# REVIEW AND EXPERIMENTAL TESTING OF GRAVITY DISTRIBUTION METHODS FOR ONSITE WASTEWATER TREATMENT SYSTEMS

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## Abstract

This project evaluated the ability of various parallel distribution devices to provide even lateral distribution between multiple drainpipes and longitudinal distribution along the length of each pipe. Drainpipes were attached to each distribution device to be tested as they would be in an onsite wastewater treatment system (OWTS), and the assembly was elevated slightly above the ground so that the effluent could be collected and measured. The devices tested included header pipes, splitter tee, distribution box, and a surge box. Each device was evaluated using clean water in multiple configurations. Configurations tested included level and tilted (2 and 5%), inflow rates of two gallons per minute (GPM), five GPM, and 25 GPM. Configurations with two or four outlet pipes, and with and without drain holes at the 6 o'clock (bottom) position of each drainpipe were also tested. It was observed that the surge box provided the most even lateral and longitudinal distribution in the majority of configurations. All devices performed well when level with an inflow of 5 GPM, two outlets, and no 6 o'clock drain holes. When these parameters were varied, the evenness of distribution provided by the header pipes, splitter tee, and distribution box decreased. The results indicted the surge box provided more even distribution both laterally and longitudinally when configured to dose a higher volume of effluent. The experiment did not evaluate the impacts of biofilm accumulation, drain field distribution media, or biomat development, all of which would be present in a real OWTS.

## Introduction

In OWTS employing parallel distribution, the gravity flow from the septic tank is designed to be split evenly across the soil treatment area (STA). Flows can be split through perforated piping and rock, synthetic media, hollow chambers, or other mechanisms. Because STA design is dependent on the flow volume, equal distribution between trenches or beds in the STA is crucial to properly treat the wastewater and preserve the lifespan of the soil (Converse et al., 1977; L. Gill, 2009; McGauhey & Winneberger, 1967; Otis et al., 1974). Even distribution includes both even flow volumes split between trenches or beds, and even longitudinal dispersal across the length of each trench or bed. Importantly, systems are sized with the assumption that even distribution is achieved. The long-term acceptance rate of a system only holds if effluent is distributed evenly. Uneven distribution poses several threats to the effectiveness of an OWTS including ineffective soil treatment and potential groundwater contamination. Excessive soil pore clogging and impacts on soil longevity are further potential risks.

There are several products on the market which are designed to split gravity driven effluent flows. Header pipes, distribution boxes, splitter tees, and surge boxes are all used in parallel distribution and are the focus of this study. Pumps and siphons change the distribution process by adding dosing, distributing effluent across the entire soil treatment area when properly designed.

Header pipes (Figure 1) directly distribute effluent from the primary treatment device to receiving drainpipes in the STA. A header pipe can be considered the simplest method of effluent distribution. Typical header pipe systems do not offer the ability to manage the soil treatment area by adjusting the effluent flow to each section. They can be used with two or more outlets.

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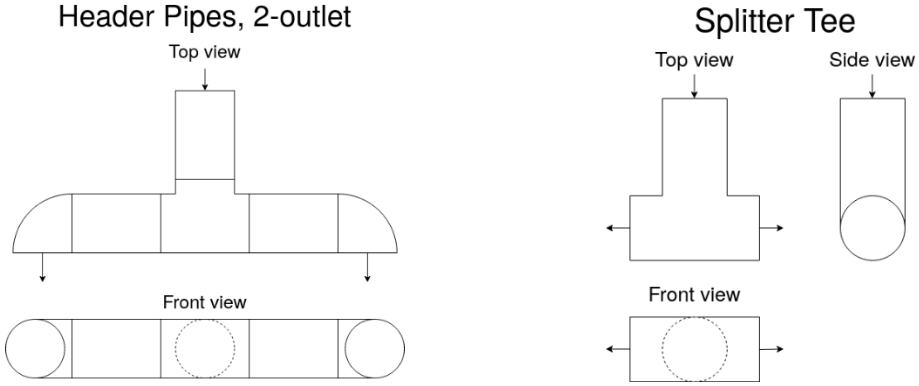


**Figure 1**: Header pipe with two outlets. And splitter tee.

A splitter tee is another option for parallel distribution drain fields. It operates very simply by splitting effluent into two flows with a baffle system inside pipe junction. A distribution box (Figure 2) is a container with a single inlet and multiple outlets. Distribution boxes are similar to header pipes in their simplicity but can allow for easier management of the soil treatment area by, for instance, adjusting the flow to each outlet with speed levelers.

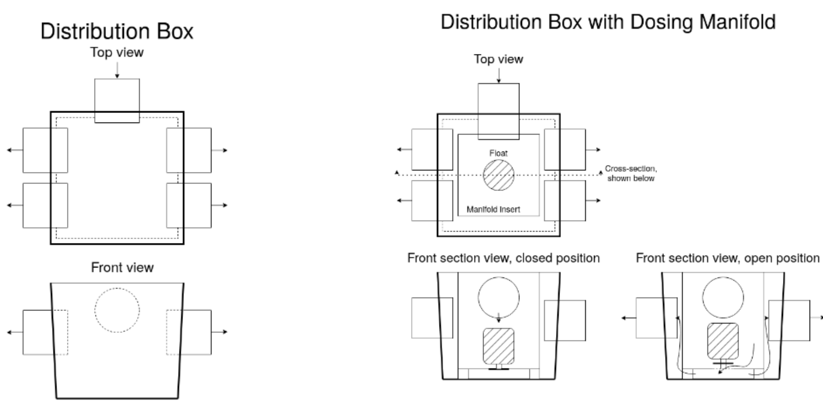


**Figure 3:** Distribution box with four outlets and a surge box.

A surge box is a dosing distribution device. Like a distribution box, they have a central box with several outlet pipes. The difference is that surge boxes can store effluent so it can be released in larger-volume pulses using, for example, a float that unseals an opening when the accumulated effluent reaches a certain level as shown in the figure. Another method of dosing is a tipping bucket that fills to a certain level before tipping and releasing effluent to one or more outlets.

Dosing can also be achieved with siphons or pumps. Siphons build up a volume of effluent in their piping until gravity creates a pressure differential that forces a pulse of effluent. A siphon requires a separate compartment or tank to function correctly. Unlike surge box, siphons and pumps provide only dosing and not flow-splitting, so a device such as a header pipe, splitter tee, or distribution box must be used to distribute the effluent,

Gravity fed distribution devices are advertised to distribute flow equally across STAs and trenches. In practice, equal distribution is nearly impossible to achieve with current gravity distribution devices. Previous studies reveal that distribution boxes and splitter tees are unreliable for even distribution (Gill et al., 2009). Even when installed perfectly level, the distribution boxes performed poorly, preferring two of four outlets. The tee splitters performed better than distribution boxes under perfect laboratory conditions (Patel et al., 2008b). However, in the field both distribution devices performed poorly—over time, uneven solids deposition and biofilm growth made even distribution impossible. A v-notch weir was added to a traditional distribution box but provided marginal improvement in distribution efficacy (Gill et al, 2009)

Realistically, settling will undoubtedly tilt even the best of installations (Hygnstrom et al., 2006). Compaction due to traffic and, in colder areas, freeze/thaw cycles, can also contribute to tilting. Many OWTS also only operate under low flow conditions (< 0.5 GPM) which contribute to preferential drainage (L. Gill, 2009). Under such conditions, a distribution box which is only a single degree off level can result in uneven drainage (Patel 2008b). The pipes exiting distribution boxes also present a risk of reduced distribution efficacy because they are not always installed at the same angle (see Figure 4). Further, the outlets of plastic distribution boxes are cut manually in the field, introducing the possibility that they may differ in height; this is less of a problem for distribution devices with outlets cut by the manufacturer.

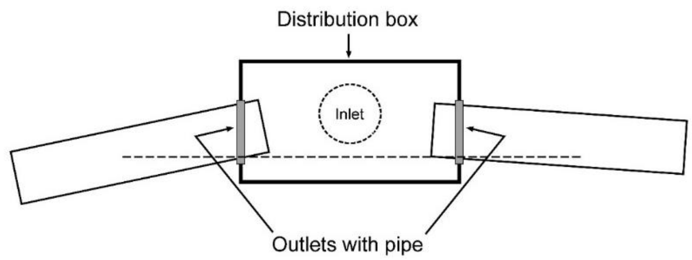


**Figure 4:** Diagram showing outlet pipes of a distribution box installed at the same elevation but different angles (CIDWT, 2009).

Siphons can be used to dose flows and still align with the passive management of gravity systems. However, previous research has found that siphons commonly trickle without frequent maintenance (Converse et al., 1984; Converse & Falkowski, 1987). Trickling reduces the efficiency of these devices. Note that these studies were conducted in the 1980s, with no research available about the function of modern siphons.

Pumps are the active alternative to siphon dosing and have been utilized effectively in pressurized systems (Converse et al., 1977). Pumps are also used to overcome elevation issues when the STA is uphill from the sewage source. A pump-to-gravity system pumps effluent into the distribution device but faces the same difficulties with even distribution as a gravity system because the effluent still drains out via gravity. The use of a pump may provide some benefits by scouring out the distribution device and avoiding the trickle flow of gravity distribution. If a pump is added to overcome elevation issues the designer and installer should consider using the pump to pressurize the system and achieve uniform distribution over the STA; the significant cost of the dosing chamber, controls, electricity, and pump have already been added to the system, so the additional cost of a pressurized system is in utilization of pressure rated pipe. Many companies recognize that completely level installations are not possible and have designed inserts such as v-notch weirs, baffles, or internal leveling devices to improve distribution, but data is generally not available about such products.

In contrast to a traditional distribution box, the SeptiSurge is a dosing manifold inside a distribution box. When sufficient volume accumulates, the device triggers and releases effluent to the distribution box outlets (SeptiSurge, 2015, 2021). In-house testing conducted by distributors of the SeptiSurge dosing manifold showed a standard deviation of under 2.05 L (0.54 gal) of flow between six outlets using a 65 L (17.17 gal) dose, even when the one side of the device was elevated by 1/8 inch. The velocity of effluent induced by the surge could overcome some limitations of gravity distribution; further distribution along the length of drain field piping and forceful removal of biofilm accumulation at the distribution device outlets could result in more equal effluent loading. The problem of inflow momentum causing certain outlets to be favored is mitigated by the location of the outlet at the bottom center of the dosing manifold insert.

## Experimental Scope

The experiment described in this report sought to compare available parallel distribution devices by assessing the ability of each to distribute flow equally to two or four outlets, and to distribute flow down the length of perforated drainpipes. The devices tested included:

1. header pipe,
2. splitter tee,
3. distribution box
4. distribution box with speed levelers
5. distribution box with SeptiSurge insert

The header pipe and distribution box were each tested in both two- and four-outlet configurations. All devices were evaluated level, 2% tilt, and 5% tilt states. This parameter was chosen because improper installation, settling, and freeze/thaw cycles can tilt distribution devices in real systems, favoring lower over higher outlets. It should be noted that the results obtained in the level configuration are not representative of the distribution efficacy of real systems, due to the extreme difficulty of installing and especially maintaining any distribution device in a perfectly level configuration. Figure 5 shows a diagram of the two-outlet header pipe in both level and 5% tilt configurations, as an illustration of how each device was tilted.

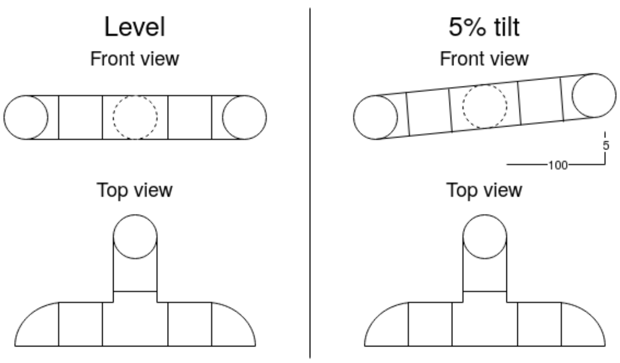


**Figure 5:** Diagram of two-outlet header pipes in both level and 5% tilt configurations.

Two kinds of drainpipes – one with only rows of 4 o'clock and 8 o'clock holes, and another with an additional 6 o'clock drain hole per 10-foot length of pipe – were also evaluated. Distribution pipes with 6 o'clock drain holes are commonly used in Canada but are less common in the United States. One of the goals of the experiment was to determine whether effluent exits through the 4 o'clock and 8 o'clock holes in pipes with 6 o'clock drain holes. Drainpipe was only used for the longitudinal distribution tests, which were performed with the distribution device in its level configuration. The drainpipes were kept approximately level along their longitudinal axes.

All devices were evaluated at flow rates of 2 US gallons per min (GPM) and 5 GPM, except for the SeptiSurge which was only evaluated at 2 GPM. The lower flow rate of 2 GPM was selected as a typical outflow rate from a septic tank, while the 5 GPM rate represents the outflow from a septic tank in a higher-volume system. The higher flow rate was expected to provide more distribution with the traditional distribution devices. Both information from the manufacturer and preliminary tests (not reported herein) indicate that the discharge flow from the SeptiSurge is not impacted by the rate of inflow when that rate is less than the outflow rate, but only by the quantity of liquid in the reservoir when the discharge triggers. Accordingly, the SeptiSurge was evaluated with a standard dose volume of approximately 10 liters (L; 2.64 US gallons) and a triple dose volume of approximately 30 L (7.93 G). A subset of configurations was also tested at a higher flow rate of 25 GPM, chosen to represent a pump-to-gravity system. The configurations tested at 25 GPM were lateral tests with no tilt and 5% tilt and longitudinal tests with 6 o'clock drain holes, using the splitter tee, distribution box with and without speed levelers, and the SeptiSurge. All 25 GPM tests were performed with four outlets, except those tests performed on the splitter tee, which was assessed with both of its two outlets. Each configuration of the experimental setup was tested once, and the results should therefore be regarded as observational in nature.

## Methods

The test setup consisted of a hose, two buckets, connecting PVC pipe, distribution device, drainpipe, and collection pans. The hose was an ordinary garden hose, the flow rate of which was adjustable using a valve. Water from the hose flowed into the reservoir bucket, which was elevated above the rest of the testing equipment. The reservoir bucket had a horizontal outlet near the bottom made of 2-inch PVC pipe, the flow through which was adjustable using a 2-inch PVC ball valve. The reservoir bucket was also graduated. The first mark on the reservoir bucket showed the water maximum level at which no water would flow through the horizontal outlet when the bucket was level; this mark is referred to as the datum. The second mark showed the water level at which the reservoir bucket and horizontal outlet pipe upstream of the valve hold one (1) gallon of water in addition to the volume required to fill the bucket to the datum; this mark is referred to as the 1-gallon mark. The third mark showed the water level at which two (2) gallons are held, the forth mark, 2.5 gallons, and the fifth mark three (3) gallons; these marks are referred to as the 2-gallon mark, the 2.5-gallon mark, and the 3-gallon mark, respectively.

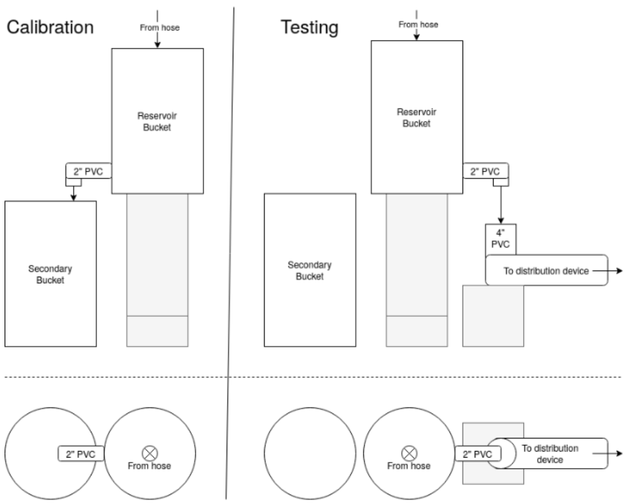


**Figure 7**: Reservoir bucket, secondary bucket, and PVC pipes to distribution device in hose calibration and testing configurations.

The secondary bucket was not used directly in the experiment. Rather, the hose was redirected into the second bucket to stop the flow of water into the reservoir bucket immediately, without varying the flow rate by adjusting the valve on the hose while still discharging into the reservoir bucket. When the valve on the horizontal outflow of the reservoir bucket was open, water flowed from the reservoir bucket through the 2-inch PVC of the horizontal outflow, and into a length of 4-inch PVC pipe. The 4-inch pipe was elevated slightly off of the floor, to the same height as the distribution device and drainpipes. Water flowed directly from the 4-inch pipe into the distribution device. During triple dose volume (7.93 G) tests of the SeptiSurge, an additional ten (10) foot length of 4-inch pipe was added directly upstream of the distribution device. Figure 7 shows a diagram of the reservoir and secondary buckets, along with the 4-inch pipe leading to the distribution device, in both hose calibration and testing configurations.

Downstream of the distribution device were four (4) 20-foot lengths of 4-inch drainpipe, elevated slightly off the floor. Collection pans were placed under the holes of each drainpipe to collect the water that flowed out of them. Depending on the test, either all four (4) drainpipes, only two (2) drainpipes, or no drainpipes were connected to the outlet of the distribution device. In case no drainpipes were connected, collection pans were placed directly beneath the outlets of the distribution device to catch all of the water that flowed out. Figure 8 shows a diagram of the drainpipe with 6 o'clock drain holes; the pipe without 6 o'clock drain holes was identical except it lacked the row of ½-inch diameter holes down the center of the pipe. Commercial drainpipe was used for the pipe with only 4 o'clock and 8 o'clock holes. For the pipe with 6 o'clock drain holes, an additional hole was drilled in each 10-foot length of pipe.

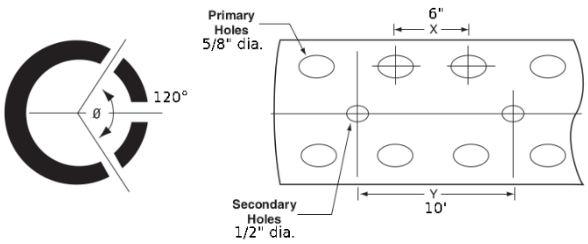


**Figure 8**: Diagram of drainpipe hole locations for pipe with 6 o'clock drain holes.

Drainpipes were elevated on concrete blocks, and a level was placed on each section of drainpipe to ensure it was approximately level along its longitudinal axis. Where necessary, pieces of wood were inserted between the drainpipe and supporting concrete block to ensure that each section of pipe was approximately level. It should be noted that drainpipes are not always level along their longitudinal axis in real soil treatment areas; for instance, Minnesota rules allow a downward slope of not more than 4 inches per 100 feet (MPCA 2020), and Ontario rules allow a downward slope between 30 mm (1.18 in) and 50 mm (1.97 in) per 10 m (32.8 ft) (Ontario 2012). Minor sagging (less than one vertical inch) was also observed in the drainpipes used in the test, which would not typically be present in a real soil treatment area due to the more uniform support provided by the underlying distribution media.

For the splitter tee, distribution box and septi-surge device evaluation they were positioned to receive the outflow from the reservoir bucket. For lateral distribution tests (i.e., with no drainpipe connected), a collection pan was placed at each outlet of the distribution device. For longitudinal distribution tests, a 20-foot length drainpipe was connected to each outlet of the distribution device, and collection pans were placed under the holes in the drainpipe. A reference meter stick was placed flat on the ground, flush with the upstream end of the distribution device. The tilt of the reference meter stick was measured with a level and adjusted by placing shims under one end of the reference meter stick until it was level. A second meter stick was then placed on top of the distribution device. A plumb line was used to measure the distance from each end of the second meter stick to the reference meter stick. The difference between this distance at each end was used to calculate the tilt of the distribution device. The tilt of the distribution device was adjusted by placing shims under one end of the distribution device until it attained the desired tilt – 5%, 2%, 0% depending on the test. For tests with the speed levelers, the speed levelers were inserted into the ends of the outlet pipes which protruded into the distribution box. Each speed leveler was adjusted to its lowest position. Additional tests were performed with correctly adjusted speed levelers as described below, but the primary set of tests was performed with the speed levelers in this unadjusted state.

For the standard header, a series of concrete blocks, two blocks for the two-outlet header or four blocks for the four-outlet header, were placed in a line near the reservoir bucket. The elevation of each block was adjusted with shims until level measurements between each adjacent pair of blocks indicated that all blocks were level. The header to be evaluated was then set on the blocks and positioned to receive outflow from the reservoir bucket. For lateral distribution tests, a collection pan was placed at each outlet of the header. For longitudinal distribution tests, a 20-foot length drainpipe was connected to each outlet of the header, and collection pans were placed under the holes in the drainpipe. For tests with 2% or 5% tilt, the necessary elevation of the header above each block to achieve the desired tilt was calculated. The header was then raised to the required elevation at each point along its length by inserting pieces of wood with known (previously measured) thickness between the header and the blocks on which it rested.

To calibrate the house the reservoir bucket was temporarily positioned such that its horizontal outflow discharged into the secondary bucket, rather than the connecting pipes leading to the distribution device. The horizontal outflow valve of the reservoir bucket was opened. The reservoir bucket was filled to the datum mark using the hose. Any water added over and above the datum was allowed to drain out into the secondary bucket. The horizontal outflow valve of the reservoir bucket was then closed. The hose was discharged into the reservoir bucket for a period of 30 seconds, as measured using a stopwatch. The depth to which the reservoir bucket had been filled during this time was noted. The reservoir bucket was then drained to datum by opening the horizontal outflow valve. The valve of the hose was adjusted, and the previous steps repeated until the bucket was filled to the desired depth – 1 gallon for 2 GPM tests or 2.5 gallons for 5 GPM tests – during the 30-second discharge period. The reservoir bucket was drained to datum by opening the horizontal outflow valve and then positioned such that its horizontal outflow would discharge into connecting pipes leading to the distribution device.

For the distribution testing the hose was discharged into the reservoir bucket with the horizontal outflow valve open, so that the water flowed into the distribution device. The time was continuously monitored using a stopwatch, and after 30 seconds the hose was immediately redirected into the secondary bucket. The hose was then turned off using its valve. The reservoir bucket was allowed to drain to datum level through the horizontal outlet. The volume of water in each collection pan was measured by emptying each pan into a graduated volumetric bottle. In SeptiSurge tests when the first 30-second discharge did not trigger a flush, the 30-second discharge was repeated until a flush was triggered.

For the pump to gravity testing 25 GPM was evaluated by replacing the elevated reservoir bucket with a larger reservoir container that sat on the ground near the inlet of the distribution device. A ¼ horsepower pump was used to pump water out of the reservoir into the distribution device. Instead of redirecting the flow to the secondary bucket to stop dosing at the end of the 30-second dosing period, the pump was simply turned off. The outflow from the pump was verified by measuring the volume of water discharged by the pump in a 12-second period. The volume was closer to 4.6 gallons than the expected 5 gallons, indicating that after head loss in the pipes between the reservoir and distribution device the flow rate was closer to 23 GPM. However, this is still well within the range of typical flow rates for a pump-to-gravity system.

In addition to the tests performed with all speed levelers in their lowest position as described above, two tests were performed with speed levelers adjusted to compensate for the tilt of the distribution device. These were conducted with the distribution box in its four-outlet lateral configuration at a 5% tilt, at flow rates of 2 GPM and 25 GPM. The speed levelers were first adjusted to their highest position, then the distribution box filled until the water reached the bottom of the outlet of the lowest speed leveler. The other three speed levelers were then adjusted until the bottoms of their outlets were also at the level of the water. Besides this speed leveler adjustment, the tests were conducted as described above.

## Results- Lateral Distribution

Table 1 shows the percentage of total flow directed into each outlet for two-outlet distribution devices at 2 GPM. Table 2 shows the same at 5 GPM. For the SeptiSurge, the results of the 2 GPM tests are provided in both tables because, as noted above under Procedure, the discharge flow rate from the SeptiSurge is independent of the inflow rate.

**Table 1:** Percentage of total outflow directed to each outlet of two-outlet devices, inflow rate of 2 GPM.

| Device | Flow to Left Outlet | Flow to Right Outlet |
|---|---|---|
| Header Pipes | | |
| Level | 49 % | 51 % |
| 2% tilt | 0 % | 100 % |
| 5% tilt | 0 % | 100 % |
| Splitter Tee | | |
| Level | 50 % | 50 % |
| 2% tilt | 9 % | 91 % |
| 5% tilt | 0 % | 100 % |
| Distribution Box | | |
| Level | 47 % | 53 % |
| 2% tilt | 0 % | 100 % |
| 5% tilt | 0 % | 100 % |
| D. Box with Speed Levelers | | |
| Level | 61 % | 39 % |
| 2% tilt | 0 % | 100 % |
| 5% tilt | 0 % | 100 % |
| D. Box with SeptiSurge, single | | |
| Level | 49 % | 51 % |
| 2% tilt | 33 % | 67 % |
| 5% tilt | 16 % | 84 % |
| D. Box with SeptiSurge, triple | | |
| Level | 47 % | 53 % |
| 2% tilt | 33 % | 67 % |
| 5% tilt | 21 % | 79 % |

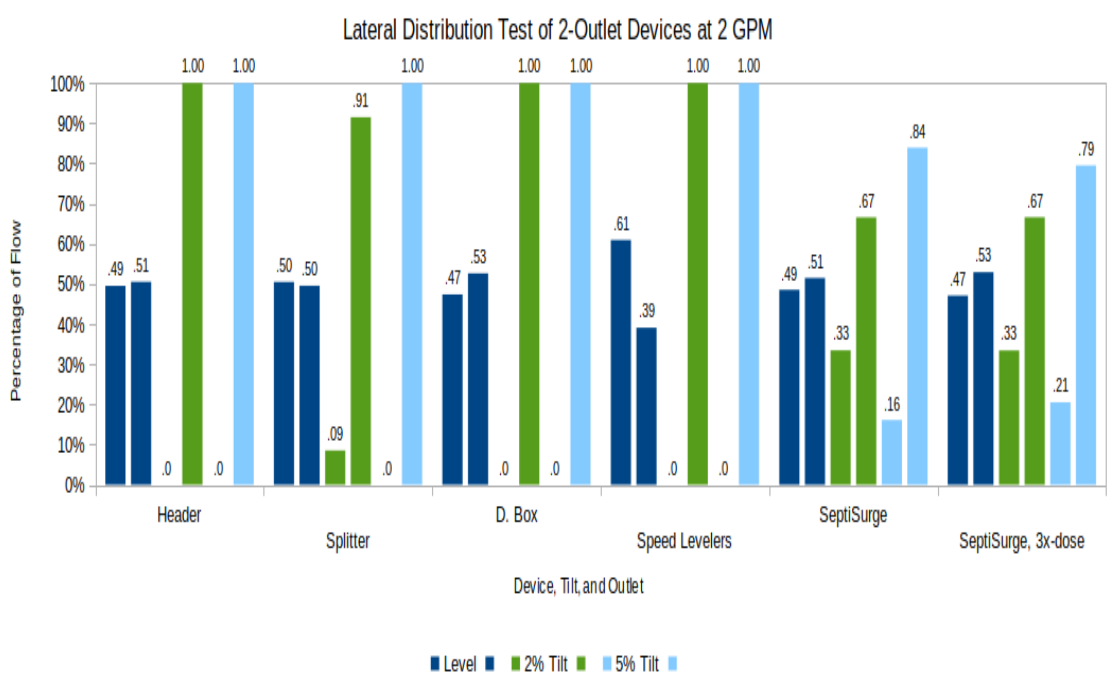


**Figure 9:** Percentage of total outflow directed to each outlet of two-outlet devices, inflow rate of 2 GPM.

**Table 2:** Percentage of total outflow directed to each outlet of two-outlet devices, inflow rate of 5 GPM.

| Device | Flow to Left Outlet | Flow to Right Outlet |
|---|---|---|
| Header Pipes | | |
| Level | 50 % | 50 % |
| 2% tilt | 1 % | 99 % |
| 5% tilt | 0 % | 100 % |
| Splitter Tee | | |
| Level | 50 % | 50 % |
| 2% tilt | 30 % | 70 % |
| 5% tilt | 0 % | 100 % |
| Distribution Box | | |
| Level | 51 % | 49 % |
| 2% tilt | 20 % | 80 % |
| 5% tilt | 0 % | 100 % |
| D. Box with Speed Levelers | | |
| Level | 55 % | 45 % |
| 2% tilt | 19 % | 81 % |
| 5% tilt | 0 % | 100 % |
| D. Box with SeptiSurge, single | | |
| Level | 49 % | 51 % |
| 2% tilt | 33 % | 67 % |
| 5% tilt | 16 % | 84 % |
| D. Box with SeptiSurge, triple | | |
| Level | 47 % | 53 % |
| 2% tilt | 33 % | 67 % |
| 5% tilt | 21 % | 79 % |

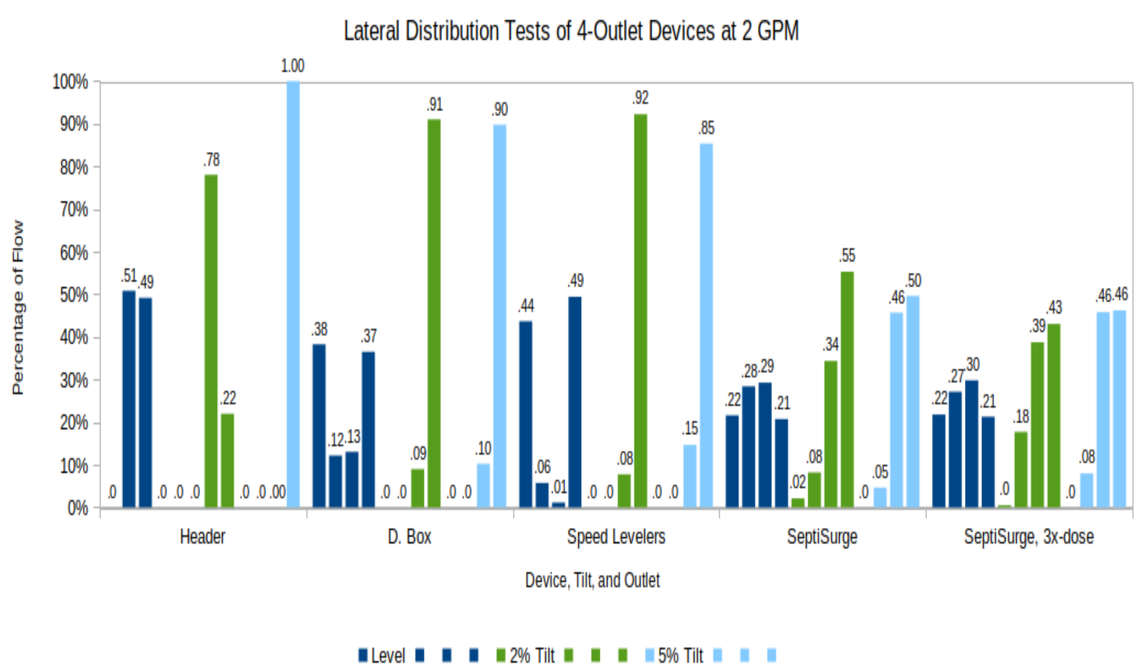


**Figure 10:** Percentage of total outflow directed to each outlet of two-outlet devices, inflow rate of 5 GPM.

As seen in tables 1 and 2, all evaluated 2-outlet devices provide approximately equal flow distribution in a level condition. However, the performance of the header pipe quickly deteriorates when titled. At the lower flow rate of 2 GPM, the splitter tee and distribution box, with or without speed levelers, also fail to provide adequate lateral distribution when tilted. At the higher flow rate of 5 GPM the splitter tee and distribution box continue to provide some lateral distribution at a 2% tilt but fail at a 5% tilt. The only device able to provide lateral distribution consistently across all tested flow rates and tilts is the distribution box with SeptiSurge. The single- and triple-dose configurations of the SeptiSurge had similar performance when level and at a 2% tilt, while at a 5% tilt the triple-dose configuration performed slightly better.

Tables 3 and 4 show the percentage of the total flow directed to each outlet at 2 GPM and 5 GPM, respectively, for the 4-outlet devices evaluated. As before, 2 GPM results from the SeptiSurge are presented in both tables. Note that due to rounding the sum of the presented values for some devices may be as low as 99% or as high as 101%.

**Table 3:** Percentage of total outflow directed to each outlet of four-outlet devices, inflow rate of 2 GPM.

| Device | Percentage of Flow to Each Outlet | | | |
|---|---|---|---|---|
| | Far Left | Middle Left | Middle Right | Far Right |
| Header Pipes | | | | |
| Level | 0 % | 51 % | 49 % | 0 % |
| 2% tilt | 0 % | 0 % | 78 % | 22 % |
| 5% tilt | 0 % | 0 % | 0 % | 100 % |
| Distribution Box | | | | |
| Level | 38 % | 12 % | 13 % | 37 % |
| 2% tilt | 0 % | 0 % | 9 % | 91 % |
| 5% tilt | 0 % | 0 % | 10 % | 90 % |
| Speed Levelers | | | | |
| Level | 44 % | 6 % | 1 % | 49 % |
| 2% tilt | 0 % | 0 % | 8 % | 92 % |
| 5% tilt | 0 % | 0 % | 15 % | 85 % |
| Adjusted, 5% tilt | 27 % | 24 % | 27 % | 22 % |
| SeptiSurge, single | | | | |
| Level | 22 % | 28 % | 29 % | 21 % |
| 2% tilt | 2 % | 8 % | 34 % | 55 % |
| 5% tilt | 0 % | 5 % | 46 % | 50 % |
| SeptiSurge, triple | | | | |
| Level | 22 % | 27 % | 30 % | 21 % |
| 2% tilt | 0 % | 18 % | 39 % | 43 % |
| 5% tilt | 0 % | 8 % | 46 % | 46 % |

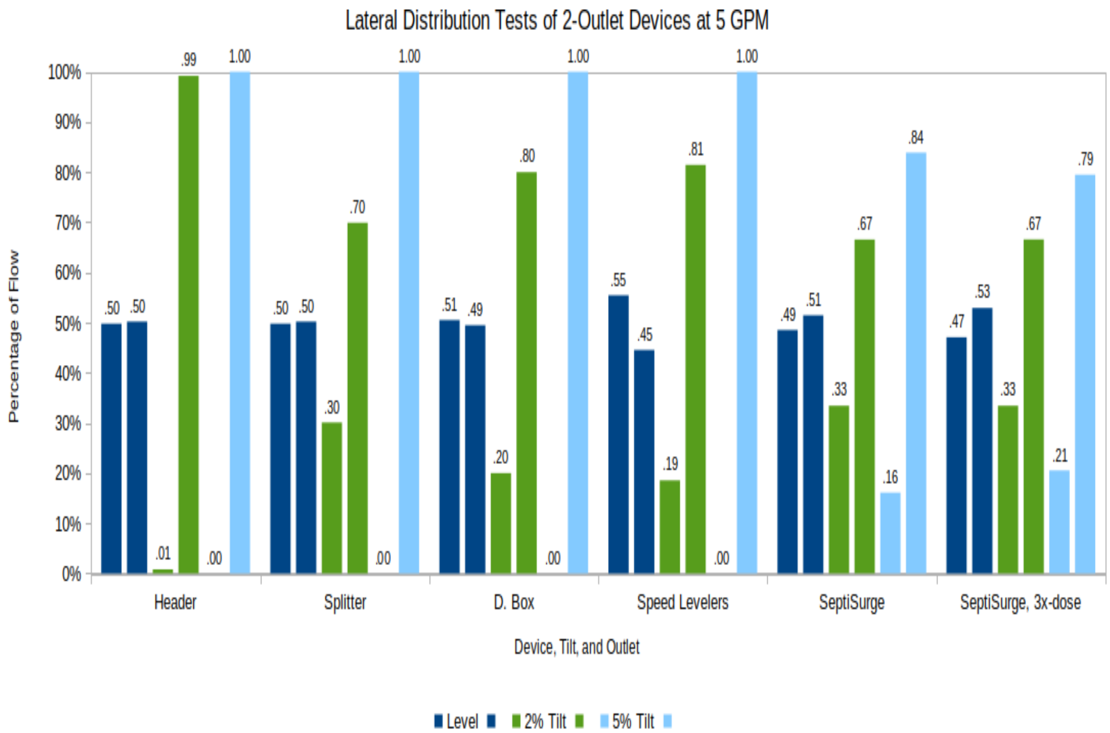


**Figure 11:** Percentage of total outflow directed to each outlet of four-outlet devices, inflow rate of 2 GPM.

**Table 4:** Percentage of total outflow directed to each outlet of four-outlet devices, inflow rate of 5 GPM.

| Device | Percentage of Flow to Each Outlet | | | |
|---|---|---|---|---|
| | Far Left | Middle Left | Middle Right | Far Right |
| Header Pipes | | | | |
| Level | 5 % | 46 % | 42 % | 7 % |
| 2% tilt | 0 % | 2 % | 61 % | 37 % |
| 5% tilt | 0 % | 0 % | 1 % | 99 % |
| Distribution Box | | | | |
| Level | 31 % | 19 % | 17 % | 33 % |
| 2% tilt | 0 % | 1 % | 26 % | 73 % |
| 5% tilt | 0 % | 0 % | 31 % | 69 % |
| Speed Levelers | | | | |
| Level | 28 % | 20 % | 12 % | 40 % |
| 2% tilt | 0 % | 2 % | 25 % | 72 % |
| 5% tilt | 0 % | 0 % | 25 % | 75 % |
| SeptiSurge, single | | | | |
| Level | 22 % | 28 % | 29 % | 21 % |
| 2% tilt | 2 % | 8 % | 34 % | 55 % |
| 5% tilt | 0 % | 5 % | 46 % | 50 % |
| SeptiSurge, triple | | | | |
| Level | 22 % | 27 % | 30 % | 21 % |
| 2% tilt | 0 % | 18 % | 39 % | 43 % |
| 5% tilt | 0 % | 8 % | 46 % | 46 % |

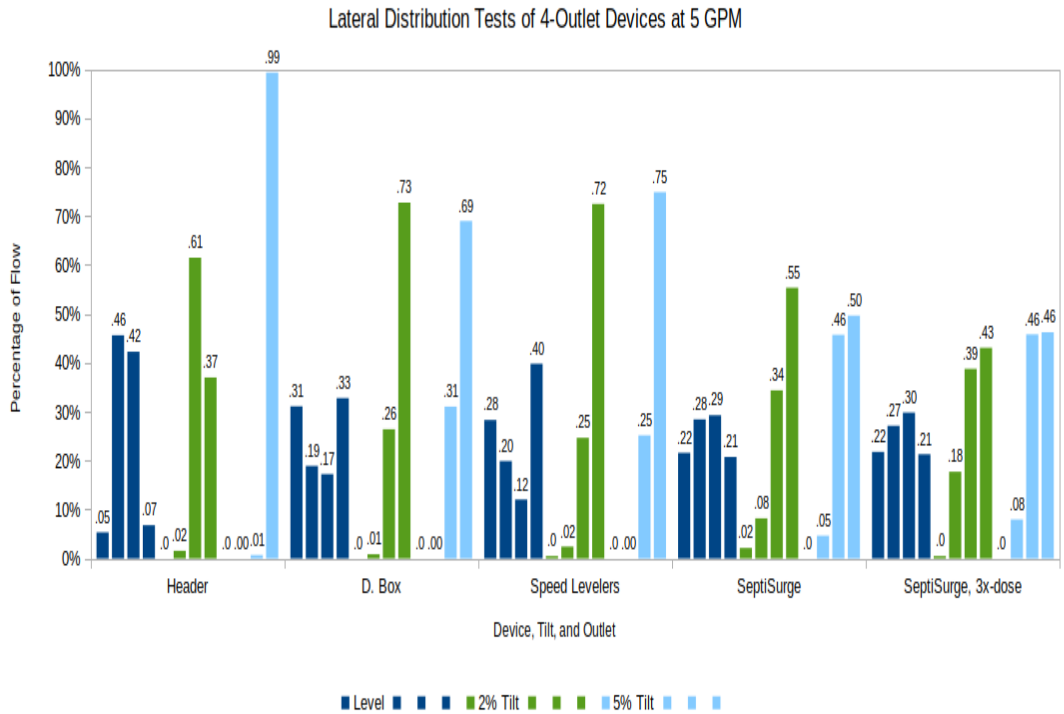


**Figure 12:** Percentage of total outflow directed to each outlet of four-outlet devices, inflow rate of 5 GPM.

As seen in Tables 3 and 4, the SeptiSurge provides the most even 4-outlet distribution in the level configuration. The standard header pipes tend to favor the middle outlets closest to the inlet, regardless of flow rate. The distribution box, with or without speed levelers, favors the outermost outlets; this trend is observed more strongly in the 2 GPM tests but is present at both flow rates. The SeptiSurge favored the middle outlets slightly in both its standard and triple-dose configurations but still provided more distribution than any of the other devices.

At a 2% tilt, the header pipes and distribution box fail to provide any significant flow to the upper two outlets, regardless of flow rate. The SeptiSurge also struggles to distribute flow to the highest of the four outlets at this tilt, but it continues to distribute flow between the other three outlets, especially in its triple-dose configuration. Except for the adjusted speed levelers, all devices struggled to provide adequate flow to the higher two outlets in the 4-outlet, 5% tilt test case, the most extreme case evaluated in this study. Only the SeptiSurge and adjusted speed levelers were able to provide any flow to the upper outlets in this case. The triple-dose SeptiSurge configuration provided more flow to the upper outlets than the standard configuration, and the adjusted speed levelers provided the most.

Table 5 shows the percentage of total flow directed to each outlet in the 25 GPM pump-to-gravity tests. All devices evaluated in this configuration had four outlets, except for the splitter tee which had two. The SeptiSurge was evaluated again at this flow rate, rather than reusing the values from the 2 GPM tests, because at 25 GPM the rate of inflow exceeded that of outflow, producing similar results to an increased reservoir size.

**Table 5:** Percentage of total outflow directed to each outlet, inflow rate of 25 GPM

| Device | Percentage of Flow to Each Outlet | | | |
|---|---|---|---|---|
| | Far Left | Middle Left | Middle Right | Far Right |
| Splitter Tee | | | | |
| Level | N/A | 51 % | 49 % | N/A |
| 5% tilt | | 72 % | 28 % | |
| Distribution Box | | | | |
| Level | 20 % | 27 % | 34 % | 19 % |
| 5% tilt | 2 % | 0 % | 35 % | 63 % |
| Speed Levelers | | | | |
| Level | 23 % | 27 % | 26 % | 24 % |
| 5% tilt | 8 % | 3 % | 30 % | 58 % |
| Adjusted, 5% | 24 % | 21 % | 31 % | 24 % |
| SeptiSurge, single | | | | |
| Level | 22 % | 26 % | 30 % | 22 % |
| 5% tilt | 2 % | 1 % | 36 % | 60 % |

As seen in Table 5, all tested devices were able to provide some flow to the upper outlets in the upper outlets in the four-outlet, 5% tilt configuration. This indicates that the higher flow rate of the pump-to-gravity configuration contributes to more even lateral distribution. As in the 2 GPM tests, the adjusted speed levelers provided the most even distribution in the tilted configuration.

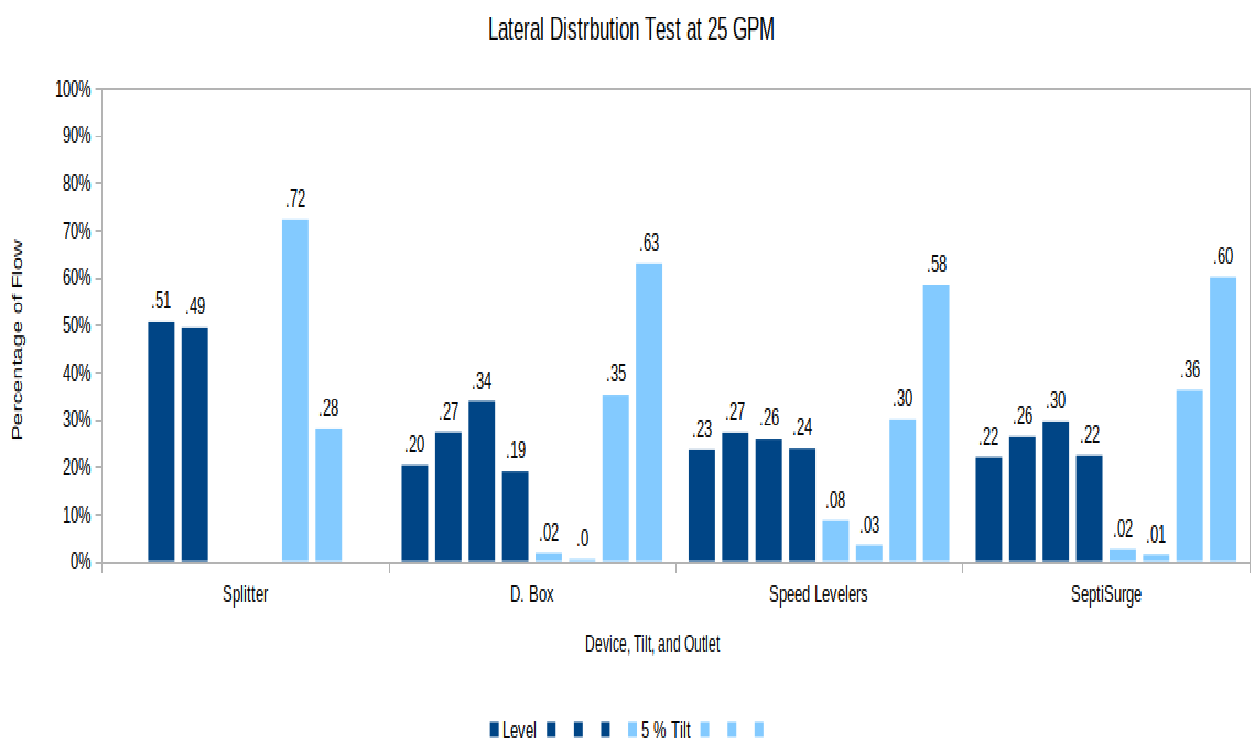


**Figure 13:** Percentage of total outflow directed to each outlet, inflow rate of 25 GPM.

Figure 14 compares lateral distribution results with unadjusted and adjusted speed levelers, at both 2 GPM and 25 GPM flow rates. As seen in the figure, no flow reached the higher two outlets in the 2 GPM test with unadjusted speed levelers at a 5% tilt, and only a combined 11% of flow reached the lower two outlets at 25 GPM. When the speed levelers were adjusted, all four outlets received between 21% and 31% of flow at both flow rates.

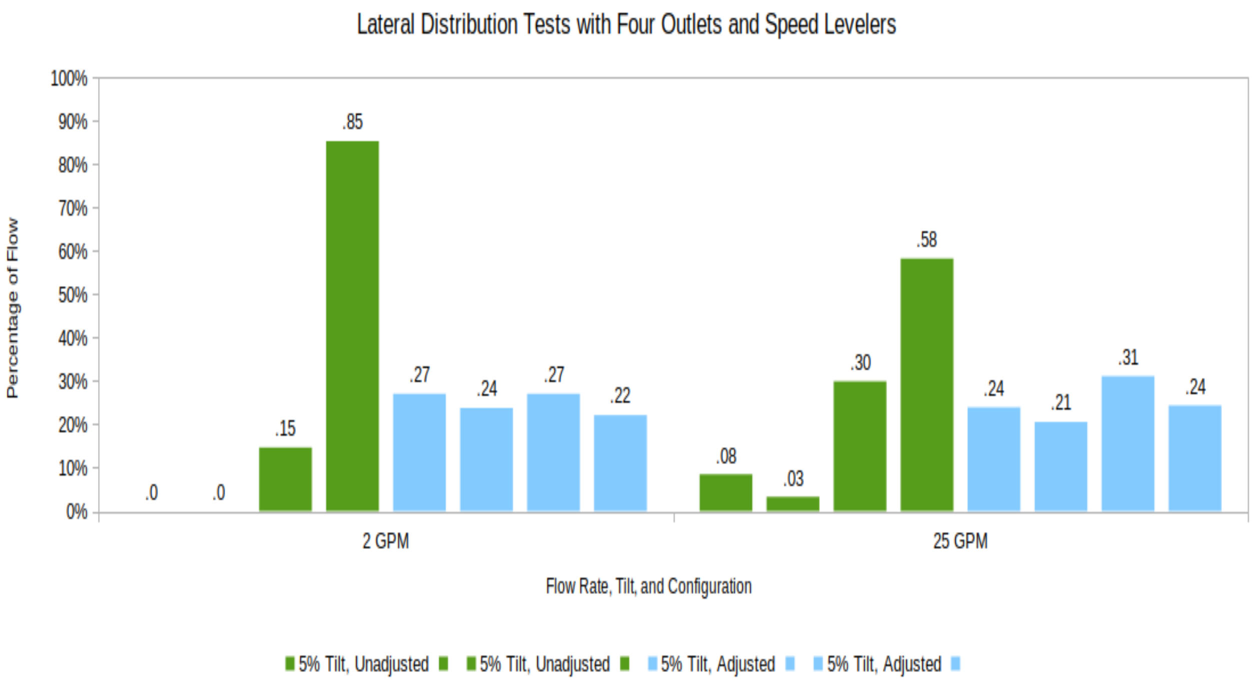


**Figure 14:** Percentage of total outflow directed to each outlet of four-outlet distribution box with speed levelers, at flow rates of 2 GPM and 25 GPM and with adjusted and unadjusted speed levelers.

## Results - Longitudinal distribution

Table 6 shows the percentage of total outflow draining from each 1-foot section of perforated drainpipe in two-outlet configurations with an inflow rate of 2 GPM, and no 6 o'clock drain holes (only the 4'clock and 8 o'clock holes). Table 7 shows the same from tests with an inflow rate of 5 GPM, except for SeptiSurge data which was measured at 2 GPM and is repeated in both tables. Note that measurements were not recorded from the last foot of each 10-foot length of pipe because the outlets in these sections were obstructed by the supports holding the pipe; outflow through these sections did not appear to be significant in any tests. Note also that the sum of percentages for each device may differ slightly from 100% due to rounding. The values presented are the averages between all attached drainpipes.

**Table 6:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over both connected pipes, in two-outlet tests with an inflow of 2 GPM and no 6 o'clock drain holes

| Drainpipe Distance ft | Header Pipe | Splitter Tee | Distribution Box | Speed Levelers | SeptiSurge Single Dose | SeptiSurge Triple Dose |
|---|---|---|---|---|---|---|
| 0-1 | 4 [4] % | 20 [20] % | 0 [0] % | 0 [0] % | 5 [5] % | 5 [5] % |
| 1-2 | 15 [19] % | 30 [51] % | 0 [0] % | 0 [0] % | 5 [10] % | 8 [13] % |
| 2-3 | 41 [60] % | 34 [84] % | 8 [8] % | 0 [0] % | 7 [17] % | 8 [20] % |
| 3-4 | 40 [100] % | 15 [99] % | 25 [33] % | 41 [41] % | 13 [30] % | 9 [29] % |
| 4-5 | 0 % | 1 [100] % | 35 [68] % | 37 [78] % | 20 [50] % | 11 [40] % |
| 5-6 | 0 % | 0 % | 23 [92] % | 19 [96] % | 16 [66] % | 13 [53] % |
| 6-7 | 0 % | 0 % | 7 [98] % | 0 [96] % | 12 [78] % | 12 [64] % |
| 7-8 | 0 % | 0 % | 0 [98] % | 0 [96] % | 8 [86] % | 10 [75] % |
| 8-9 | 0 % | 0 % | 2 [100] % | 4 [100] % | 5 [91] % | 8 [82] % |
| 10-11 | 0 % | 0 % | 0 % | 0 % | 0 [91] % | 0 [82] % |
| 11-12 | 0 % | 0 % | 0 % | 0 % | 0 [91] % | 0 [82] % |
| 12-13 | 0 % | 0 % | 0 % | 0 % | 0 [91] % | 1 [83] % |
| 13-14 | 0 % | 0 % | 0 % | 0 % | 1 [92] % | 3 [86] % |
| 14-15 | 0 % | 0 % | 0 % | 0 % | 3 [95] % | 4 [90] % |
| 15-16 | 0 % | 0 % | 0 % | 0 % | 2 [97] % | 4 [95] % |
| 16-17 | 0 % | 0 % | 0 % | 0 % | 1 [99] % | 3 [98] % |
| 17-18 | 0 % | 0 % | 0 % | 0 % | 1 [100] % | 2 [100] % |
| 18-19 | 0 % | 0 % | 0 % | 0 % | 0 % | 0 % |

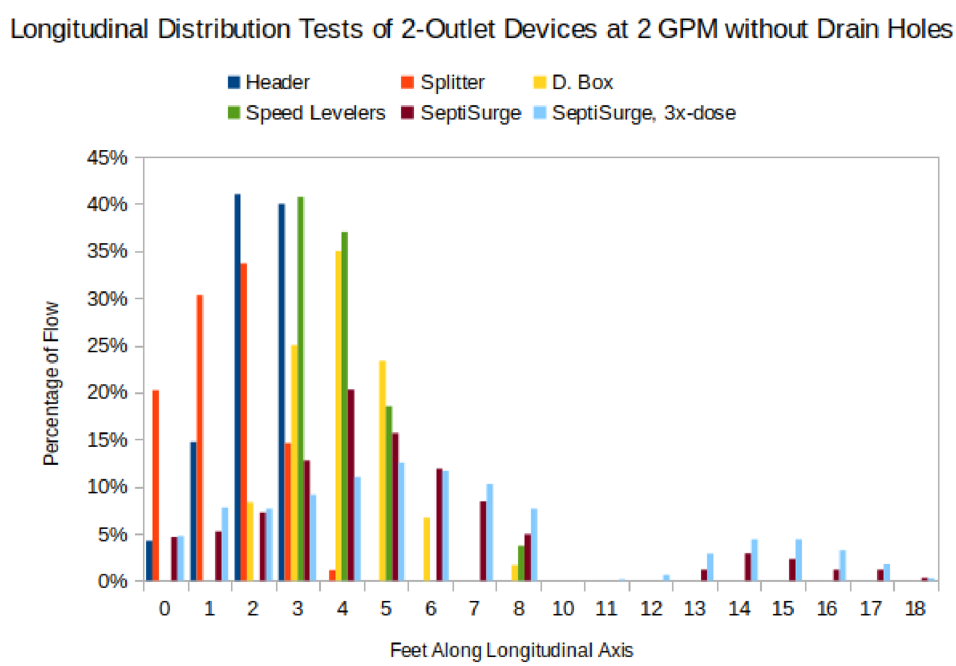


**Figure 15:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over both connected pipes, in two-outlet tests with an inflow of 2 GPM and no 6 o'clock drain holes.

**Table 7:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over both connected pipes, in two-outlet tests with an inflow of 5 GPM and no 6 o'clock drain holes.

| Drainpipe Distance ft | Header Pipe | Splitter Tee | Distribution Box | Speed Levelers | SeptiSurge Single Dose | SeptiSurge Triple Dose |
|---|---|---|---|---|---|---|
| 0-1 | 12 [12] % | 20 [20] % | 1 [1] % | 4 [4] % | 5 [5] % | 5 [5] % |
| 1-2 | 19 [30] % | 28 [48] % | 2 [3] % | 12 [16] % | 5 [10] % | 8 [13] % |
| 2-3 | 29 [59] % | 29 [77] % | 10 [12] % | 16 [32] % | 7 [17] % | 8 [20] % |
| 3-4 | 27 [87] % | 17 [95] % | 17 [29] % | 22 [54] % | 13 [30] % | 9 [29] % |
| 4-5 | 11 [98] % | 4 [99] % | 26 [55] % | 22 [75] % | 20 [50] % | 11 [40] % |
| 5-6 | 2 [100] % | 1 [100] % | 19 [74] % | 12 [87] % | 16 [66] % | 13 [53] % |
| 6-7 | 0 % | 0 % | 11 [85] % | 5 [92] % | 12 [78] % | 12 [64] % |
| 7-8 | 0 % | 0 % | 4 [89] % | 1 [93] % | 8 [86] % | 10 [75] % |
| 8-9 | 0 % | 0 % | 1 [90] % | 0 [93] % | 5 [91] % | 8 [82] % |
| 10-11 | 0 % | 0 % | 0 [90] % | 0 [93] % | 0 [91] % | 0 [82] % |
| 11-12 | 0 % | 0 % | 0 [90] % | 0 [93] % | 0 [91] % | 0 [82] % |
| 12-13 | 0 % | 0 % | 0 [90] % | 0 [93] % | 0 [91] % | 1 [83] % |
| 13-14 | 0 % | 0 % | 0 [90] % | 0 [93] % | 1 [92] % | 3 [86] % |
| 14-15 | 0 % | 0 % | 7 [97] % | 5 [97] % | 3 [95] % | 4 [90] % |
| 15-16 | 0 % | 0 % | 3 [100] % | 7 [100] % | 2 [97] % | 4 [95] % |
| 16-17 | 0 % | 0 % | 0 % | 0 % | 1 [99] % | 3 [98] % |
| 17-18 | 0 % | 0 % | 0 % | 0 % | 1 [100] % | 2 [100] % |
| 18-19 | 0 % | 0 % | 0 % | 0 % | 0 % | 0 % |

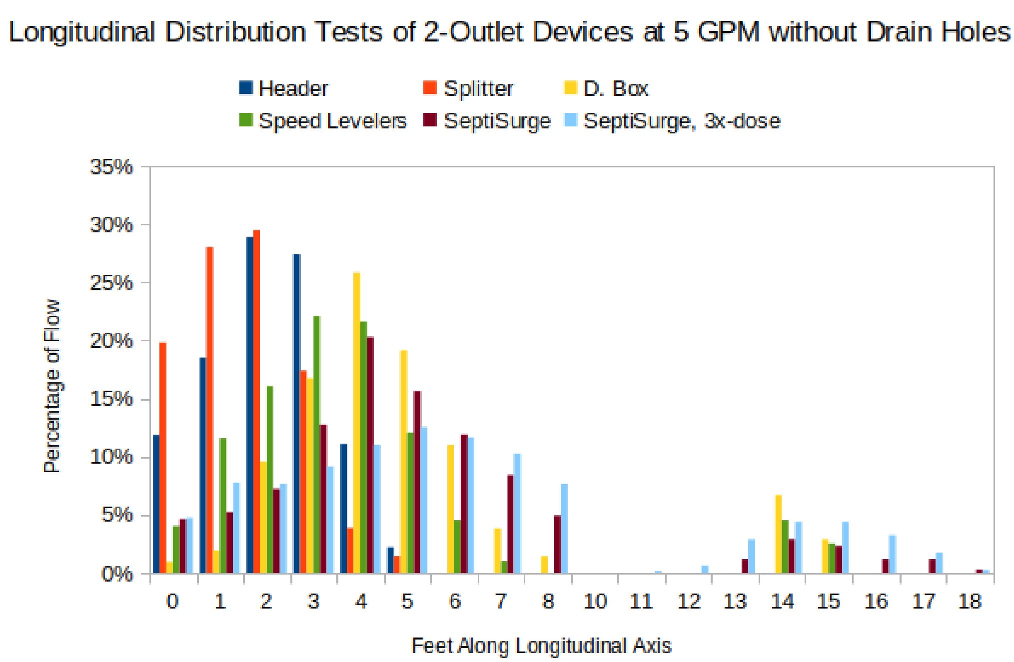


**Figure 16:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over both connected pipes, in two-outlet tests with an inflow of 5 GPM and no 6 o'clock drain holes.

As seen in Tables 6 and 7, the SeptiSurge consistently provided the most even longitudinal distribution. In 2 GPM tests it was the only device that provided flow to the farther half of each drainpipe. In 5 GPM tests, effluent from the distribution box without the SeptiSurge also reached the farther half of each pipe, but effluent from the SeptiSurge drained through more total 1-foot sections and was more evenly distributed. The triple-dose SeptiSurge configuration provided more even distribution than the standard configuration.

Tables 8 and 9 show the percentage of total outflow draining through each 1-foot section of perforated drainpipe in tests with four (4) outlets and no 6 o'clock holes. Table 8 shows results from 2 GPM tests, and Table 9 results from 5 GPM tests, except for SeptiSurge data which was measured at 2 GPM and is repeated in both tables. As with the 2-outlet tests, outflow from the last foot of each 10-foot section of pipe was insignificant and was not measured. The values presented are the averages over all four connected pipes. The sum of all percentages for each device may vary slightly from 100% due to rounding.

**Table 8:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over all four (4) connected pipes, in 4-outlet tests with an inflow of 2 GPM and no 6 o'clock drain holes.

| Drainpipe Distance ft | Header Pipe | Distribution Box | Speed Levelers | SeptiSurge Single Dose | SeptiSurge Triple Dose |
|---|---|---|---|---|---|
| 0-1 | 9 [9] % | 0 [0] % | 3 [3] % | 7 [7] % | 5 [5] % |
| 1-2 | 22 [31] % | 0 [0] % | 0 [3] % | 2 [9] % | 5 [10] % |
| 2-3 | 44 [75] % | 11 [11] % | 0 [3] % | 5 [14] % | 8 [18] % |
| 3-4 | 22 [97] % | 30 [40] % | 26 [29] % | 16 [30] % | 10 [28] % |
| 4-5 | 3 [100] % | 43 [83] % | 35 [65] % | 31 [61] % | 10 [38] % |
| 5-6 | 0 % | 6 [89] % | 26 [91] % | 17 [78] % | 16 [54] % |
| 6-7 | 0 % | 6 [96] % | 3 [94] % | 11 [89] % | 15 [70] % |
| 7-8 | 0 % | 0 [96] % | 0 [94] % | 7 [97] % | 13 [82] % |
| 8-9 | 0 % | 4 [100] % | 6 [100] % | 3 [100] % | 7 [89] % |
| 10-11 | 0 % | 0 % | 0 % | 0 % | 1 [89] % |
| 11-12 | 0 % | 0 % | 0 % | 0 % | 0 [89] % |
| 12-13 | 0 % | 0 % | 0 % | 0 % | 0 [90] % |
| 13-14 | 0 % | 0 % | 0 % | 0 % | 1 [91] % |
| 14-15 | 0 % | 0 % | 0 % | 0 % | 3 [94] % |
| 15-16 | 0 % | 0 % | 0 % | 0 % | 3 [97] % |
| 16-17 | 0 % | 0 % | 0 % | 0 % | 2 [99] % |
| 17-18 | 0 % | 0 % | 0 % | 0 % | 1 [100] % |
| 18-19 | 0 % | 0 % | 0 % | 0 % | 0 % |

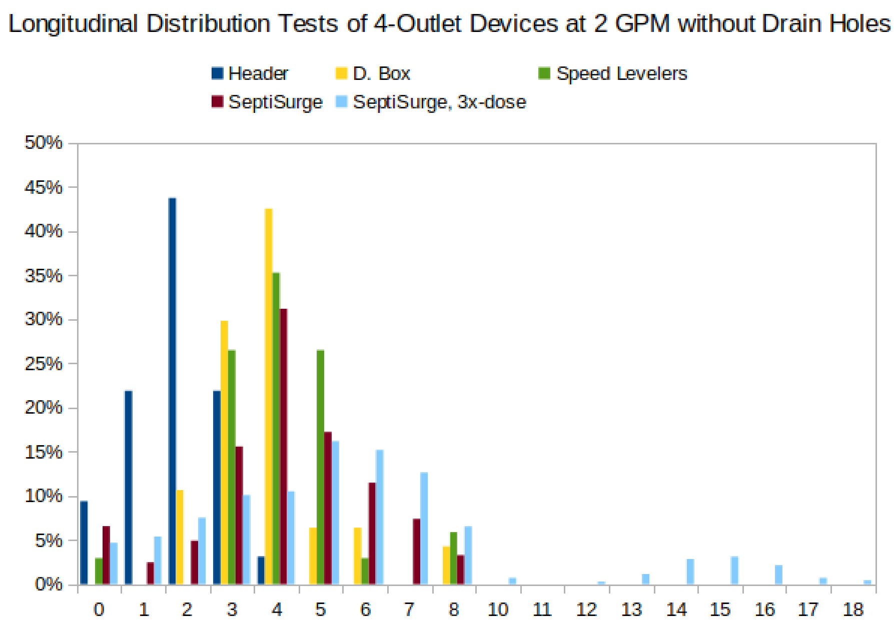


**Figure 17:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over all four (4) connected pipes, in 4-outlet tests with an inflow of 2 GPM and no 6 o'clock drain holes.

**Table 9:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over all four (4) connected pipes, in 4-outlet tests with an inflow of 5 GPM and no 6 o'clock drain holes.

| Drainpipe Distance ft | Header Pipe | Distribution Box | Speed Levelers | SeptiSurge Single Dose | SeptiSurge Triple Dose |
|---|---|---|---|---|---|
| 0-1 | 14 [14] % | 0 [0] % | 1 [1] % | 7 [7] % | 5 [5] % |
| 1-2 | 33 [47] % | 4 [4] % | 7 [9] % | 2 [9] % | 5 [10] % |
| 2-3 | 22 [69] % | 12 [16] % | 12 [20] % | 5 [14] % | 8 [18] % |
| 3-4 | 25 [94] % | 14 [30] % | 19 [39] % | 16 [30] % | 10 [28] % |
| 4-5 | 6 [100] % | 23 [53] % | 27 [66] % | 31 [61] % | 10 [38] % |
| 5-6 | 0 % | 30 [83] % | 19 [85] % | 17 [78] % | 16 [54] % |
| 6-7 | 0 % | 6 [88] % | 9 [94] % | 11 [89] % | 15 [70] % |
| 7-8 | 0 % | 0 [89] % | 1 [95] % | 7 [97] % | 13 [82] % |
| 8-9 | 0 % | 0 [89] % | 1 [96] % | 3 [100] % | 7 [89] % |
| 10-11 | 0 % | 0 [89] % | 0 [96] % | 0 % | 1 [89] % |
| 11-12 | 0 % | 0 [89] % | 0 [96] % | 0 % | 0 [89] % |
| 12-13 | 0 % | 0 [89] % | 0 [96] % | 0 % | 0 [90] % |
| 13-14 | 0 % | 4 [93] % | 0 [96] % | 0 % | 1 [91] % |
| 14-15 | 0 % | 2 [95] % | 3 [99] % | 0 % | 3 [94] % |
| 15-16 | 0 % | 0 [95] % | 1 [100] % | 0 % | 3 [97] % |
| 16-17 | 0 % | 0 [95] % | 0 % | 0 % | 2 [99] % |
| 17-18 | 0 % | 2 [97] % | 0 % | 0 % | 1 [100] % |
| 18-19 | 0 % | 3 [100] % | 0 % | 0 % | 0 % |

As seen in Tables 8 and 9, the triple-dose SeptiSurge consistently provided the best distribution. In the 2 GPM tests, it was the only device configuration to provide flow to the farther half of each drainpipe. In the 5 GPM tests the distribution box without SeptiSurge was able to provide flow to the farther half, but the triple-dose SeptiSurge still provided the most even longitudinal distribution.

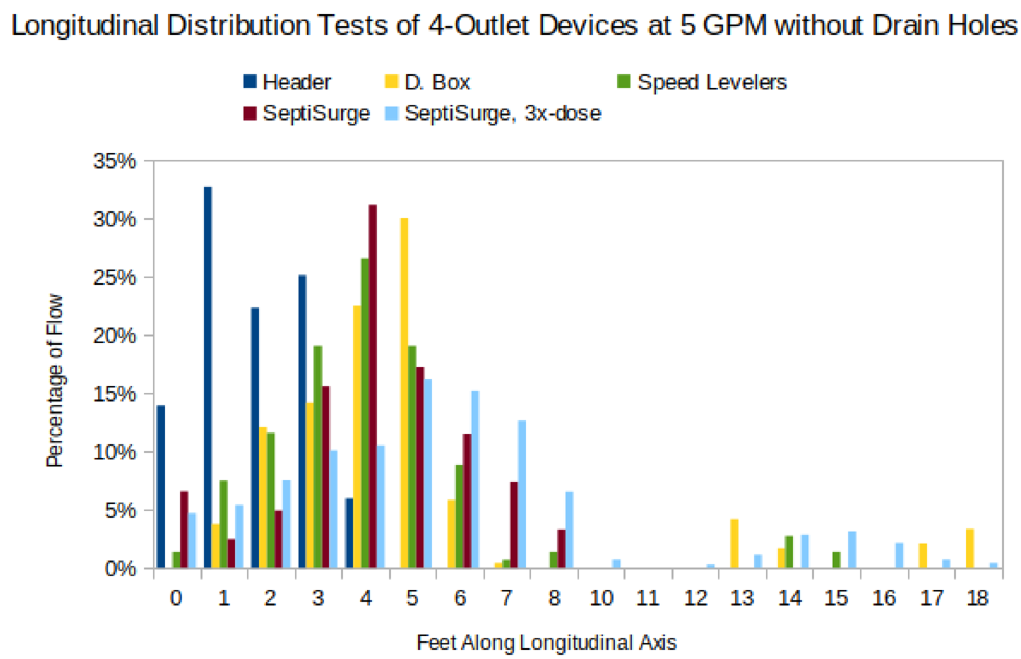


**Figure 18:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over all four (4) connected pipes, in 4-outlet tests with an inflow of 5 GPM and no 6 o'clock drain holes.

Tables 10, 11, 12, and 13 show the percentage of total outflow draining through each 1-foot section of perforated drainpipes with a 6 o'clock drain hole in each 10-foot section of pipe. The drain holes were located in the 4th and 14th foot of each branch of drainpipe, as indicated in the tables. Tables 10 and 11 show results from tests with two (2) outlets, while Tables 12 and 13 show results from tests with four (4) outlets. Tables 10 and 12 show results from 2 GPM tests, while Tables 11 and 13 show results from 5 GPM tests, with the exception of the SeptiSurge data which was measured at an inflow rate of 2 GPM and is repeated in both pairs of tables because it is independent of inflow rate. As above, drainage from the last foot of each 10-foot section of pipe was insignificant and was not measured. Presented values represent averages over all connected sections of pipe. The sum of percentages for each device may differ slightly from 100% due to rounding.

**Table 10:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over both connected pipes, in two-outlet tests with an inflow of 2 GPM and a single 6 o'clock drain hole per 10-foot length.

| Drainpipe Distance ft | Header Pipe | Splitter Tee | Distribution Box | Speed Levelers | SeptiSurge Single Dose | SeptiSurge Triple Dose |
|---|---|---|---|---|---|---|
| 0-1 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 1 [1] % | 1 [1] % |
| 1-2 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 1 [2] % | 1 [2] % |
| 2-3 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [2] % | 1 [3] % |
| 3-4 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [2] % | 1 [4] % |
| (Drain) 4-5 | 100 [100] % | 100 [100] % | 100 [100] % | 100 [100] % | 45 [47] % | 29 [33] % |
| 5-6 | 0 % | 0 % | 0 % | 0 % | 0 [47] % | 6 [39] % |
| 6-7 | 0 % | 0 % | 0 % | 0 % | 0 [47] % | 6 [45] % |
| 7-8 | 0 % | 0 % | 0 % | 0 % | 0 [47] % | 4 [48] % |
| 8-9 | 0 % | 0 % | 0 % | 0 % | 0 [47] % | 1 [49] % |
| 10-11 | 0 % | 0 % | 0 % | 0 % | 0 [47] % | 0 [49] % |
| 11-12 | 0 % | 0 % | 0 % | 0 % | 0 [47] % | 0 [49] % |
| 12-13 | 0 % | 0 % | 0 % | 0 % | 0 [47] % | 0 [49] % |
| 13-14 | 0 % | 0 % | 0 % | 0 % | 0 [47] % | 2 [51] % |
| (Drain) 14-15 | 0 % | 0 % | 0 % | 0 % | 51 [98] % | 31 [82] % |
| 15-16 | 0 % | 0 % | 0 % | 0 % | 0 [98] % | 4 [86] % |
| 16-17 | 0 % | 0 % | 0 % | 0 % | 1 [99] % | 6 [92] % |
| 17-18 | 0 % | 0 % | 0 % | 0 % | 1 [99] % | 6 [98] % |
| 18-19 | 0 % | 0 % | 0 % | 0 % | 1 [100] % | 2 [100] % |

**Table 11:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over both connected pipes, in two-outlet tests with an inflow of 5 GPM and a single 6 o'clock drain hole per 10-foot length of pipe.

| Drainpipe Distance ft | Header Pipe | Splitter Tee | Distribution Box | Speed Levelers | SeptiSurge Single Dose | SeptiSurge Triple Dose |
|---|---|---|---|---|---|---|
| 0-1 | 0 [0] % | 9 [9] % | 0 [0] % | 0 [0] % | 1 [1] % | 1 [1] % |
| 1-2 | 0 [0] % | 8 [17] % | 0 [0] % | 0 [0] % | 1 [2] % | 1 [2] % |
| 2-3 | 0 [0] % | 4 [22] % | 0 [0] % | 0 [0] % | 0 [2] % | 1 [3] % |
| 3-4 | 0 [0] % | 2 [23] % | 0 [0] % | 0 [0] % | 0 [2] % | 1 [4] % |
| (Drain) 4-5 | 98 [98] % | 73 [97] % | 74 [74] % | 73 [73] % | 45 [47] % | 29 [33] % |
| 5-6 | 0 [98] % | 0 [97] % | 0 [74] % | 0 [73] % | 0 [47] % | 6 [39] % |
| 6-7 | 0 [98] % | 0 [97] % | 0 [74] % | 0 [73] % | 0 [47] % | 6 [45] % |
| 7-8 | 0 [98] % | 0 [97] % | 0 [74] % | 0 [73] % | 0 [47] % | 4 [48] % |
| 8-9 | 0 [98] % | 0 [97] % | 0 [74] % | 0 [73] % | 0 [47] % | 1 [49] % |
| 10-11 | 0 [98] % | 0 [97] % | 0 [74] % | 0 [73] % | 0 [47] % | 0 [49] % |
| 11-12 | 0 [98] % | 0 [97] % | 0 [74] % | 0 [73] % | 0 [47] % | 0 [49] % |
| 12-13 | 0 [98] % | 0 [97] % | 0 [74] % | 0 [73] % | 0 [47] % | 0 [49] % |
| 13-14 | 0 [98] % | 0 [97] % | 0 [74] % | 0 [73] % | 0 [47] % | 2 [51] % |
| (Drain) 14-15 | 2 [100] % | 3 [100] % | 26 [100] % | 27 [100] % | 51 [98] % | 31 [82] % |
| 15-16 | 0 % | 0 % | 0 % | 0 % | 0 [98] % | 4 [86] % |
| 16-17 | 0 % | 0 % | 0 % | 0 % | 1 [99] % | 6 [92] % |
| 17-18 | 0 % | 0 % | 0 % | 0 % | 1 [99] % | 6 [98] % |
| 18-19 | 0 % | 0 % | 0 % | 0 % | 1 [100] % | 2 [100] % |

As seen in Tables 10 and 11, the triple-dose configuration of the SeptiSurge provided the most even distribution. In the 2 GPM tests, flow from both SeptiSurge configurations drained through holes other than the 6 o'clock drain hole, while flow from all of the other devices used only the first 6 o'clock hole. In the 5 GPM tests, flow from the other devices reached the second drain hole, and flow from the splitter tee drained through some of the 4 o'clock and 8 o'clock holes, but no device provided distribution as even as the triple-dose SeptiSurge. Irrespective of flow rate or distribution device, most effluent exited through the 6 o'clock drain holes.

**Table 12:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over all four (4) connected pipes, in 4-outlet tests with an inflow of 2 GPM and a single 6 o'clock drain hole per 10-foot length of pipe.

| Drainpipe Distance ft | Header Pipe | Distribution Box | Speed Levelers | SeptiSurge Single Dose | SeptiSurge Triple Dose |
|---|---|---|---|---|---|
| 0-1 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % |
| 1-2 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % |
| 2-3 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % |
| 3-4 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [1] % |
| (Drain) 4-5 | 100 [100] % | 100 [100] % | 100 [100] % | 68 [68] % | 52 [53] % |
| 5-6 | 0 % | 0 % | 0 % | 0 [68] % | 2 [55] % |
| 6-7 | 0 % | 0 % | 0 % | 0 [68] % | 1 [56] % |
| 7-8 | 0 % | 0 % | 0 % | 0 [68] % | 0 [56] % |
| 8-9 | 0 % | 0 % | 0 % | 0 [68] % | 0 [56] % |
| 10-11 | 0 % | 0 % | 0 % | 0 [68] % | 0 [56] % |
| 11-12 | 0 % | 0 % | 0 % | 0 [68] % | 0 [56] % |
| 12-13 | 0 % | 0 % | 0 % | 0 [68] % | 0 [56] % |
| 13-14 | 0 % | 0 % | 0 % | 0 [68] % | 0 [56] % |
| (Drain) 14-15 | 0 % | 0 % | 0 % | 32 [100] % | 42 [98] % |
| 15-16 | 0 % | 0 % | 0 % | 0 % | 0 [99] % |
| 16-17 | 0 % | 0 % | 0 % | 0 % | 1 [99] % |
| 17-18 | 0 % | 0 % | 0 % | 0 % | 1 [100] % |
| 18-19 | 0 % | 0 % | 0 % | 0 % | 0 % |

**Table 13:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over all four (4) connected pipes, in 4-outlet tests with an inflow of 5 GPM and a single 6 o'clock drain hole per 10-foot length of pipe.

| Drainpipe Distance ft | Header Pipe | Distribution Box | Speed Levelers | SeptiSurge Single Dose | SeptiSurge Triple Dose |
|---|---|---|---|---|---|
| 0-1 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % |
| 1-2 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % |
| 2-3 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % |
| 3-4 | 0 [0] % | 0 [0] % | 0 [0] % | 0 [0] % | 0 [1] % |
| (Drain) 4-5 | 100 [100] % | 97 [97] % | 90 [90] % | 68 [68] % | 52 [53] % |
| 5-6 | 0 % | 0 [97] % | 0 [90] % | 0 [68] % | 2 [55] % |
| 6-7 | 0 % | 0 [97] % | 0 [90] % | 0 [68] % | 1 [56] % |
| 7-8 | 0 % | 0 [97] % | 0 [90] % | 0 [68] % | 0 [56] % |
| 8-9 | 0 % | 0 [97] % | 0 [90] % | 0 [68] % | 0 [56] % |
| 10-11 | 0 % | 0 [97] % | 0 [90] % | 0 [68] % | 0 [56] % |
| 11-12 | 0 % | 0 [97] % | 0 [90] % | 0 [68] % | 0 [56] % |
| 12-13 | 0 % | 0 [97] % | 0 [90] % | 0 [68] % | 0 [56] % |
| 13-14 | 0 % | 0 [97] % | 0 [90] % | 0 [68] % | 0 [56] % |
| (Drain) 14-15 | 0 % | 3 [100] % | 10 [100] % | 32 [100] % | 42 [98] % |
| 15-16 | 0 % | 0 % | 0 % | 0 % | 0 [99] % |
| 16-17 | 0 % | 0 % | 0 % | 0 % | 1 [99] % |
| 17-18 | 0 % | 0 % | 0 % | 0 % | 1 [100] % |
| 18-19 | 0 % | 0 % | 0 % | 0 % | 0 % |

As seen in Tables 12 and 13, all devices struggled to provide even distribution with four (4) outlets and 6 o'clock drain holes. The triple-dose SeptiSurge was the only device from which flow reached the 4 o'clock and 8 o'clock holes. In the 2 GPM tests, only the SeptiSurge provided flow to the farther half of each drainpipe length. In the 5 GPM tests, the distribution box with and without speed levelers also provided flow to the farther half of each length of drainpipe, but the flow from the SeptiSurge was much closer to evenly divided. As in the two-outlet tests, most effluent exited through the 6 o'clock drain holes regardless of the flow rate or distribution device used.

Table 14 shows the percentage of total outflow draining through each 1-foot section of perforated drainpipes with a 6 o'clock drain hole in each 10-foot section of pipe. The drain holes were located in the 4$^{th}$ and 14$^{th}$ foot of each branch of drainpipe; however, the outflow from the drain hole in the 14th foot was collected in the pan beneath the 15$^{th}$ foot, as shown in the table. Table 14 shows data from 25 GPM tests; all devices were assessed with four outlets, except the splitter tee which was tested with two. Presented values represent averages over all connected sections of pipe. The sum of percentages for each device may differ slightly from 100% due to rounding.

**Table 14:** Percentage of total outflow from each 1-foot section of drainpipe, averaged over all connected pipes, in tests with an inflow of 25 GPM and a single 6 o'clock drain hole per 10-foot length.

| Drainpipe Distance ft | Two-Outlet Splitter Tee | Four-Outlet Distribution Box | Speed Levelers | SeptiSurge Single Dose |
|---|---|---|---|---|
| 0-1 | 4 [4] % | 0 [0] % | 0 [0] % | 0 [0] % |
| 1-2 | 1 [5] % | 0 [1] % | 0 [1] % | 0 [0] % |
| 2-3 | 1 [6] % | 0 [1] % | 0 [1] % | 0 [0] % |
| 3-4 | 0 [6] % | 0 [1] % | 0 [1] % | 0 [0] % |
| (Drain) 4-5 | 26 [32] % | 45 [46] % | 44 [45] % | 48 [49] % |
| 5-6 | 0 [33] % | 2 [48] % | 1 [46] % | 2 [50] % |
| 6-7 | 1 [34] % | 3 [51] % | 2 [48] % | 2 [52] % |
| 7-8 | 2 [36] % | 2 [53] % | 1 [49] % | 2 [54] % |
| 8-9 | 5 [40] % | 1 [54] % | 0 [49] % | 0 [54] % |
| 10-11 | 6 [46] % | 0 [54] % | 0 [49] % | 0 [55] % |
| 11-12 | 7 [53] % | 0 [54] % | 1 [50] % | 0 [55] % |
| 12-13 | 7 [61] % | 2 [56] % | 2 [52] % | 2 [57] % |
| 13-14 | 7 [68] % | 3 [59] % | 3 [55] % | 2 [59] % |
| 14-15 | 4 [72] % | 4 [63] % | 8 [63] % | 2 [61] % |
| (Drain) 15-16 | 21 [93] % | 32 [95] % | 34 [97] % | 36 [97] % |
| 16-17 | 4 [97] % | 3 [98] % | 2 [99] % | 2 [99] % |
| 17-18 | 2 [99] % | 2 [100] % | 1 [100] % | 1 [100] % |
| 18-19 | 1 [100] % | 0 % | 0 % | 0% |

As seen in Table 14, the majority of the outflow in all cases used the 6 o'clock drain holes. However, distribution through the 4 and 8 o'clock holes was much higher in the 25 GPM tests than the lower flow-rate tests across all devices.

## Conclusions

Installers, regulators, and manufacturers involved with OWTS realize anecdotally that traditional gravity fed distribution devices are unlikely to provide even flow distribution. Research on gravity distribution is limited, but the few studies that have been conducted support the anecdotal evidence that even gravity distribution is difficult or impossible to achieve in the field with traditional distribution devices. Many gravity-fed drain fields receive uneven distribution either laterally between trenches, or longitudinally along each trench, due to factors such as poor installation, natural settling, low flow rates, and biofilm accumulation. Uneven distribution can lead to overloading of parts of the STA. For instance, if effluent reaches only half of the distribution area, then that half will be loaded at twice the expected rate. This effect is compounded when both lateral and longitudinal distribution are uneven: if effluent travels halfway down two out of four trenches and does not enter the other two, then the area it reaches will be loaded at four times the expected rate. This can lead to a shorter STA lifespan, excessive soil pore clogging, and, most detrimentally, groundwater contamination. Despite recognition of the limitations of distribution technologies, OWTS rules and regulations often assume even distribution across gravity soil treatment areas.

The experiment described in this report compared the performance of traditional parallel distribution devices including header pipes, a splitter tee, and a distribution box, as well as the newer SeptiSurge dosing device. The ability of each device to provide even lateral and longitudinal distribution was compared at different flow rates, with different degrees of tilting, and using pipes both with and without 6 o'clock drain holes. The SeptiSurge consistently outperformed the traditional devices. The traditional devices performed best in the level configuration with fewer outlets, higher inflow rate, and no 6 o'clock drain holes, when these parameters were varied their performance deteriorated. The SeptiSurge provided the most even lateral distribution when tilted, and the most even longitudinal distribution both with and without 6 o'clock drain holes. It was the only device to provide flow to the higher outlets in the most extreme tilted tests, and the only device to provide flow to the 4 o'clock and 8 o'clock holes in low-flow tests with 6 o'clock drain holes. However, most of the effluent exit through the 6 o'clock drain holes when they were present regardless of the distribution device used. When the flow rate was increased to 25 GPM the efficacy of the splitter tee and distribution box improved significantly in both tilted lateral tests and longitudinal tests with 6 o'clock drain holes; however, the distribution was still far from completely even in these cases. Because the traditional distribution devices provide poor longitudinal distribution rates even when laterally level, real OWTS with long trenches may consider pressure distribution or a high-volume dosing manifold such as the SeptiSurge to provide even longitudinal distribution. This is particularly important in OWTS that may not develop a traditional biomat such as with secondary treated effluent. On the other hand, the distribution media and biomat in a real OWTS provide additional longitudinal distribution; such considerations are discussed in further detail below.

The tests performed with speed levelers adjusted to compensate for the tilt of the distribution device resulted in the best lateral distribution at a 5% tilt of any device evaluated. However, in a real OWTS speed levelers require frequent maintenance to prevent biofilm or other solids from accumulating in the openings and to correct for changes in tilt caused by settling. Without such maintenance speed levelers could hinder rather than improve even distribution by restricting the flow of effluent.

Finally, it should be noted that the triple-dose configuration of the SeptiSurge also consistently provided better distribution than the standard configuration. The single-dose configuration also performed better with a 25 GPM inflow than a 2 GPM inflow despite the independence of the outflow rate from the inflow rate of the SeptiSurge; this is likely due to the higher inflow rate exceeding the outflow rate and thereby inducing the same effect as an increased dose volume. The dosing volume of the SeptiSurge can be increased simply by adding more pipes upstream; it is reasonable to expect that further increases in dosing volume would result in further improvement to distribution efficacy or extend longitudinal distribution to a greater length than the 20 feet tested in this experiment.

This experiment did not consider factors such as biofilm accumulation, distribution media, and biomat development, all of which can impact the distribution of real OWTS. Uneven biofilm development in pipes and distribution devices can cause or worsen problems with uneven effluent distribution (L. Gill et al., 2007; L. Gill et al., 2005; Patel et al., 2008a, 2008b). Higher flow rates can help keep distribution devices clear of solids (L. Gill et al., 2005), and as such devices such as surge boxes could help counteract the problem. Media such as rock or polystyrene used to fill trenches or seepage beds contributes to distribution (University of Minnesota, 2020). The media also provides support to the drainpipes and could be expected to prevent the sagging observed in this experiment, possibly improving longitudinal distribution. Biomat development also helps to even out distribution, with the areas of the biomat that receive more effluent growing thicker and thereby becoming less permeable, and vice versa (University of Minnesota, 2020). Both distribution media and biomat formation could be expected to counteract some of the unevenness of distribution in a real OWTS as compared to the observations made in this experiment. However, it should also be noted that a mature biomat may take months or years to form depending on the characteristics of the effluent (Knappe et al., 2020, Heger et al. 2008). Finally, sloping the drainpipes downward could help effluent flow further before exiting the pipe. Fully evaluating the impacts of all these factors on distribution would require extensive field testing over a period of years.

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