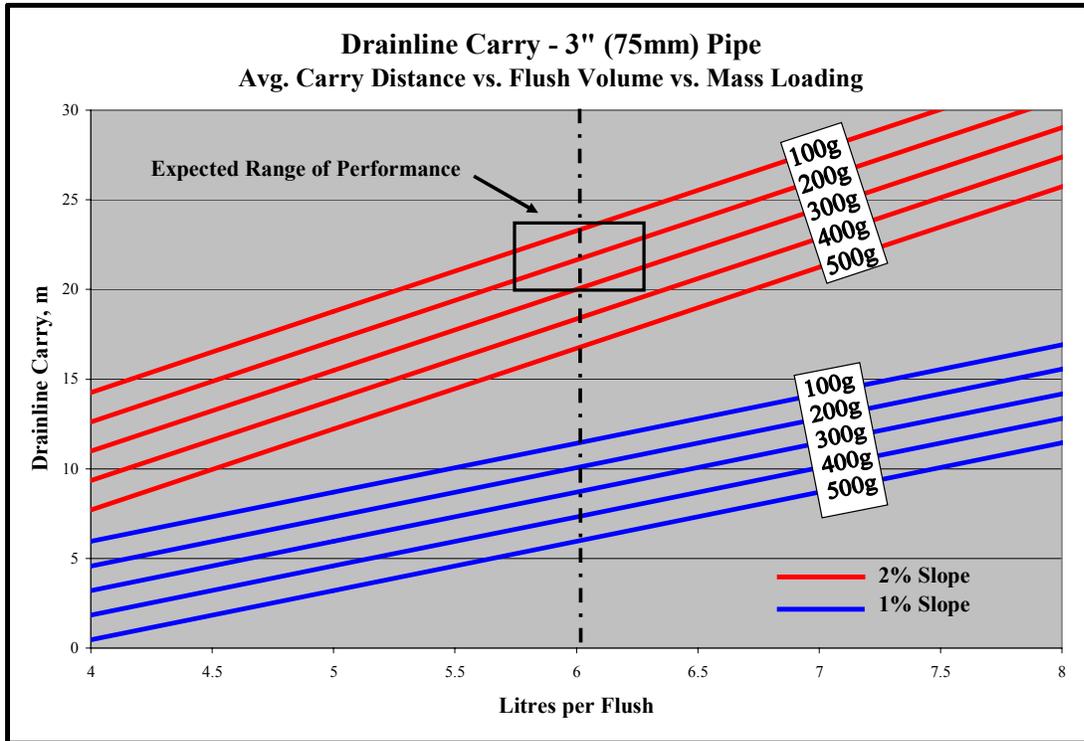
Perhaps the most important performance consideration to consumers is the ability of a toilet to fully remove all waste from the bowl in a single flush. Bowl clearing, though very important, was not addressed during this project as it was addressed in an earlier study³.

Conclusion

Under expected and required conditions virtually all 6-litre (1.6-gallon), and even 4-litre (1.1-gallon), toilets should meet or exceed household requirements regarding sewage flow even with no supplemental flows (e.g., from showers or clothes washers). Problems with drainline clogging or blocking are likely attributable to either installation problems, broken or misaligned pipes, buildup of grease or grit within the drain, or the flushing of inappropriate materials rather than the low flush volumes of today’s water-efficient toilets.

Installations with extremely long drainage distances, e.g., shopping malls or industrial sites, may require evaluation on a site-by site basis, especially if no supplemental flows are available.

³ MaP or Maximum Performance Testing of Popular Toilet Models, Gauley & Koeller, 2003



EVALUATION OF LOW-FLUSH-VOLUME TOILET TECHNOLOGIES TO CARRY WASTE IN DRAINLINES

STUDY BACKGROUND

Toilet fixtures and the carry of waste

Toilet fixtures have been the catalyst in a debate about waste carry for many years, the question being: do low-flow (6 litres – 1.6 gallons) toilet fixtures provide enough water to move waste from the fixture along the drainline to the sanitary sewer? For example, there is currently some question regarding how well drainlines in older construction can carry toilet waste.

Critics suggest that ultra-low-flush (ULF) toilet technology, using only six litres of water vs. either the 13 or 20 litres used by water-saver or standard toilets respectively, is insufficient to draw waste away from the building through existing drainlines whose size, length, and slope were designed when greater flow rates were the norm. They further contend that this leads to clogging or plugging of the drainline, poor toilet performance, and potentially expensive clean-out costs. However, most *documented* problems relating to ULF toilets have involved the toilet itself, poor installation practices, or the flushing of inappropriate materials (infant and adult diapers, hygiene products, etc.).

Supporters of ULF toilet technology correctly point out that little scientific research of actual fixture and drainline installations has been done to validate the critics' theories.

Plumbing standards based upon past studies

Laboratory studies have been conducted within a variety of environments to provide information on waste carry under different conditions and with a variety of toilet fixtures. These studies were intended to provide information necessary to reduce or eliminate the concerns of plumbing professionals. As a consequence, plumbing standards for toilet fixtures were developed for Canada and the U.S. that reflected engineers' best estimates of what represented actual movement of waste in a drainline. Those standards mandated a drainline carry averaging no less than 12m (40 feet) when depositing 100 spherical polypropylene balls 19 ± 0.4 mm diameter (0.75 ± 0.015 in)⁴ into the bowl of the toilet fixture under test. Consult the appropriate standards for further details on the test procedure and performance requirements⁵.

Re-visiting waste carry through two new studies

Since that time, new toilet fixture flushing technologies have been developed, flush volumes of some models have been reduced to below 6 litres (1.6 gallons), and different test media have been identified that appears to better represent "real world" conditions. As such, the drainline

⁴ For further information on the history of the development of a drainline carry test, read the article titled "ANSI's Drainline Carry Test" by R. Bruce Martin, published in *Plumbing Engineer*, March 2004.

⁵ Canadian Standards Association B45, Plumbing Fixtures; American Society of Mechanical Engineers A112.19.2-2003, Vitreous China Plumbing Fixtures and Hydraulic Requirements for Water Closets; these two standards are currently in the process of harmonization into a single standard for both countries.

carry issue is being re-visited in 2004 through two distinctly different studies. The U.S. Department of Energy (DOE) is funding a study at the Texas A&M University⁶ and the Canada Mortgage and Housing Corporation (along with various municipal funding partners) sponsored this study at Veritec Consulting, Inc., in Mississauga, Ontario.

Purpose of this study

The current debate regarding the ability of a 6-litre (1.6-gallon) flush to sufficiently carry waste through the drainline tends to focus on the following variables:

- slope of the drainline,
- diameter of the drainline,
- media used to simulate human waste in drainline carry studies,
- type of flushing action used, e.g., siphonic vs. washdown, gravity vs. pressure assist, etc., used to removed waste from the toilet fixture,
- effect of second (water-only) flush, and
- proper venting of drainline.

As such, there is a real need to identify if conventional ULF toilet fixtures flushing at 6 litres (1.6 gallons) and the new 4.0-Lpf (1.1-gpf) High-Efficiency Toilet (HET) fixtures can potentially lead to problems, especially when installed in older buildings.

The purpose of this study, then, was to provide new data on the ability of popular water-efficient toilet fixture technologies to carry solid waste through the drainline to the sewer. Using realistic test media and measuring drainline carry distances generated by the different flushing technologies under different pipe slope and diameter scenarios provides results that enable science-based decisions by water agencies and municipalities, industry, building trades, and the public regarding drainline installations.

Importance of Clearing the bowl

Perhaps the most important performance consideration from a consumer point of view is the ability of a toilet to fully remove all waste from the bowl in a single flush. Although we fully recognize the importance of 'clearing the bowl' in overall performance evaluation, bowl clearing was the primary focus of an earlier study⁷ and was not addressed as part of this project. Perhaps further testing (if any) may combine bowl clearing and drainline carry requirements into a single program.

⁶ Promoted by the American Society of Plumbing Engineers Research Foundation (ASPERF), the DOE is funding approximately \$100,000US toward the effort. A description of the work may be found in the March-April 2003 issue of *Plumbing Systems & Design*: <http://www.psdmagazine.org/pdf/index04-03.htm>

⁷ MaP or Maximum Performance Testing of Popular Toilet Models, Gauley & Koeller, 2003

TEST/STUDY METHODOLOGY

The test regime for this study involved physically measuring the effectiveness of several different *types* of water-efficient toilets to carry a realistic test media (combination of soybean paste and toilet paper) along both 3” and 4” (75mm and 100mm respectively) drainlines installed at different slopes and under various conditions.

The following photographs show the media and equipment used in this study. Note that the top right photo shows 200g of media (the mass of media used in testing) and four balls of toilet paper, and the bottom right photo shows the two levels of the test rig – the lower level was used to test the minimum drop height and the upper level was used to test the maximum drop height. Figures 1 and 2 on the following page illustrate the overall setup of the test rig/drainlines.



Bulk Media, Toilet Paper, extruded Media



Extruded Media & Toilet Paper



Test Media in Bowl



Test Rig and 3” line

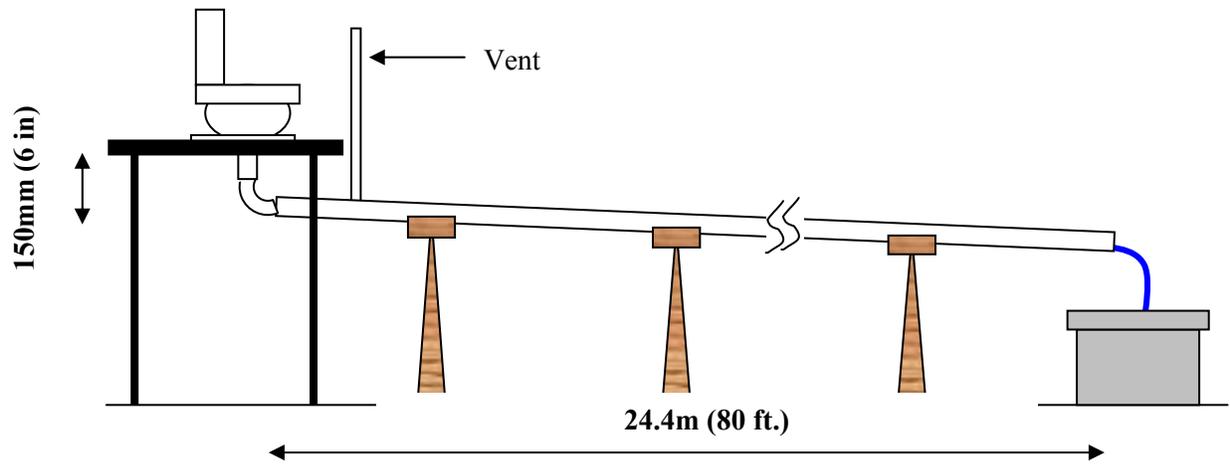


Figure 1: Set-up Minimum Drop Height

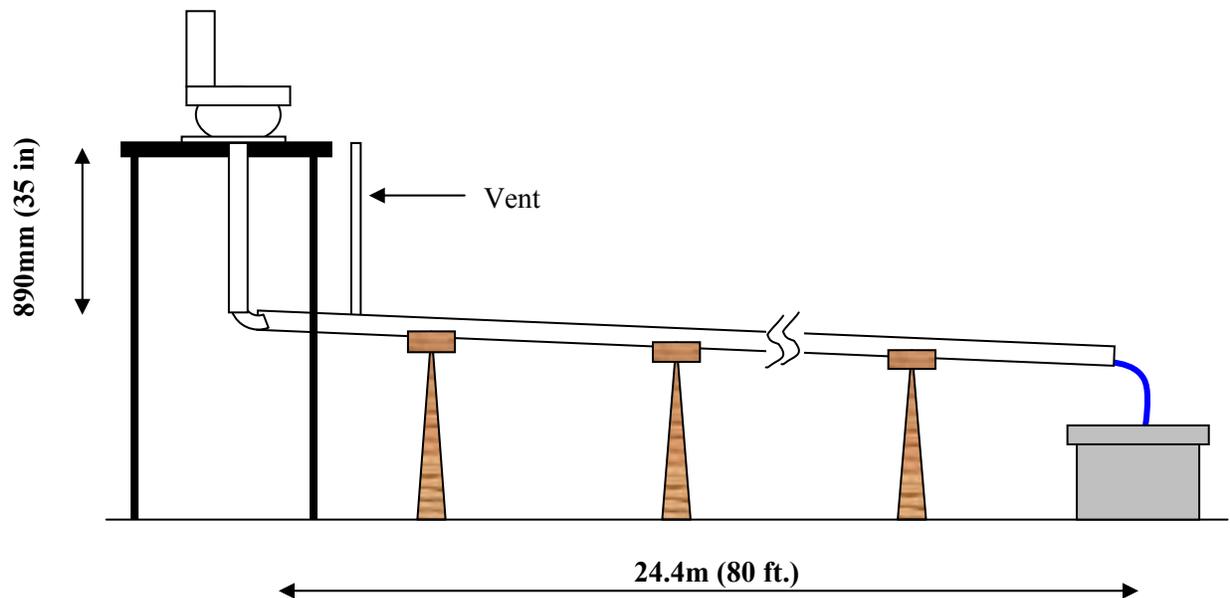


Figure 2: Set-up Maximum Drop Height

Test Variables

The critical variables incorporated and evaluated within the study are as follows:

Toilet fixtures

Nine (9) different *types* of toilet fixtures were included in the study, each type utilizing a different flushing action, in order to determine if the different flushing actions have different effects on drainline carry distances. Although the models selected are *intended* to represent the different type of flushing types commonly found in the marketplace, no particular effort has been spent to assure that this is, in fact, the case. Those types of technologies, and the fixtures selected to represent are shown in Table 1.

Table 1. Flushing Technologies Included Within the Study

Flushing Technology	Technology Represented By
Gravity - Washdown (European/Australian)	Caroma Caravelle
Gravity – 75mm (3 in) Flush Valve	Toto Drake
Gravity – Tipping Bucket	Niagara Flapperless
Gravity – Siphon Jet in Trapway	Western Pottery Aris
Gravity – Siphon Jet in Sump of Bowl	American Standard Sonoma
Gravity – Rim Jet	Toto CST703
Gravity – Vacuum-Assist	Briggs Vacuity
Pressure-Assist – 6.0-Lpf (1.6-gpf)	Gerber Ultra Flush
Pressure-Assist – 4.0-Lpf (1.1-gpf)	Mancesa Cyclone

Drainline slopes

Three (3) drainline slopes were evaluated:

- 1) Two percent (2%) per code⁸,
- 2) One percent (1%), and
- 3) Flat (0%)⁹

Drainline pipe diameters

Two (2) different pipe sizes were included in the study:

- 1) 75 mm (3 in)¹⁰, and
- 2) 100 mm (4 in)¹¹

Vertical drop heights

Two different vertical drop heights from the floor flange to the drainline were tested to reflect both the upper and lower limits set forth by code:

- 1) 150 mm (6 in)¹²
- 2) 900 mm (35 in)¹³

⁸ 7.4.8.1 (1) 1997 Ontario Building Code, “Every drainage pipe that has a size of 3 in. or less, and every fixture drain shall have a downward slope in the direction of flow of at least 1 in 50.”

⁹ Flat slopes were tested only as part of the ‘slope vs. carry distance’ portion of the project.

¹⁰ 7.4.9.2 (1) 1997 Ontario Building Code, “every drainage piping that serves a water closet shall be at least 3 in.”

¹¹ 7.4.9.2 (2) 1997 Ontario Building Code, the “size of every *horizontal branch* downstream of the third water closet *fixture drain* connection shall be at least 4 in.”

¹² Basically, minimum possible height when attaching a 90-degree elbow to a toilet floor flange.

¹³ 7.5.5.3 (3) 1997 Ontario Building Code, “No vertical leg of the waste pipe from a water closet or other fixture having an integral siphonic flushing action shall exceed 900 mm (2 ft 11 in).”

Test set-up and methodology

Test media

Tests were typically conducted using 200 grams of a media closely simulating human waste (i.e., soybean paste and toilet paper)¹⁴, though different mass loadings were used to evaluate the effect of ‘mass vs. carry distance’ portion of the project. For a complete background on the media and typical waste demands upon a toilet fixture, consult the Final Report on Maximum Performance (MaP) testing of toilet fixtures¹⁵. Four test samples of 50g each are shown in photo on right.



Test set-up

A test rig was constructed such that each toilet could be bolted to a typical toilet floor flange. Clear plastic piping was used to facilitate observations and all piping was installed by a licensed plumber to ensure that it was installed correctly and in accordance with code. Flexible rubber-sleeve mechanical couplings (see photographs below) were used to connect the pipe sections¹⁶. A laser level was used to establish a benchmark and ensure pipe slopes were properly adjusted. A string-line was used to ensure pipe runs were straight and true.¹⁷



Flexible rubber-sleeve mechanical coupling

Flushing technologies numbers 1 through 7 (listed in Table 1) were adjusted to 6-Lpf (1.6-gpf) where possible. Pressure-assist fixtures (numbers 8 and 9) could not be adjusted¹⁸. Static line pressure in the plumbing system serving the test rig was set at 50 pounds per square inch (psi).

¹⁴ Average human loading demands are approximately 130g, but can be greater than 250g.

¹⁵ Gauley, William and Koeller, John, *Maximum Performance Testing of Popular Toilet Models*, Final Report, December 2003. Available for download from http://www.cuwcc.org/products_tech.lasso and other websites.

¹⁶ Originally, rigid ABS couplings were used but it was found that these couplings interfered with flow at the pipe junctions, thereby reducing carry distances.

¹⁷ It should be noted that the piping used during testing was new clear plastic pipe, free from buildup that may occur in older installations. The piping was installed in perfectly straight runs (except when testing the effects of sags), and slopes were accurately determined. Because clear piping was used, it was possible to identify any interference from pipe couplings protruding into the pipe – observations not possible in actual field conditions. A laser level was used to ensure pipe slopes were accurate, whereas this type of leveling would not be expected in the field.

¹⁸ The flush volumes of the gravity toilets were adjusted during flush volume vs. carry testing, whereas the pressure-assist toilets, which could not be adjusted, were not included in flush volume vs. carry testing.

Measurements

Measurements of waste carry distances centered around the following three key conditions:

- 1) The distance the waste carried in the drainline (to a maximum of 24 meters, or 80 feet¹⁹) for a single test flush at different slopes for 3” and 4’ piping;
- 2) The effect on the initial deposit of a second water-only flush (simulating a “double-flush”); and
- 3) The effect upon that distance of completely blocking the vent stack.

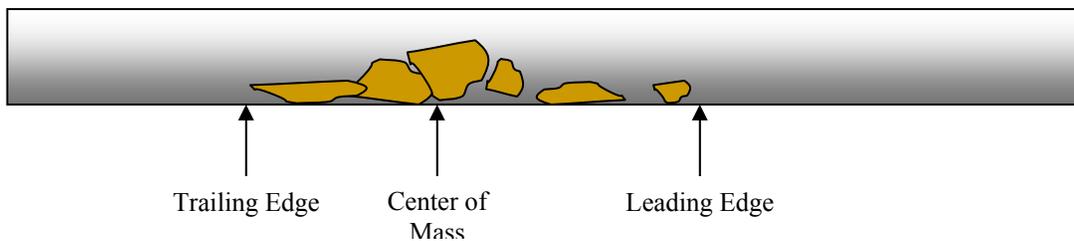
Waste in Drain (Waste Plug)

One advantage of performing drainline carry testing with water-filled balloons or plastic balls is that they occupy a discrete position which is easy to measure; the obvious disadvantage is that water-filled balloons and plastic balls are in no way similar to human waste and, therefore, may not behave like human waste insofar as drainline carry testing is concerned.

The test media used in this study is a combination of extruded soybean paste and toilet paper balls. This combination of media is free to break up into smaller pieces and to either spread out as it is carried through the drainline or to ‘clump up’ in a ball, i.e., there is some variation in the size of the waste plug.

Measurements identified in this study are based on the centre of mass of the deposited media, i.e., the technician noted the leading and trailing edge of the waste plug and visually assessed the the position of the center of mass. Figure 3 below helps illustrate how the measurements were made within the drainline.

Figure 3: Identifying Centre of Mass Stopped within Drainline



¹⁹ Total length of test piping was 24.4m or 80 ft.

The length of waste plug sizes ranged from 12 cm (5 in) to 3.6 m (11.8 ft) with an *average* size of 63 cm (25 in) and a *median* of 53 cm (22 in). Figure 4 illustrates the range in plug sizes (data sorted from shortest to longest length). What's more, in most cases, the second (water-only) flush tended to shorten or compact the plug length slightly but in a small number of instances it caused the plug to spread out significantly (Figure 5).

Figure 4: Lengths of Media Plug – Single Flush

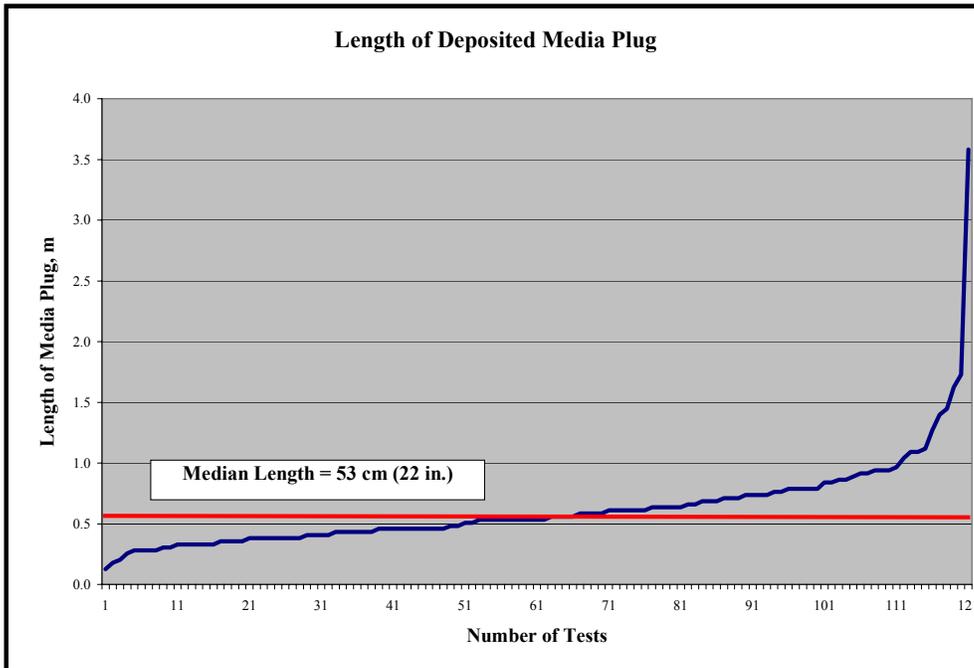
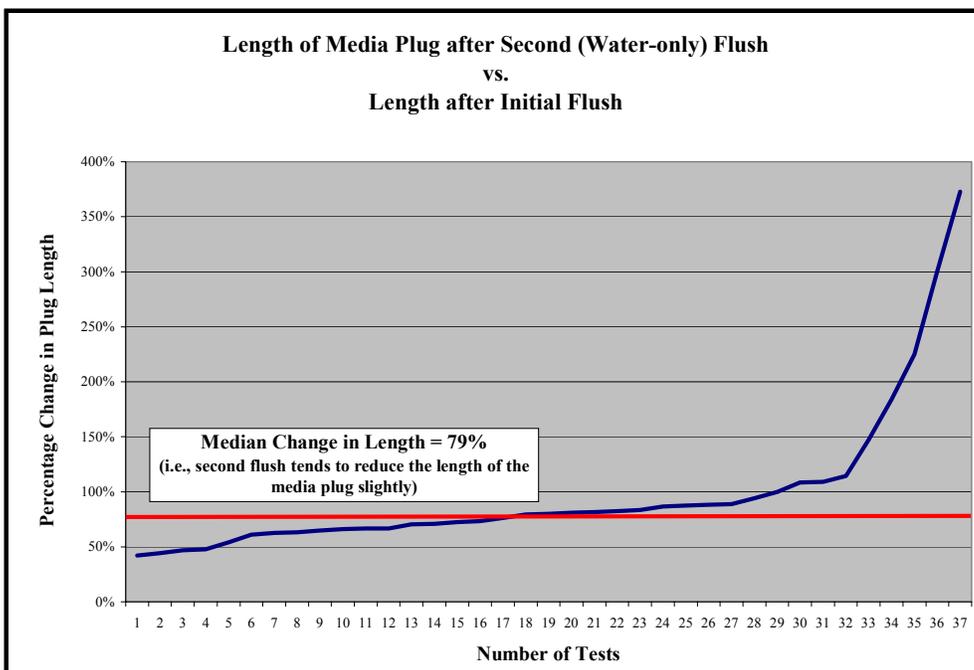


Figure 5: Effect of Second Flush on Length of Media Plug



TEST RESULTS

The results of this study have been divided into sections, with each section dealing with one of the drainline carry distance elements of the test regime. The findings have been further divided into major and minor findings as follows:

Major Study Findings

1. Effect of different toilet flushing systems
2. Effect of toilet flush volume
3. Effect of drainline slope and diameter
4. Effect of mass loading
5. Effect of second (water-only) flush
6. Minimum expected carry distance for 6 Lpf (1.6 gpf) models

Minor Study Findings

7. Effect of dips and sags in the drainline
8. Effect of blocking the vent
9. Comparison of simulated waste and ‘Water Wigglers’²⁰

1. Effect of different flushing systems

As stated earlier, nine different flushing technologies or systems were evaluated in this study. The methodology used was to compare waste carry distances of each of the different flushing systems with the average carry distance of all of the systems²¹ under each testing scenario (pipe diameter, drop height, and slope). As noted earlier, a solids loading of 200 grams of soybean paste plus toilet paper was used in testing.

Testing was completed using the 75 mm (3 in) pipe at 0%, 0.5%, 1%, 1.5%, and 2% slopes and using the 100 mm (4 in) pipe at 1% and 2% slopes for both minimum and maximum drop heights.

Results indicate that there is very little difference in average carry distance between maximum and minimum drop heights (within 1% for the 75 mm pipe and within 4% for the 100 mm pipe). As such, the data for minimum and maximum drop heights were combined for this analysis.

Test regimes where solids cleared the entire 24 metre length of piping (e.g., the 75 mm pipe at 2% slope for both drop heights and the 100 mm pipe at 2% slope for maximum drop height) were not included in the results as it was not possible to identify final carry distance.

The results illustrated in Tables 2a through 4 compare the average carry distance of each flushing technology to the overall average carry distance of all models under the same testing regime for each of the two pipe diameters.

²⁰ “Water Wigglers” have been used by manufacturers and other testing laboratories as representative of human waste. The purpose of the analysis in this study was to compare the carry distances of the two types of media when all other variables are held constant.

²¹ The Mancesa Cyclone (pressure-assist) results were not included when calculating the average, since this toilet flushes at a maximum of only 4-Lpf (1.1-gpf).

Table 2a Waste Carry Distances (m)

3" Diameter, Minimum Drop Height, 200g

Flushing Technology/Slope	0%	0.5%	1%	1.5%	2%
Pressure-Assist – 6.0-Lpf (1.6-gpf)	7.5	8.8	13.6	20.1	*
Gravity – Rim Jet	7.3	9.5	11.8	16.3	*
Gravity – 75mm (3 in) Flush Valve	7.5	7.6	10.6	14.9	*
Gravity –Jet in Sump of Bowl	6.5	8.2	11.3	14.8	*
Gravity – Jet in Trapway	6.2	8.3	11.3	14.0	*
Gravity – Tipping Bucket	7.0	7.9	9.1	15.0	*
Gravity - Washdown	4.9	6.1	8.8	10.9	19.4
Gravity – Vacuum-Assist	5.2	5.8	6.8	8.1	12.7
Pressure-Assist – 4.0-Lpf (1.1-gpf)	4.6	5.9	6.8	8.3	12.8
Average (not incl. 4.0-litre P-A)	6.5	7.8	10.4	14.3	-

* media travelled entire length of drainline

Table 2b Waste Carry Distances (m)

3" Diameter, Maximum Drop Height, 200g

Flushing Technology/Slope	0%	0.5%	1%	1.5%	2%
Pressure-Assist – 6.0-Lpf (1.6-gpf)	6.4	7.8	14.0	19.9	*
Gravity – Rim Jet	8.2	8.7	9.9	17.8	*
Gravity – 75mm (3 in) Flush Valve	7.5	8.2	14.1	17.0	*
Gravity –Jet in Sump of Bowl	6.2	7.5	10.8	12.7	*
Gravity – Jet in Trapway	5.6	8.6	11.2	16.5	*
Gravity – Tipping Bucket	5.0	7.6	10.0	12.8	*
Gravity - Washdown	4.6	6.7	8.4	13.6	*
Gravity – Vacuum-Assist	5.1	5.8	9.1	9.1	15.5
Pressure-Assist – 4.0-Lpf (1.1-gpf)	3.5	5.6	6.6	12.5	16.3
Average (not incl. 4.0-litre P-A)	6.1	7.6	10.9	14.9	-

* media travelled entire length of drainline

Table 2c Waste Carry Distances (m)

4" Diameter, Minimum Drop Height, 200g

Flushing Technology/Slope	1%	2%
Pressure-Assist – 6.0-Lpf (1.6-gpf)	10.6	19.5
Gravity – Rim Jet	8.8	16.6
Gravity – 75mm (3 in) Flush Valve	9.2	15.7
Gravity –Jet in Sump of Bowl	7.8	16.3
Gravity – Jet in Trapway	8.7	11.8
Gravity – Tipping Bucket	7.3	14.2
Gravity - Washdown	6.4	10.3
Gravity – Vacuum-Assist	7.1	9.8
Pressure-Assist – 4.0-Lpf (1.1-gpf)	6.7	9.2
Average (not incl. 4.0-litre P-A)	8.2	14.3

**Table 3a Comparative Waste Carry Distances (Percent vs. Avg. Carry)
3" Diameter, Minimum Drop Height, 200g**

Flushing Technology/Slope	0%	0.5%	1%	1.5%	2%
Pressure-Assist – 6.0-Lpf (1.6-gpf)	116%	114%	130%	141%	*
Gravity – Rim Jet	112%	123%	113%	114%	*
Gravity – 75mm (3 in) Flush Valve	115%	98%	102%	105%	*
Gravity –Jet in Sump of Bowl	100%	106%	109%	104%	*
Gravity – Jet in Trapway	96%	106%	109%	98%	*
Gravity – Tipping Bucket	107%	102%	87%	105%	*
Gravity - Washdown	75%	78%	85%	76%	*
Gravity – Vacuum-Assist	79%	75%	65%	57%	*
Pressure-Assist – 4.0-Lpf (1.1-gpf)	71%	76%	65%	58%	*

* media travelled entire length of drainline

**Table 3b Waste Carry Distances (Percent vs. Avg. Carry)
3" Diameter, Maximum Drop Height, 200g**

Flushing Technology/Slope	0%	0.5%	1%	1.5%	2%
Pressure-Assist – 6.0-Lpf (1.6-gpf)	105%	102%	128%	133%	*
Gravity – Rim Jet	135%	115%	91%	119%	*
Gravity – 75mm (3 in) Flush Valve	123%	108%	128%	114%	*
Gravity –Jet in Sump of Bowl	102%	98%	99%	85%	*
Gravity – Jet in Trapway	92%	113%	102%	110%	*
Gravity – Tipping Bucket	83%	99%	92%	86%	*
Gravity - Washdown	75%	88%	77%	91%	*
Gravity – Vacuum-Assist	84%	77%	83%	61%	*
Pressure-Assist – 4.0-Lpf (1.1-gpf)	58%	73%	61%	84%	*

* media travelled entire length of drainline

**Table 3c Waste Carry Distances (Percent vs. Avg. Carry)
4" Diameter, Minimum Drop Height, 200g**

Flushing Technology/Slope	1%	2%
Pressure-Assist – 6.0-Lpf (1.6-gpf)	129%	137%
Gravity – Rim Jet	106%	116%
Gravity – 75mm (3 in) Flush Valve	112%	110%
Gravity –Jet in Sump of Bowl	95%	114%
Gravity – Jet in Trapway	106%	82%
Gravity – Tipping Bucket	88%	100%
Gravity - Washdown	78%	72%
Gravity – Vacuum-Assist	86%	69%
Pressure-Assist – 4.0-Lpf (1.1-gpf)	82%	64%

**Table 3d Waste Carry Distances (Percent vs. Avg. Carry)
Average of All Slopes and Drop Heights, 200g**

Flushing Technology/Slope	3"	4"	Avg.
Pressure-Assist – 6.0-Lpf (1.6-gpf)	121%	133%	127%
Gravity – Rim Jet	115%	111%	113%
Gravity – 75mm (3 in) Flush Valve	112%	111%	111%
Gravity –Jet in Sump of Bowl	100%	105%	102%
Gravity – Jet in Trapway	103%	94%	99%
Gravity – Tipping Bucket	95%	94%	95%
Gravity - Washdown	81%	75%	78%
Gravity – Vacuum-Assist	73%	77%	75%
Pressure-Assist – 4.0-Lpf (1.1-gpf)	68%	73%	71%

It is interesting to note that the first two **gravity** toilets listed in Table 3d (rim jet with a 2” flapper and siphon jet with a 3” flapper) have very similar results (average values within 3% of each other) even though they use what seems to be significantly different flushing systems.

The 6.0-Lpf (1.6-gpf) pressure-assist model had the best results (Table 3d), with average carry distances more than 20% further than the average in the 3 inch pipe and more than 30% further in the 4 inch pipe.

The gravity-fed washdown and the gravity-fed vacuum-assist fixtures scored lower average drainline carry distances even though both models scored very highly in the MaP²² testing program.

While the 4-Lpf (1.1-gpf) pressure-assist toilet had the shortest carry distance, it should be remembered that it uses only about two-thirds of the water per flush as do the other eight fixtures.

Although the test results reveal distinct differences in waste carry among the different flushing systems, the results are somewhat surprising. That is, the flushing systems that are better at clearing media from the bowl (based on MaP testing results) are not necessarily the same systems that carry waste the furthest in the drainline. It is apparent from Table 4 that there is no strict correlation between flushing solids from the bowl and carrying it down the drainline.

Table 4. Flushing Technologies and Pipe Diameter – Comparison to MaP Testing
3” Diameter, 200g, 1.5% Slope²³

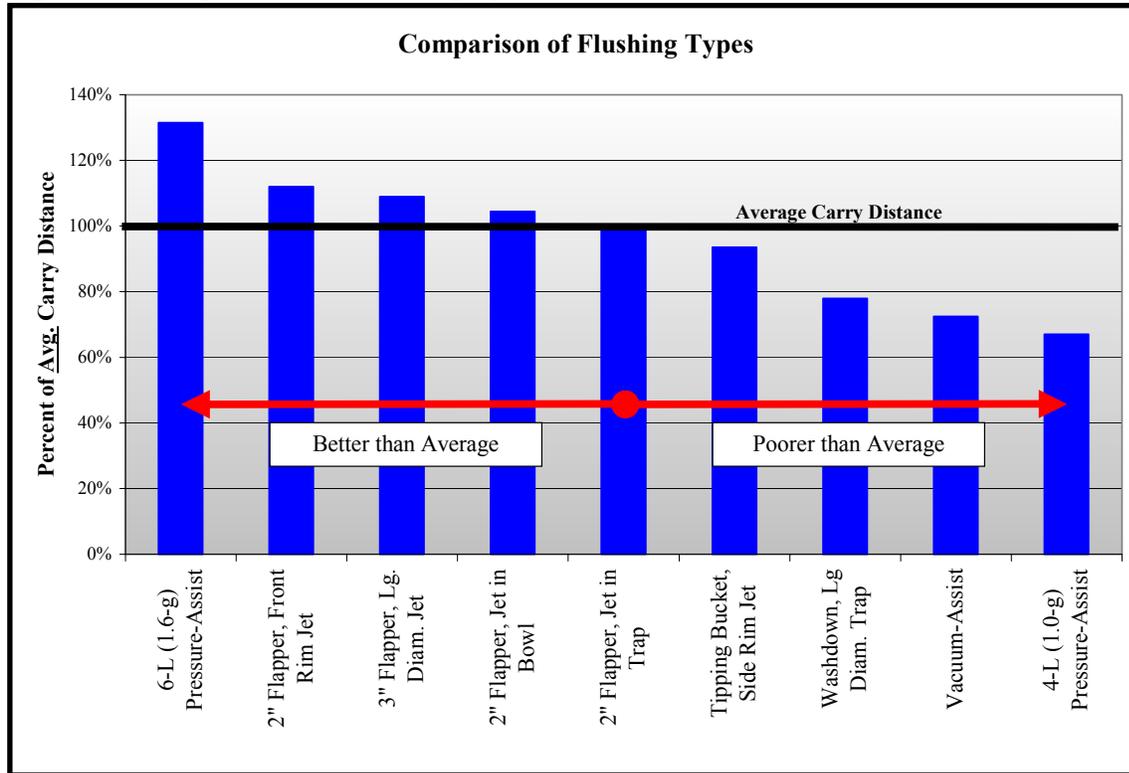
Flushing Technology	Average Carry Distance - metres (from Table 2)	MaP Testing Results for Representative Fixture – grams (from MaP reports)
Pressure-Assist – 6.0-Lpf (1.6-gpf)	20.1	900
Gravity – Rim Jet	16.3	550
Gravity – 75mm (3 in) Flush Valve	14.9	900
Gravity – Siphon Jet in Sump of Bowl	14.8	325
Gravity – Siphon Jet in Trapway	14.0	375
Gravity – Tipping Bucket	15.0	725
Gravity - Washdown	10.9	650
Gravity – Vacuum-Assist	8.1	500
Pressure-Assist – 4.0-Lpf (1.1-gpf)	8.3	650

Figure 6 on the following page compares the different flushing systems. Each system is compared to the average of all 6-L systems (data for the 4-L pressure-assist model is not included in the average carry distance calculation).

²² Gauley, William and Koeller, John, Maximum Performance Testing of Popular Toilet Models, Final Report, December 2003. Available for download from http://www.cuwcc.org/products_tech.lasso and other websites.

²³ A 2% slope was not used as carry distance exceeded pipe length for most toilet samples

Figure 6: Comparison of Flushing Systems



2. Effect of toilet flush volume

As expected, there is naturally some variability and randomness related to this type of testing since we are dealing with how the solids ‘line up’ in the bowl (the media samples are dropped into the bowl through a drop guide and not ‘placed’ in the bowl), and how they ‘line up’ as they exit the bowl upon flushing and drop into the horizontal drainline. Furthermore, in some cases (generally at 2% slopes), the media was carried through the entire 24.4m (80ft) length of piping and the data, therefore, is not suitable for inclusion in calculations (i.e., it is not known how much further the waste would have traveled beyond 24.4m). For example, the only set of data for piping installed at 2% is for the 4” pipe at minimum drop height²⁴, whereas there are three sets of data for 1% slopes (4” minimum drop and 3” both minimum and maximum drop). Fortunately, enough testing was completed and enough data collected to reach the conclusions presented later in this report.

Variations in flush volumes were achieved by either holding the flush handle open for an extended period or physically closing the flapper early by pushing on it with a thin wooden dowel. In all cases the resulting flush volumes were recorded.

²⁴ Nearly all of the 75mm (3-in) pipe tests at 2% slope cleared greater than 24m (80 ft). As stated earlier, the 100mm (4-in) max drop height tests were not included in the calculations because it is not known exactly what slope they were performed at due to faulty laser leveling equipment. That said, the testing generally concluded that there is only a marginal difference in drainline carry between the minimum and maximum drop heights.

As expected, there is a correlation between flush volume and drainline carry distance, i.e., higher flush volumes generally equate to greater carry distances. Although this relationship seems to be somewhat intuitive, what is not intuitive is the minimum flush volume required to adequately carry waste to the sewer.

The results of the testing have been charted (Figures 7a, 7b, 7c, and 7d). Even with the somewhat random nature of the media ‘lining up’ in the bowl and the drainline, the trendlines for each set of data have similar slopes indicating a high level of confidence.

The results of the testing indicate the following relationships:

- Additional 2.7m per extra litre of flush volume at 1% slope (34 ft/gallon),
- Additional 4.7m per extra litre of flush volume at 2% slope (59 ft/gallon).

The accuracy of these curves at extreme ranges of flush volumes is not known and, as such, these charts are presented with a flush volume range between 3 and 8 litres.

Figure 7a: 3” Pipe, 1% Slope, Maximum Drop Height

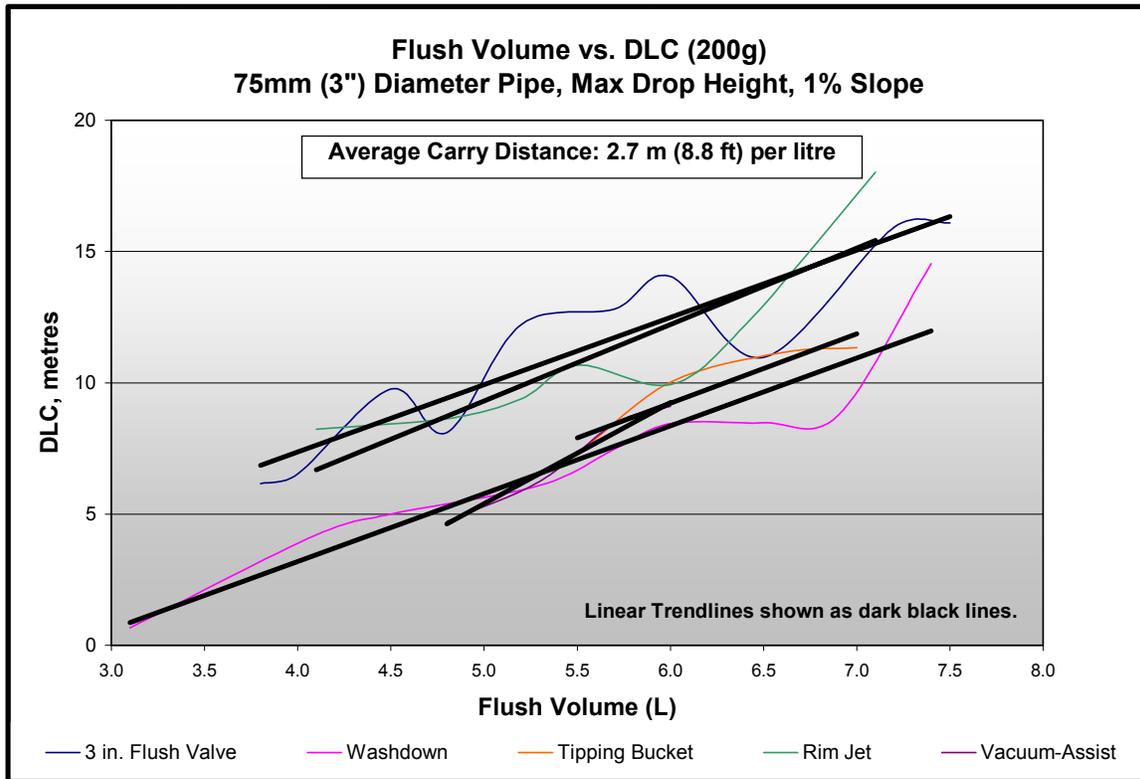


Figure 7b: 3" Pipe, 1% Slope , Minimum Drop Height

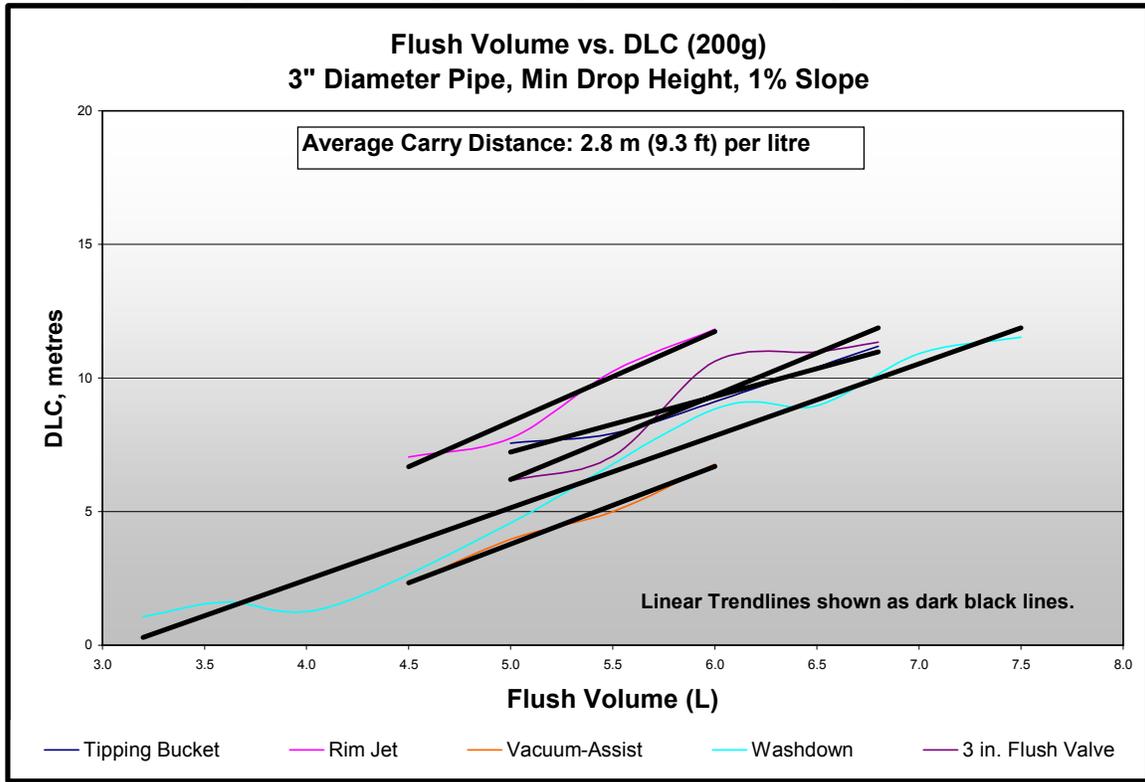


Figure 7c: 4" Pipe, 1% Slope, Minimum Drop Height

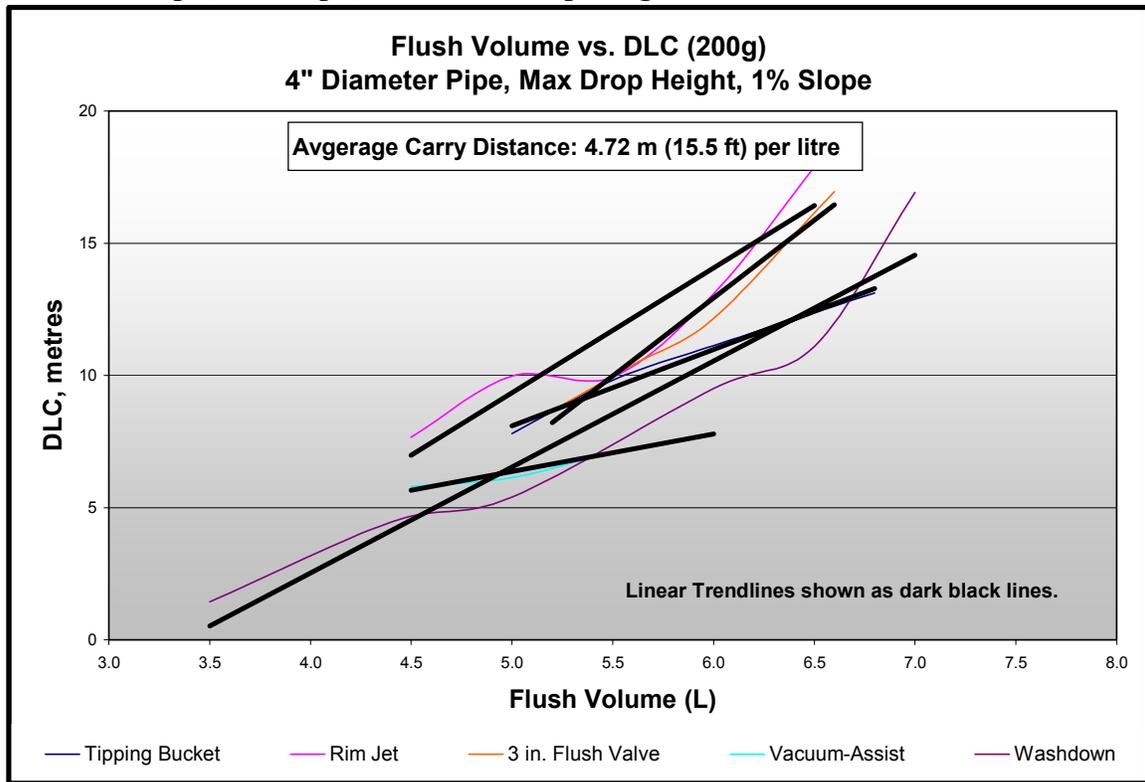
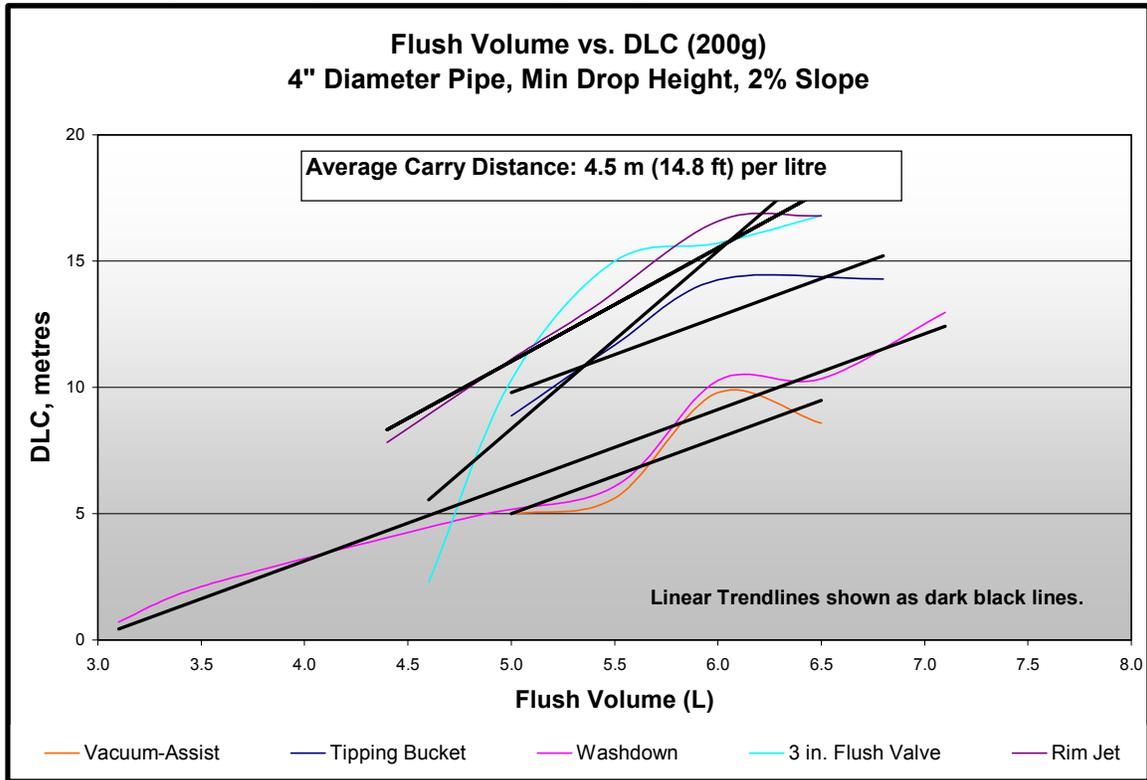


Figure 7d: 4" Pipe, 2% Slope, Minimum Drop Height



3. Effect of Drainline Slope and Diameter

As expected, there was a correlation between drainline slope and drainline carry, i.e., the carry distance increases as the pipe slope increases²⁵. Based on test results a set of curves for pipe slope vs. carry distance was developed for mass loadings of 200g mass. These curves illustrate the relationship between slope and carry distance for the different system variables.

Note in Figure 8 that the curves for the 75mm (3 in) pipe are similar for both the minimum drop height and the maximum drop height (though the maximum drop height provides slightly greater carry), with both curves indicating carry distances of approximately 10m (33 ft) at a 1% slope and 22m (72 ft) at a 2% slope.

Carry distance in the 100mm (4-in) drainline was somewhat less, with an average carry of 8.0m (26 ft) at 1% slope and 13.7m (45 ft) at 2%. These results agree favorably with the Swaffield-Galwin study²⁶, which found that the carry distance is more affected by slope than pipe diameter (i.e., a 4 in pipe at 2% should provide a greater carry than a 3 in pipe at 1%).

²⁵ Some claim that with slopes of greater than 2% the water will ‘out race’ the waste. Our results indicate that if such a phenomenon were to occur it would likely require extreme slopes of *considerably greater* than 2% (this observation is supported by the Danish requirement of a 4% pipe slope).

²⁶ To The Limits – Wastes in Drainage Systems, Transport in Drainlines – Unsteady Flow Conditions, pg 1998, Swaffield and Galwin

It was interesting to note that even under a 0% slope all of the 6.0-Lpf (1.6-gpf) toilet fixtures were able to carry the 200g of waste more than 4.6m (15 ft)²⁷ for both 75mm (3-in) and 100mm (4-in) drainlines. This information may be of some interest for those involved in new construction where achieving slopes of 2% is not always possible (see Appendix A).

Note in Figure 8 that a curve has been projected for a 100mm (4-in) pipe with a maximum drop height²⁸. This curve is based on the relationships found between minimum and maximum drop height conditions with the 75 mm (3-in) drainline.

Figure 8: Slope vs. Carry Distance



²⁷ The 4-Lpf (1.1-gpf) pressure-assist fixture was able to transport the waste media 3.5m (11.5 ft) at a 0% slope.

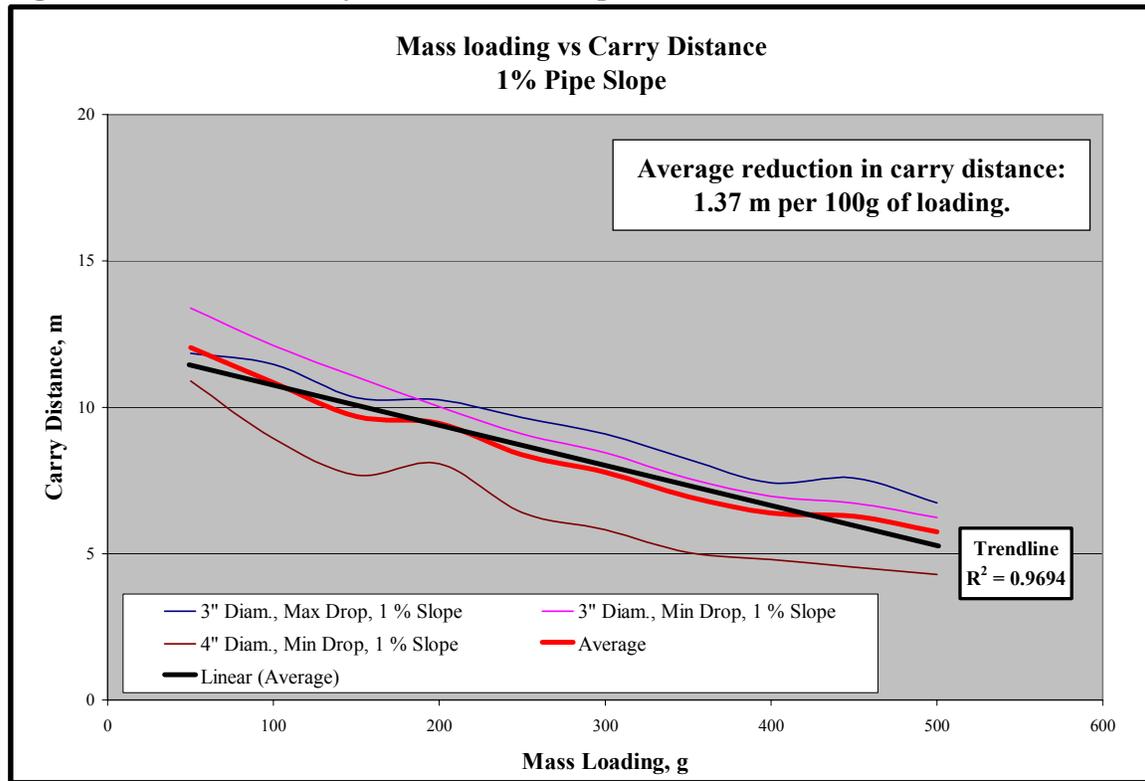
²⁸ A Black and Decker auto laser level was used to facilitate the adjusting of pipe slopes to ensure that they were true. At one point in the study during a drainline setup change, i.e., when setting up the 100mm (4-in) pipe with the maximum pipe drop, the laser level apparently became damaged (cause unknown) and it was later found to be out of calibration. As a result, the entire series of tests completed at the maximum drop height were, in fact, completed at unknown slopes. The data was discarded and the laser replaced by a new piece of equipment. The testing continued, although the tests of maximum drop with the 100mm (4 in) drainline were not repeated.

4. Effect of Mass Loading

As might be expected, increasing the mass of waste discharged into a drainline will reduce the distance of drainline carry. As can be seen in Figures 9a and 9b, a pipe sloped at 1% loses about 1.37m (4.5 ft) of carry distance for every additional 100g of loading, whereas a pipe sloped at 2% loses 1.64m (5.4 ft) of carry distance for every additional 100g of loading.

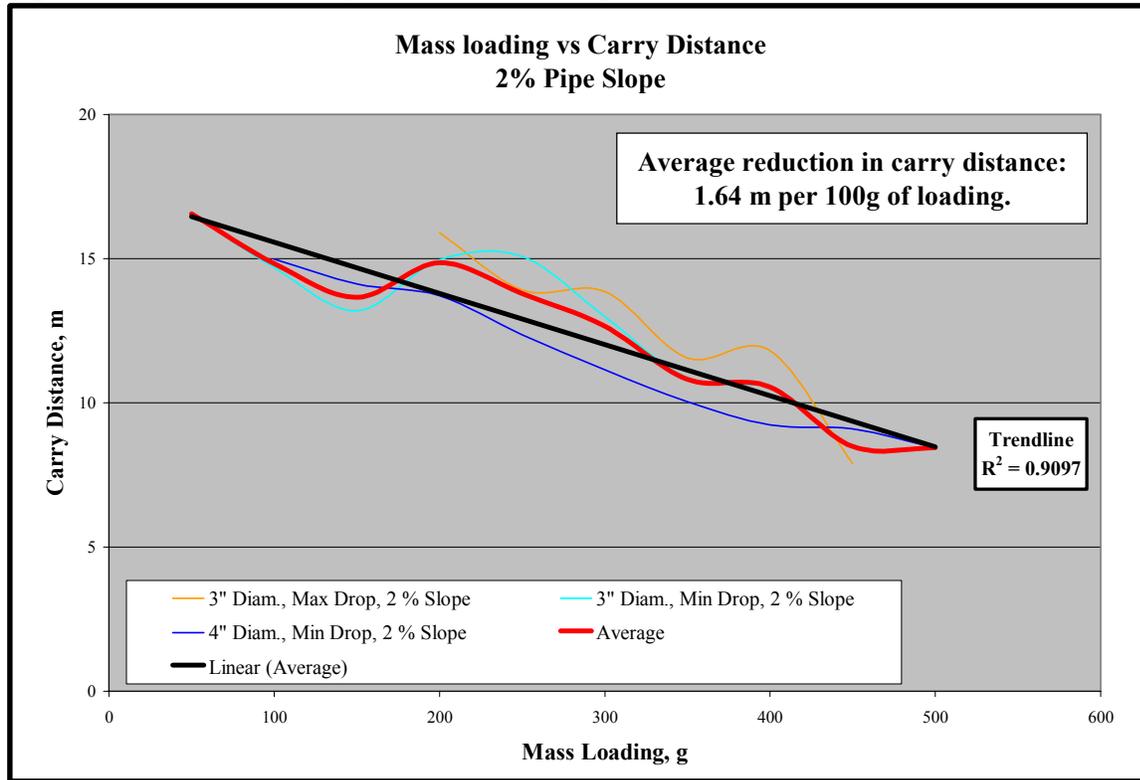
The curves appear to be somewhat linear, especially within the narrow range of normal solids loading of a toilet fixture (approximately 100 – 300g²⁹).

Figure 9a: Mass vs. Carry Distance, 1% Slope



²⁹ For details on the average demand placed upon a toilet fixture, consult the report: Gauley, William and Koeller, John, Maximum Performance Testing of Popular Toilet Models, Final Report, December 2003. Available for download from http://www.cuwcc.org/products_tech.lasso and other websites.

Figure 9b: Mass vs. Carry Distance, 2% Slope



5. Effect of Second Flush

As expected, a second (water-only) flush serves to carry the waste media some additional distance. In real-world conditions the timing of a second flush would be somewhat variable, i.e., it may occur immediately after an initial solids flushing or it may occur after an extended period (e.g., a day or more) has passed. In the lab, however, it is not practical to wait for extended periods of time between flushes. As such, the second flushes conducted as part of this study followed initial flushing by approximately two to three minutes, i.e., after most, but not necessarily all, of the water trailing the media had dissipated. The results of the second-flush testing portion of this study should, therefore, be taken in context and not considered to necessarily represent the effects of second flushes under all scenarios.

Water-Only Second Flushes

It was interesting to note that the toilet paper included as part of the test media acted hold the solids in a group or ‘plug’ as it traveled down the pipe. The velocity of the ‘plug’ typically slows down as it travels in the drain until it settles in the pipe, wherein the trailing water often became dammed up behind the plug (see Figure 10). Unlike simulated media that allows water to easily pass through, the realistic media/toilet paper combination often forms a dam that, although not impenetrable, is capable of retaining the trailing water for several minutes.

The second water-only flush was typically activated while some of the water from the original solids flush was still dammed up behind the plug (remaining water). As the water from the second flush moves through the remaining water a wave or bore is created. When the wave front hits the plug it lifts and moves the plug a short distance further downstream. Of course, repeated flushing of water-only flushes eventually results in enough water being dammed up behind the plug to remove it from the test pipe.

Figure 11 illustrates the effects of a second (water-only) flush on the media plug. The effect of the second flush appears to be slightly more pronounced in the 3" pipe where it pushes the waste to 170% of the original carry distance, whereas in the 4" pipe the second flush moves the waste to 159% of the original distance.

Figure 10: Media Dam and Second Flush Wave

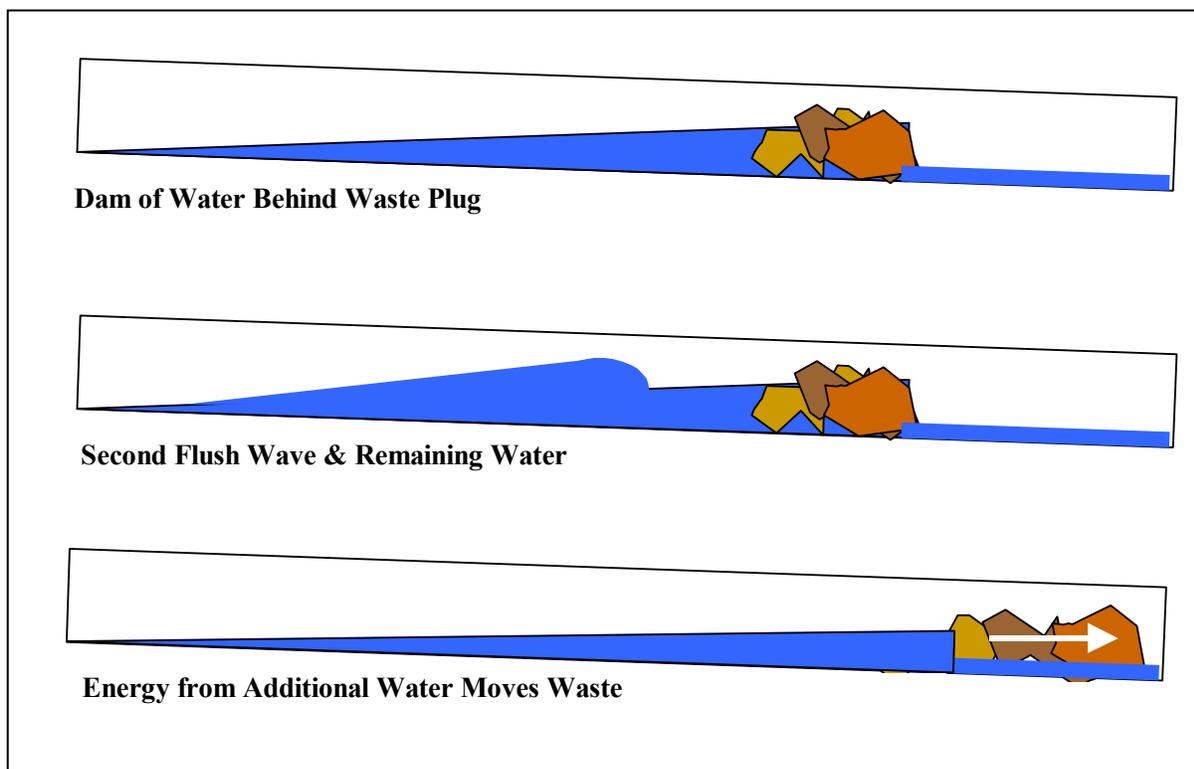
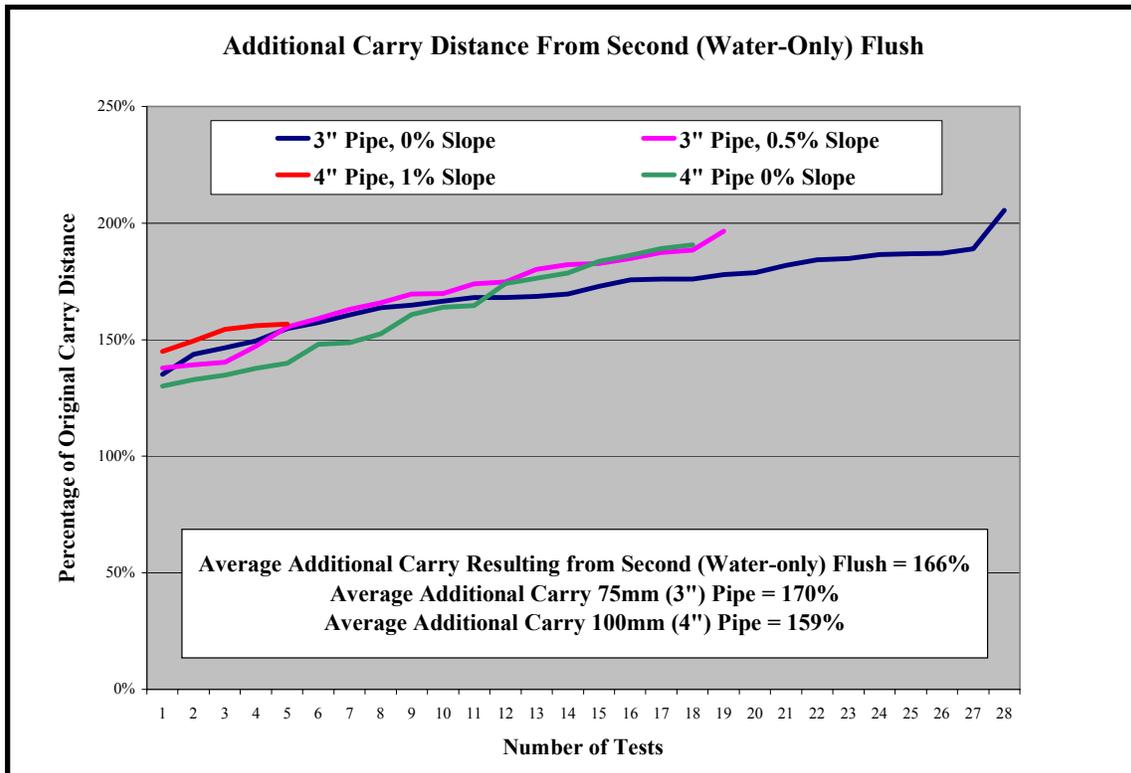


Figure 11: Additional Carry from Second Flush



Solids Second Flushes

Although only a limited amount of testing was completed involving second flushes that included solids (i.e., two consecutive solids flushes) the results were that in most cases the second (solids) flush moved the centre of mass of the test media only *slightly* further along in the pipe. In some cases the media from the first and second flush would form an even larger *plug*.

These results appear to agree with the Swaffield/Galowin study³⁰ which shows that a subsequent solids flush in a 4" pipe at 1% slope will move the centre of mass of the waste media to approximately 125% of its position after a single solids flush (vs. slightly greater than 150% for a second liquid flush under the same conditions).

Fortunately, in residential applications solids flushes are generally followed by one or more liquid-only flushes. This may not be the case in commercial applications, especially in Mens washrooms where urinals are present (i.e., toilets may be used primarily for solids flushing).

³⁰ To The Limits – Wastes in Drainage Systems, Transport in Drainlines – Unsteady Flow Conditions, Swaffield & Galowin, Figure 17, pg 2023 shows carry of approximately 26.5 m at 13.25 litres vs. 8 m at 6 litres (2.6 m/L).

6. Minimum expected carry distance for 6.0-Lpf (1.6-gpf) toilets.

Based on the results of this study it seems clear that many of the concerns surrounding the use of 6.0-Lpf (1.6-gpf) toilets and the potential for drainline blockages are unfounded. Although this study was entirely a lab-based effort, many of the findings are largely supported by other field-based studies or computer modeling programs.

Most of the concerns expressed by the public concerned the ability of water-efficient toilets to carry solid waste to the sewer, especially if there are no supplemental flows (e.g. from showers or clothes washers) available.

When only a single toilet is installed on a horizontal drainline (as in residential applications) the size of the drainline is typically 3" and a slope of 2% is required. Under these conditions the results of this study project a 6-litre (1.6-gallon) toilet will have an average carry distance³¹ of approximately 21m (70 ft) in a single flush, with a range of between 16m and 27m (52 ft to 88 ft) depending on the type of flush system used³². This carry distance far exceeds any field requirements in typical household applications, though not necessarily in commercial applications.

The minimum distance specified within the Canadian and U.S. plumbing standards for any given fixture is at least 12m (40 ft) for a 100mm (4-in) drainline at a 2% slope. Given that 4" pipes would only be used for multiple toilet installations or where there are significant supplemental flows it appears highly unlikely under these conditions, based on the results of this study, that water-efficient toilets would lead to any type of drainline clogging or blocking under normal use.

Table 5 summarizes the average distance achieved by the eight 6.0-Lpf (1.6-gpf) fixtures and the one 4.0-Lpf (1.1-gpf) fixture. These values assume, of course, that the drainline is properly installed and in good condition.

³¹ Based on a mass loading of 200g.

³² Conclusion based on results using plastic pipe and toilet models identified in this report.

Table 5. Waste Carry Distances (at 200g load)³³

Fixture Type	Drainline Installation Characteristics			
	75mm (3-in) drainline		100mm (4-in) drainline	
	1% slope	2% slope	1% slope	2% slope
Pressure-Assist – 6.0-Lpf (1.6-gpf)	13.6m (45 ft)	24.4m (80 ft)	10.6m (33 ft)	19.5 m (64 ft)
Gravity – Rim Jet	11.8 (39 ft)	24.4m (80 ft)	8.8 m (29 ft)	16.6 m (54 ft)
Gravity – 75mm (3 in) Flush Valve	10.6 (35 ft)	24.4m (80 ft)	9.2 m (30 ft)	15.7 m (52 ft)
Gravity –Jet in Sump of Bowl	11.3 (37 ft)	24.4m (80 ft)	7.8 m (26 ft)	16.3 m (53 ft)
Gravity – Jet in Trapway	11.3 (37 ft)	24.4m (80 ft)	8.7 m (29 ft)	11.8 m (39 ft)
Gravity – Tipping Bucket	9.1 m (30 ft)	24.4m (80 ft)	7.3 m (24 ft)	14.2 m (47 ft)
Gravity - Washdown	8.8 m (29 ft)	19.4 m (64 ft)	6.4 m (21 ft)	10.3 m (34 ft)
Gravity – Vacuum-Assist	11.3 (37 ft)	12.7 m (42 ft)	7.1 m (23 ft)	9.8 m (32 ft)
Pressure-Assist – 4.0-Lpf (1.1-gpf)	11.3 (37 ft)	12.8 m (42 ft)	6.7 m (22 ft)	9.2 m (30 ft)

Given the relatively short drainline lengths *within* typical homes³⁴ there should be no concern regarding the installation of a 6.0-Lpf (1.6-gpf) toilet fixture even if there are no other supplemental flows from showers, faucets, washing machines, etc. Furthermore, even if a 2% slope cannot be achieved³⁵ with horizontal pipe runs (which are generally 15 feet or less in residential new construction), there should likewise be no concern, since a 1% slope will be satisfactory in most instances.

Some professionals (including some plumbers) have stated that 6.0-Lpf (1.6-gpf) toilets are particularly not suitable for use in basements, i.e., that they are more susceptible to drainline blockages. Our study does not support this belief. In fact, if the drainline diameters, slopes, etc., are installed correctly, there should be no difference in performance (a pipe doesn't "know" that it is installed in a basement). The problem may be related to the fact that it is sometimes more difficult to install piping to service basement fixtures, e.g., excavation of subsoil may be difficult resulting in drainlines being installed with inadequate slopes or with dips, sags, or bends, or the length of drain piping installed may be greater than typically installed in above-grade situations.

In summary, Figures 12 and 13 illustrate expected drainline carry distances given the three most important factors: slope, flush volume, and mass loading. A rectangle indicator on the charts identifies the expected performance range for an average 6.0-Lpf (1.6-gpf) toilet and a drainline of 2% slope.

³³ Total length of test piping was 24.4 m (80 ft).

³⁴ Lengths of drains from home to sewer or septic tank may be considerably longer but would benefit from the addition of supplemental flows.

³⁵ In fact, a 2% slope is almost impossible to achieve in residential new construction with runs of greater than 1.27m (4 ft), as is noted in Appendix A.

Figure 12: Drainline Carry in 3" Diameter Pipe

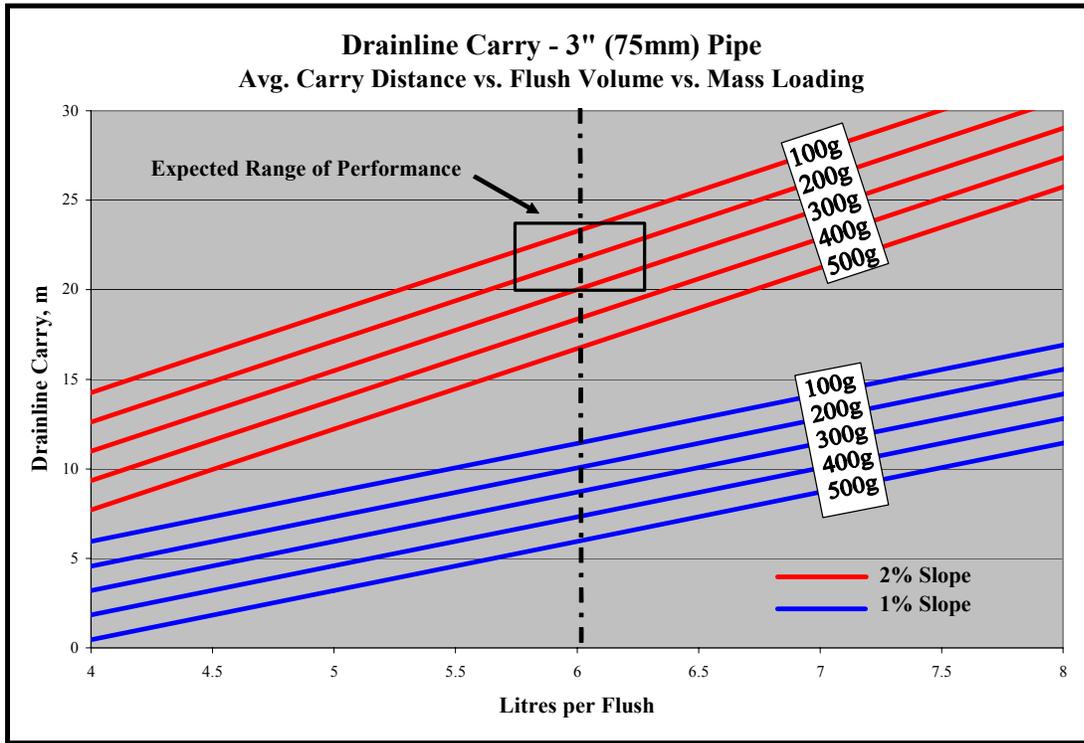
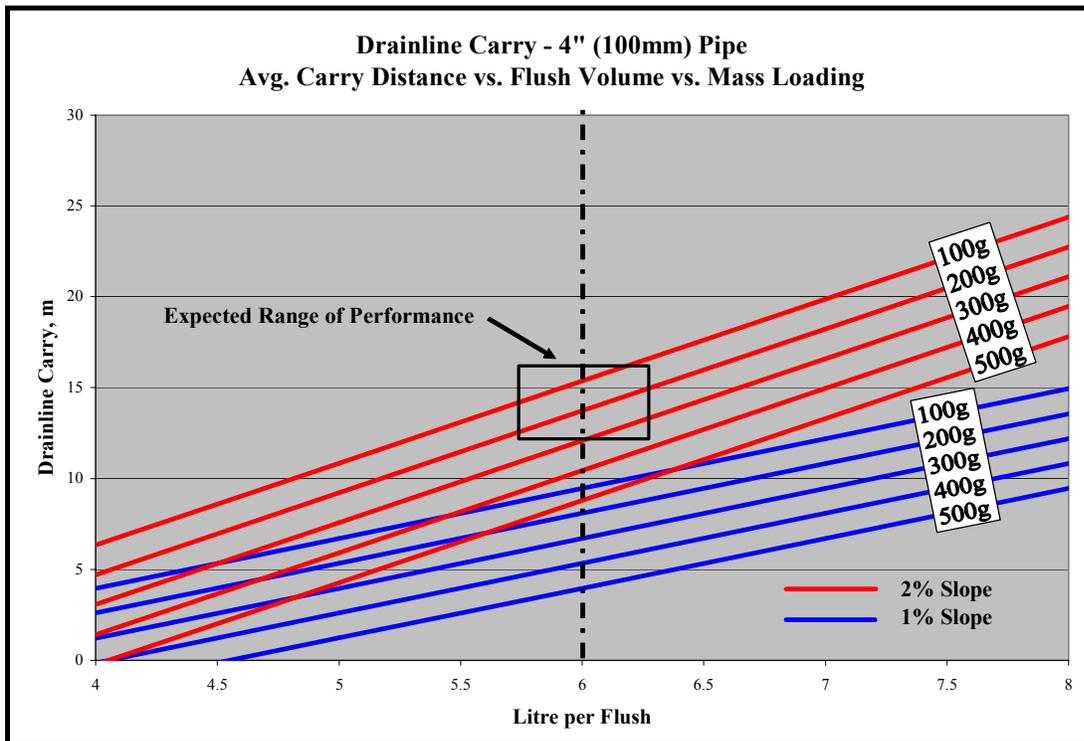


Figure 13: Drainline Carry in 4" Diameter Pipe



7. Effect of Drainline Dips or Sags on Waste Carry

As expected, dips or sags in the drainline will affect waste carry distances. Although this aspect of the testing program was not exhaustive (there is an unlimited number of possible variables to evaluate dips, sags, bends, bumps, buildup within the pipe, rough pipe walls, etc.), it was intended to verify that installing piping that is not straight and true can lead to reductions in carry distances. As such, the results of this analysis are meant only as examples of the type of findings that may result if drainline installations are not straight and true.

The methodology used involved beginning with a straight and true length of 3" drainline at 2% slope and then imparting a sag to the line by lowering a support at one of the pipe joints. An example of the methodology used is illustrated in Figure 14 below. The amount of the sag was increased in 12mm (0.5 in) stages from zero to 36mm (1.5 in) and the effect on carry distance was recorded. Two sag locations were tested for the 6-litre rim-jet toilet (Figure 15a) at 3 and 6m (10 and 20 ft) and a single sag location was tested for the 4-litre (1.1-gallon) pressure-assist toilet (Figure 15b) at 3m (10 ft).

Figure 14: Illustration of Imparting a Sag to Drainline

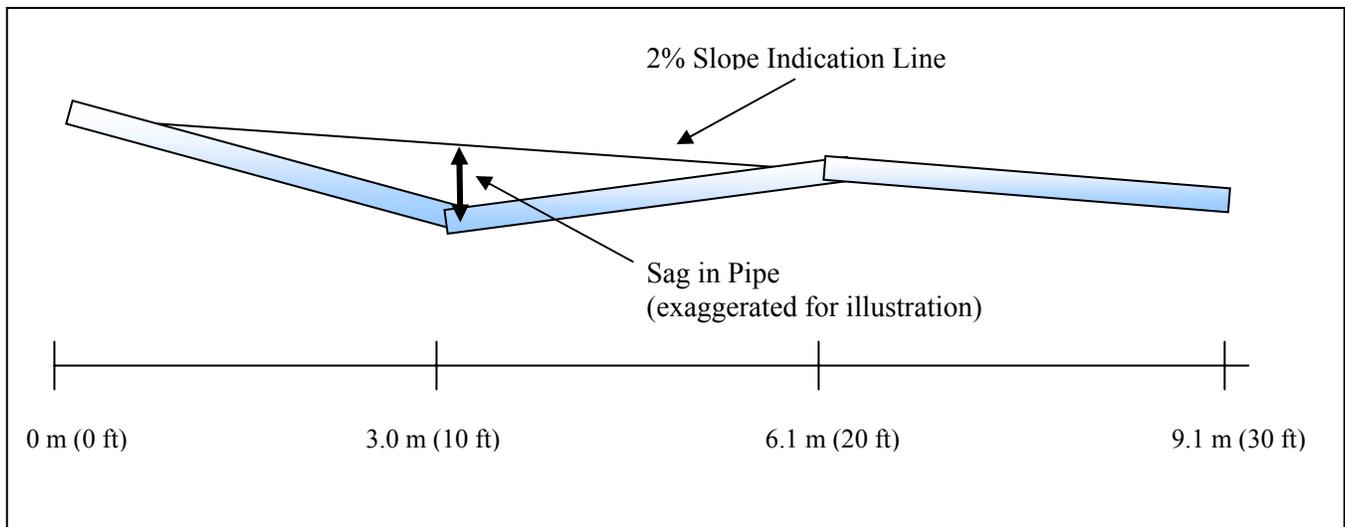


Figure 15a: Effects of Sag in Pipe Slope

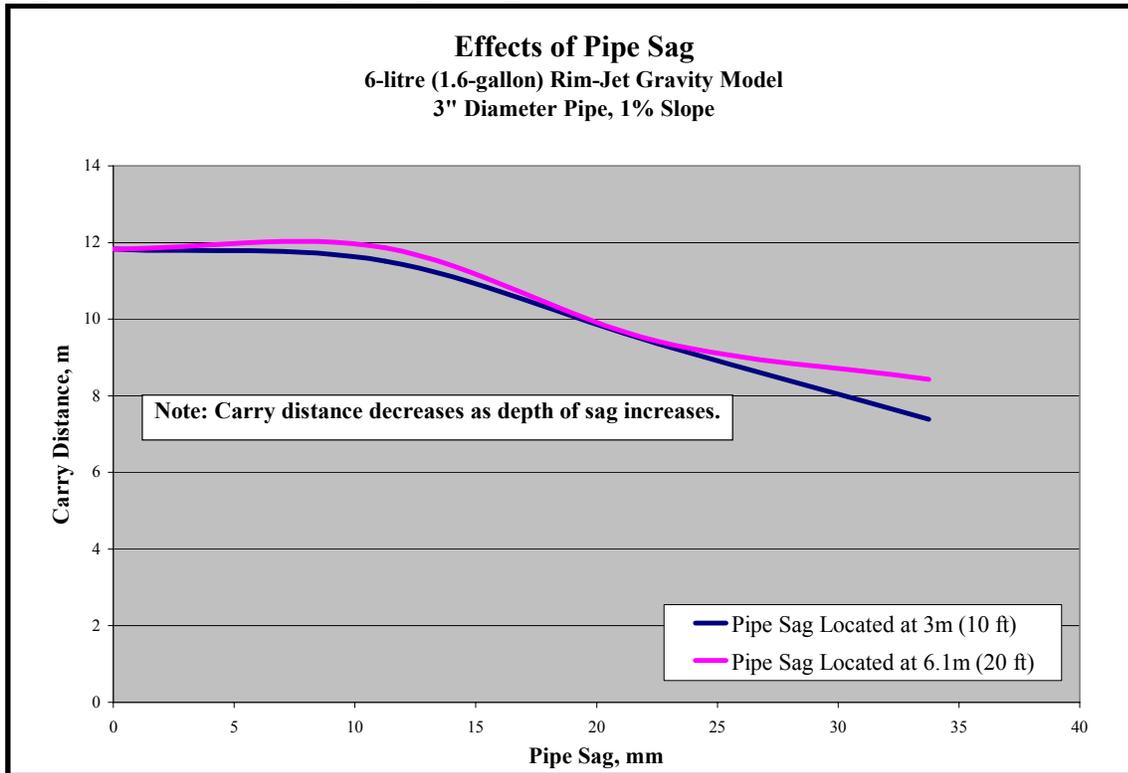


Figure 15b: Effects of Sag in Pipe Slope



8. Effect of Blocking the Vent on Waste Carry

Approximately ten consecutive tests were completed measuring waste carry distances alternately completely blocking and then opening the vent to the drainage system. Further testing was not completed as no difference in drainline carry was observed under these two different conditions.

It should be remembered, however, that in this study the piping discharged to atmosphere vs. the normal condition of discharging into a sewer. Venting may also be more of a problem if larger flows are introduced (e.g., via a clothes washer) or if significant dips or sags are present in the pipe that may prevent the flow of air.

9. Comparison of Solid Media: Soybean Paste to ‘Water Wigglers’

Because they are re-usable and are promoted as representative of human waste in a plumbing system, ‘Water Wigglers’ are being used by manufacturers and other testing laboratories as one of several test media. The purpose of the analysis in this study was to compare the carry distances of the soybean paste and toilet paper used in this test regime with ‘Water Wigglers’ when all other variables are held constant. Two different wigglers were used as test specimens: the green sample was approximately 12cm (4.75 in) long and 4.0cm (1.6 in) in diameter with a mass of about 160g and the red specimen was approximately 12cm (4.75 in) long and 3.5cm (1.4 in) in diameter with a mass of about 132g (see photo).



Although not exact, the green specimen (160g) was compared to a media mass loading of 150g, and both the green and red specimens combined (292g) was compared to a media mass loading of 300g. Testing was completed on three different toilet types: rim-jet gravity model, 4-L pressure-assist model, and washdown model. Test results are illustrated in Figures 16a and 16b.

In general, it was more difficult to flush the ‘Water Wigglers’ from the toilet than the test media, i.e., they often became stuck in the toilet trap, causing clogs. When they did flush from the toilet they would float in the pipe even with very little water to buoy them and, therefore, they traveled a significant distance further than the simulated soybean paste media used in our testing. As noted in Figures 16a and 16b, the ‘Water Wigglers’ exhibited very different drainline carry characteristics than the simulated waste (soybean paste and toilet paper).

Though, as stated earlier, the comparison testing between the realistic test media used in this study and ‘Water Wigglers’ as a test media was not extensive, the results show ‘Water Wigglers’ were carried an average of 159% of the distance of the soybean media in a 3” pipe at 1% slope. Based on these limited results it does not appear that ‘Water Wigglers’ constitute a suitable test media for toilet drainline carry studies.

Figure 16a: Comparison of Soybean Test Media and Water Wigglers

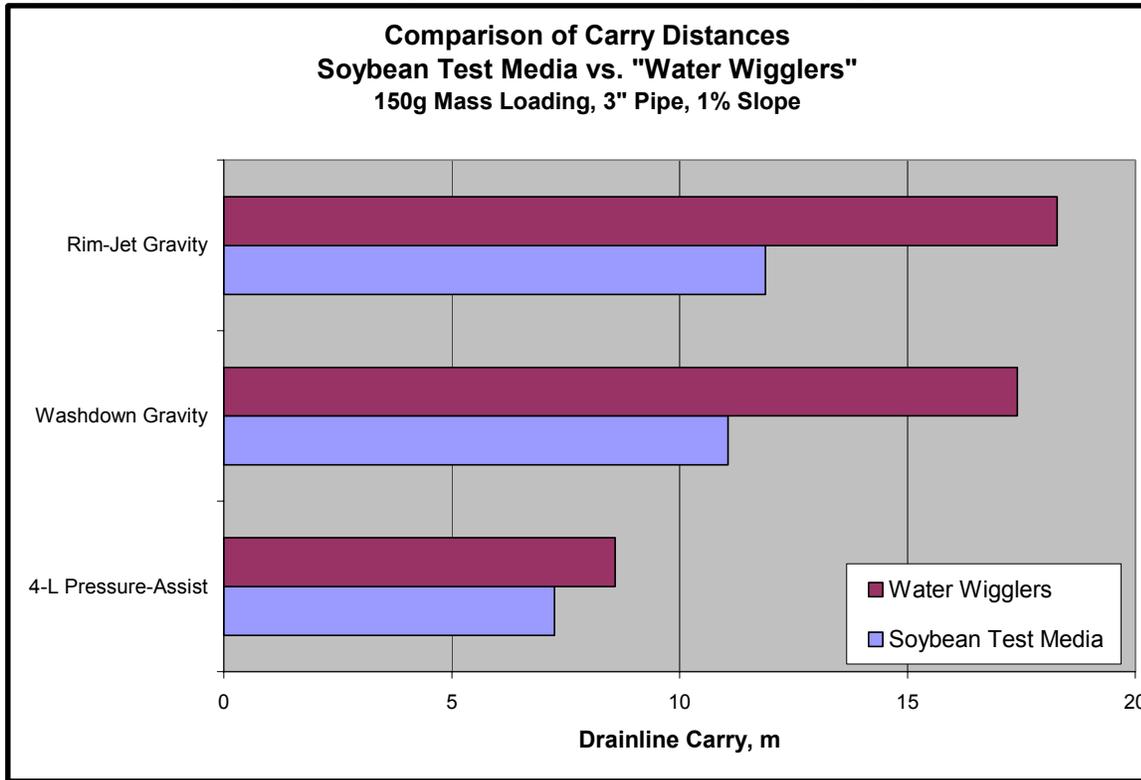
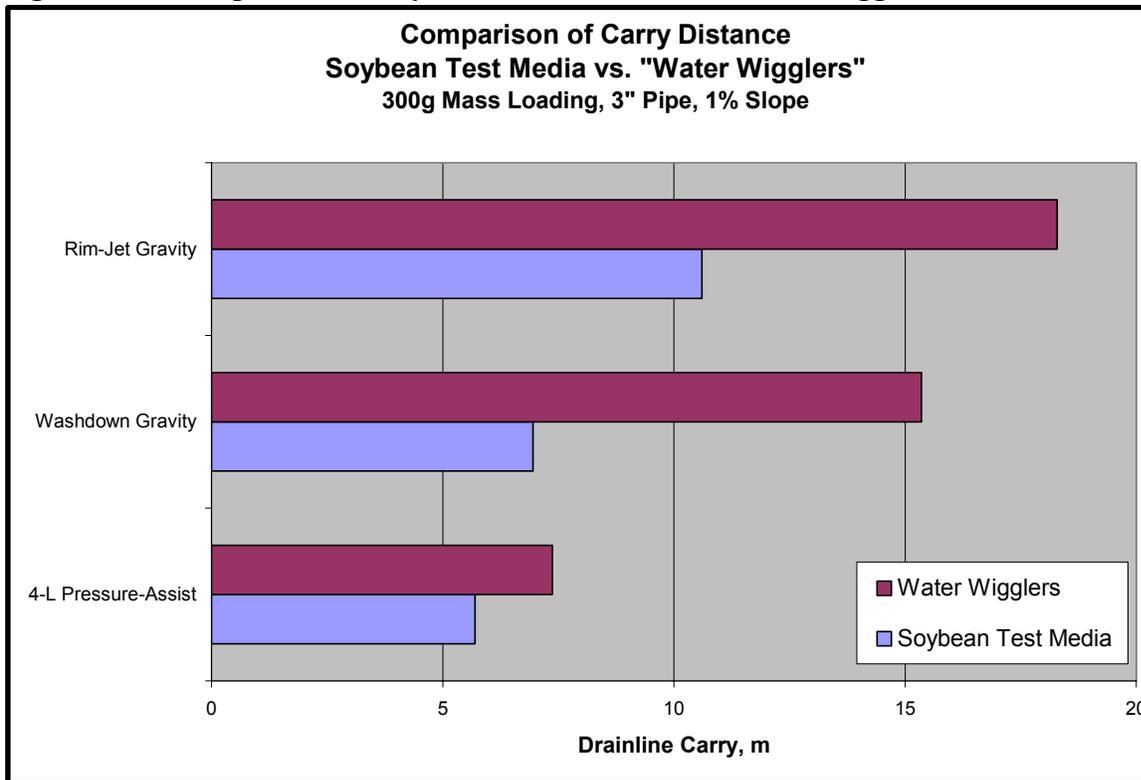


Figure 16b: Comparison of Soybean Test Media and Water Wigglers



CONCLUSION

Under expected and required conditions virtually all 6-litre (1.6-gallon), and even 4-litre (1.1-gallon), toilets should meet or exceed household requirements regarding sewage flow even with no supplemental flows (e.g., from showers or clothes washers). Problems with drainline clogging or blocking are likely attributable to either installation problems, the intrusion of roots, buildup of grease or grit in the pipe, broken or misaligned pipes, or the flushing of inappropriate materials rather than the low flush volumes of today's water-efficient toilets.

Installations with extremely long drainage distances, e.g., shopping malls or industrial sites, may require evaluation on a site-by site basis, especially if no supplemental flows are available.

Possible Further Testing

Budget and time constraints naturally resulted in the following limitations to project testing:

- cast iron pipes were not tested due to insufficient budget and difficulty in observing carry distances without cutting holes in pipe (holes will alter 'venting' characteristics)
- waste media failing to clear the entire length of drainline in a single flush was not allowed to dry out completely before the second flush (simulating weekend or vacation drying of media in drain) because of time constraints
- no testing was completed using sanitary napkins
- no testing was completed using increasing loadings of toilet paper
- no testing was completed on old piping removed from demolished buildings
- no testing was completed to assess the effects of supplemental flows from faucets, showers, clothes washers, or dishwashers
- no testing was completed on toilet models that repeatedly fail to clear at least 200g
- testing was completed for only two flange-to-drain conditions (minimum and maximum drop heights); a more circuitous route from flange-to-drain may effect carry distances.
- no testing was completed to compare the various test media and methodologies used for drainline testing by different test agencies or nations.

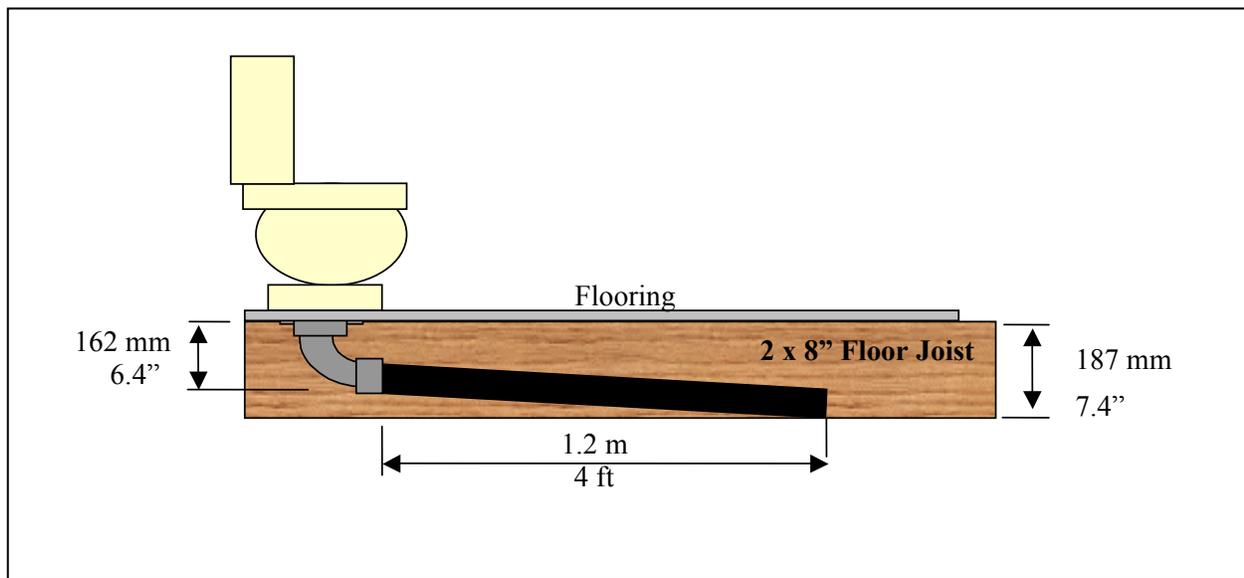
APPENDIX A

ACHIEVING SLOPES OF 2% IN NEW CONSTRUCTION

During an interview with a plumbing inspector, it was learned that although the plumbing code calls for slopes of 2% (often stated as a quarter of an inch per foot), this is sometimes not practical given the limited depth available in typical floor construction. That is, 2 x 8 inch lumber is commonly used as floor joists and, when dressed, this lumber typically has a depth of only 187mm (7 3/8 in).

The inspector stated that, because it is often not possible to achieve a 2% pipe slope without protruding below the bottom of the floor joists he (and he suspects most other inspectors) permit slopes of less than 2%, even though they do not meet code requirements, without issuing violation notices.

The illustration below helps to define this situation.



A 75mm (3 in) drainline used with a typical floor flange and 90 degree elbow has a total depth to the bottom of the pipe of approximately 162mm (6-3/8 in). Therefore, only about 25 mm (1 in) of space is available before running out of depth. At a 2% slope, this limited dimension permits a run of only about 1.2m (4 ft) before the drain pipe would drop below the bottom of the joist. Even at 1% slope, the maximum distance would be only 2.4m (about 8 feet).

Based on this assessment, it is likely that drainline slopes in many residential dwellings may be less than 2%. Fortunately, the results of this study indicate that slopes of 1% (and even less) may be sufficient to carry waste materials the short distances normally required in household applications.