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Hydraulic Consideration for SDI Systems

Freddie R. Lamm, Research Irrigation Engineer
Kansas State University, Colby, Kansas, flamm@ksu.edu

Danny H. Rogers, Extension Irrigation Engineer,
Kansas State University, Manhattan, Kansas, drogers@ksu.edu

***Abstract*.** Subsurface drip irrigation (SDI) systems are increasingly being used for grain and fiber crops which have much less income potential than fruit, vegetable, vine and tree crops. These systems when used on the lesser value crops are typically have a deeper installation and are intended for multiple years of usage without replacement. As with any irrigation system, SDI must be designed with careful consideration of the hydraulic requirements, but the SDI system longevity must also be carefully considered when being used for lower value crops that need many years to amortize the initial cost. Longer length driplines are generally desirable for these SDI systems being used for lower value crops because that reduces the system cost and may reduce the irrigation management time. Because the systems are being used for many years without replacement, careful consideration must be given to the flushing requirements.

Keywords. microirrigation, subsurface drip irrigation, irrigation design

Introduction

A guiding principle in microirrigation design is to obtain and maintain high water application uniformity along the length of the driplines. Dripline and emitter characteristics and hydraulic properties, system operating pressure, and land slope are the major governing factors controlling the hydraulic design. These factors determine the acceptable dripline lengths for the SDI system with respect to the field size and shape and grower preferences. Longer driplines may result in a less expensive system to install and operate, which is of great importance to those growers using SDI on lower-valued crops typically grown in the Great Plains. Additionally, longevity of SDI systems is affected by how well the system is maintained and periodic flushing with a sufficient flushing velocity is considered an important aspect of routine maintenance.

Hydraulic Considerations for Dripline Length

Many different design criteria and procedures are used to calculate the maximum dripline length. Two uniformity criteria often used in microirrigation design are emitter discharge variation, q_{var}, and design emission uniformity, *EU,* and are given by

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \qquad \text{(Eq. 1)}$$

and

$$EU = 100\left[1.0 - \frac{1.27\,CV}{\sqrt{n}}\right]\frac{q_{min}}{q_{avg}} \qquad \text{(Eq. 2)}$$

where q_{max}, q_{min}, and q_{avg}, are the maximum, minimum, and average emitter discharge rates (gal/hr), respectively, along the dripline, *EU* is the design emission uniformity, n is the number of drip emitters per plant or 1, whichever is greater, and *CV* is the manufacturer's coefficient of variation.

Emitter flow variation of 10% or less is generally desirable, between 10% and 20% is acceptable, and greater than 20% is unacceptable (Bralts et al., 1987). Design emission uniformities of 80 to 90 are recommended for line-source emitters on uniform slopes and 70 to 85 on steep or undulating slopes (ASAE EP405.1, 2010). It should be noted that the use of these recommended q_{var} and *EU* criteria produce different results. Both criteria are reasonable for design purposes, however, and interrelationships exist for many of the design criteria used in microirrigation. Other hydraulic design procedures are available (Burt and Styles, 2007) and many of the dripline manufacturers provide their own software programs for system design. Some of these software programs will be used in this discussion to demonstrate important factors related to dripline design.

Emitter flow variation increases and design emission uniformity decreases as the emitter discharge rate and dripline length increase (Figure 1). In this example, for a 0.785 inside diameter *(ID)* dripline and dripline lengths of 500, 750, or 1000 feet, only four options have q_{var} values less than 10%, the 500 ft length with any of the emitter discharge rates and the 750 ft length for the 0.20 g/h emitter discharge rate. The acceptable 20% q_{var} criterion allows more acceptable emitter discharge and length combinations. Figure 1 also illustrates some discrepancy in the acceptable ranges between the q_{var} and *EU* design criteria, with a larger number of emitter discharge rate and length combinations providing an acceptable *EU.* There has been discussion among irrigation engineers that the ASABE EP405.1 design emission uniformity criteria for line-source emitters may need to be increased to values similar to those for point-source emitters. Manufacturing processes for line-source emitters have improved over the years and lower *EU* values for these products may no longer be necessary. A portion of the rationale for allowing reduced *EU* for line-source products is related to the typical single-year use of these products for DI where the long-term effects (season to season) of reduced uniformity would not occur. Thus, greater *EU* values may have more importance for multiple-year SDI systems.

Longer driplines with higher uniformity can be designed by increasing the dripline diameter while holding the emitter discharge constant (Figure 2). This design technique is popular for larger SDI systems used on the lower-valued commodity crops (fiber, grains and oilseeds) because it helps to reduce installation costs through fewer pipelines, controls, and trenches. This design technique is not without its concerns, however, because larger dripline diameters increase the propagation time of applied chemicals (Figure 3), and flushing flowrates can become quite large. Chemigation travel times for the larger-diameter driplines can exceed the period of the planned irrigation event on coarse-textured soils and thus lead to leaching and/or improper chemical application. Figure 3 also illustrates that chemigation travel times are not greatly affected by dripline length (slight increases with increase length), are moderately affected by emitter discharge (moderate decrease with increased emitter discharge), and are strongly affected by dripline diameter (major increases with increased diameter).

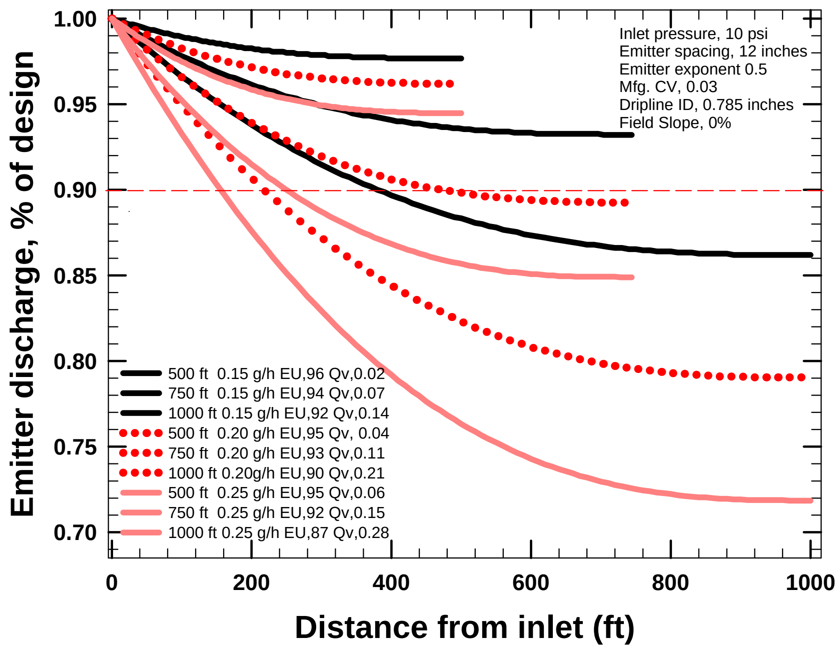

Figure 1. Calculated emitter discharge, emission uniformity (EU), and emitter discharge variation (q_{var}) as affected by dripline length and nominal design emitter discharge. Results for hypothetical dripline calculated with software from Roberts Irrigation Products (2003).

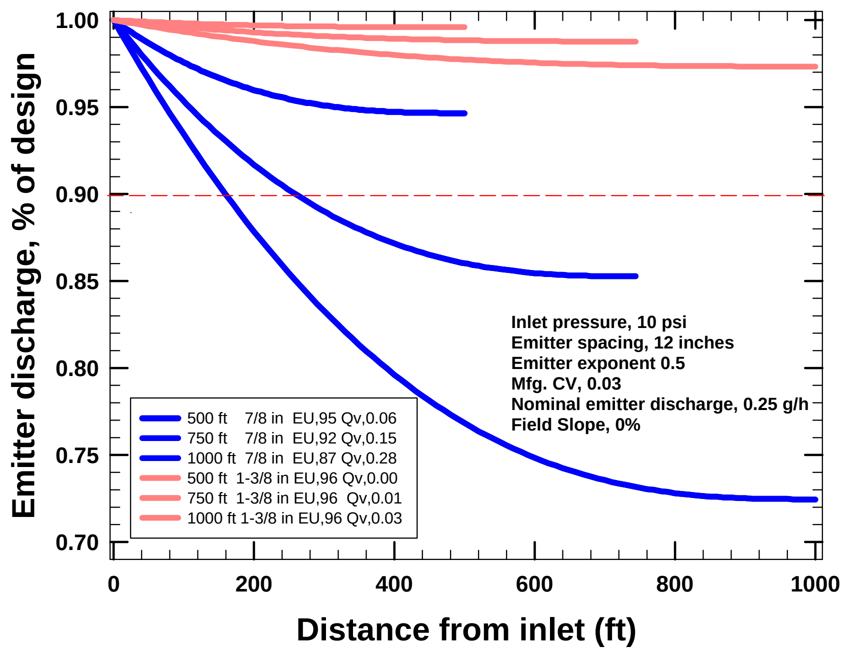

Figure 2. Calculated emitter discharge, emission uniformity (EU), and emitter discharge variation (q_{var}) as affected by dripline length and inside diameter. Results for hypothetical dripline calculated with software from Roberts Irrigation Products (2003).

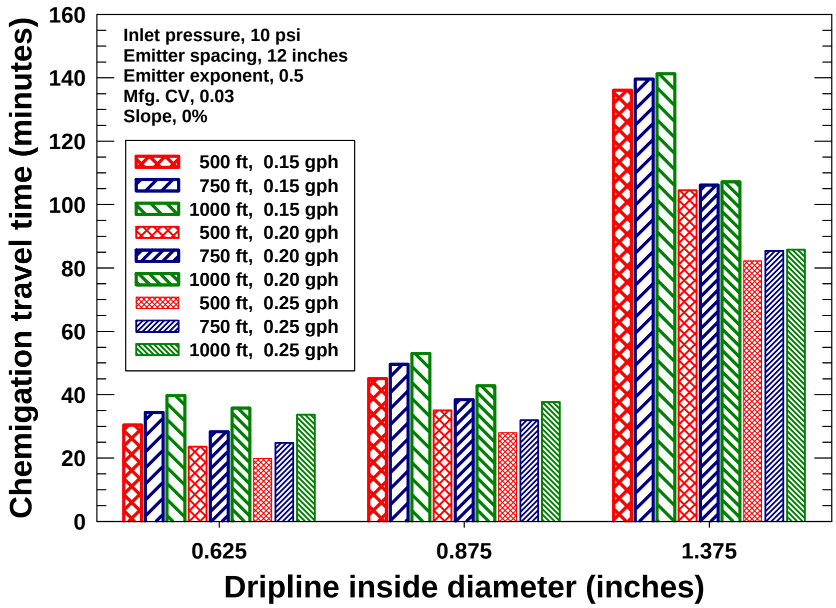

Figure 3. Approximate chemigation travel times as affected by dripline length and diameter, and emitter discharge rate. Results for hypothetical dripline calculated with software from Roberts Irrigation Products (2003).

While maintaining system uniformity, dripline length can also be increased by increasing the emitter spacing while holding the emitter discharge rate constant (Figure 4). This is also a popular design technique for larger SDI systems used on lower-valued crops, but is limited because the emitter spacing must be consistent with uniform water uptake by the crop. Emitter spacing may become too great as random emitters begin to clog.

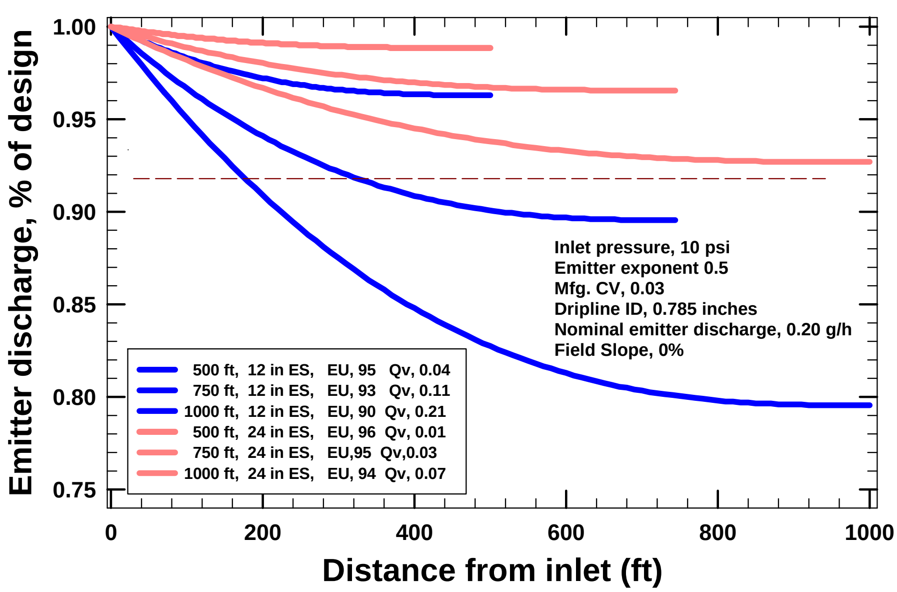

Figure 4. Calculated emitter discharge, emission uniformity (EU), and emitter discharge variation (q_{var}) as affected by dripline length and emitter spacing *(ES)*. Results for hypothetical dripline calculated with software from Roberts Irrigation Products (2003).

The land slope can have either a positive or negative effect on the emitter discharge rate along the dripline lateral (Figure 5). Driplines running uphill always result in increasing pressure losses along the dripline and thus lower system uniformity. When the downhill slope is too great, the emitter discharge rate at the end of the dripline becomes unacceptably high. In the example shown (Figure 5), the optimum slope is 1% downslope, but this will vary with dripline and emitter characteristics. Designers may even use these hydraulic factors to their advantage to balance elevation head gains with increased friction losses from smaller diameter driplines. When slopes are too great, designers may recommend that the driplines be installed across the slope or along the contour.

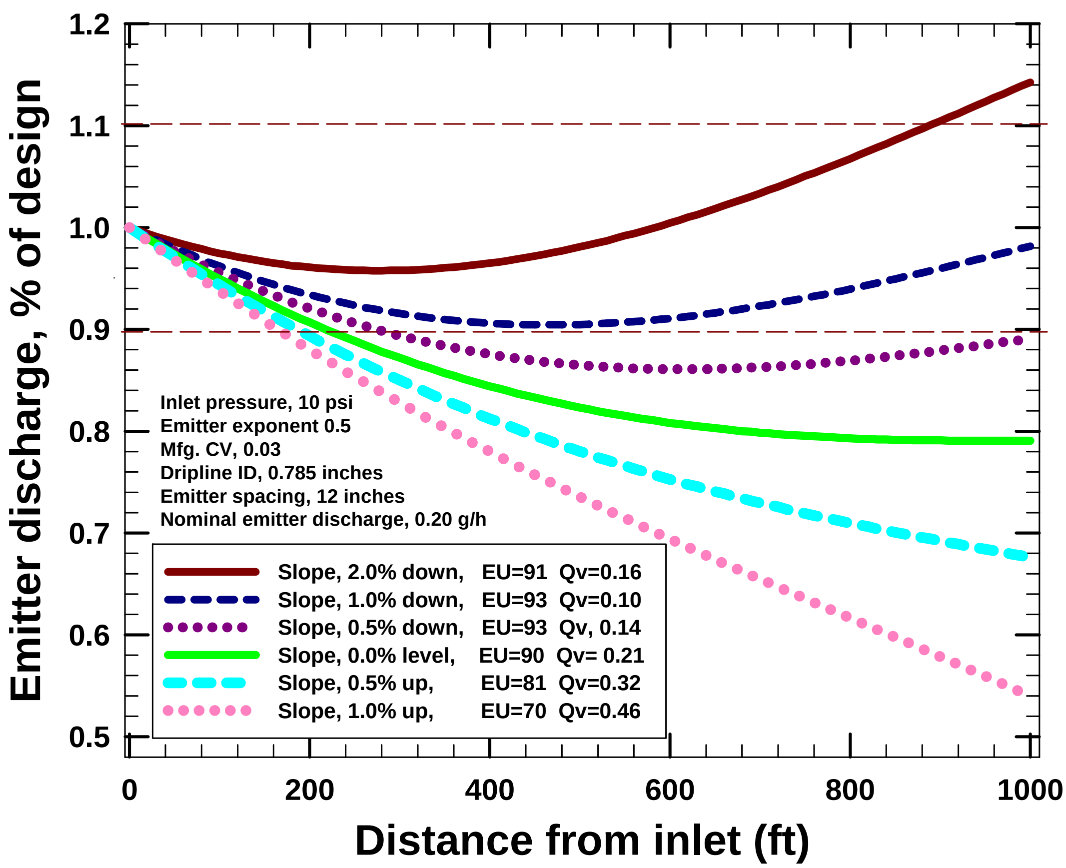

Figure 5. Calculated emitter discharge, emission uniformity (EU), and emitter discharge variation (q_{var}) as affected by topography. Results for hypothetical dripline calculated with software from Roberts Irrigation Products (2003).

The emitter discharge (q) can generally be characterized by a simple power equation

$$q = kH^{x} \qquad \text{(Eq. 3)}$$

where k is a constant depending upon the units of q and H, H is the pressure and x is the emitter exponent. The value of x is typically between 0 and 1, although values outside the range are possible. For an ideal product, x equals 0, meaning that the emitter discharge is independent of the pressure. This would allow for high uniformity on very long driplines, which would minimize cost (Figure 6). An emission product with an x of 0 is said to be fully pressure compensating (PC). An x value of 1 is noncompensating (NPC), meaning any percentage change in pressure results in an equal percentage change in emitter discharge rate. Many lay-flat dripline products have an emitter exponent of approximately 0.5. A 20% change in pressure along the dripline results in a 10% change in emitter discharge rate if the exponent is 0.5. Pressure-compensating emitters are widely used on steep land slopes, but are not always cost-competitive for lower-valued commodity crops.

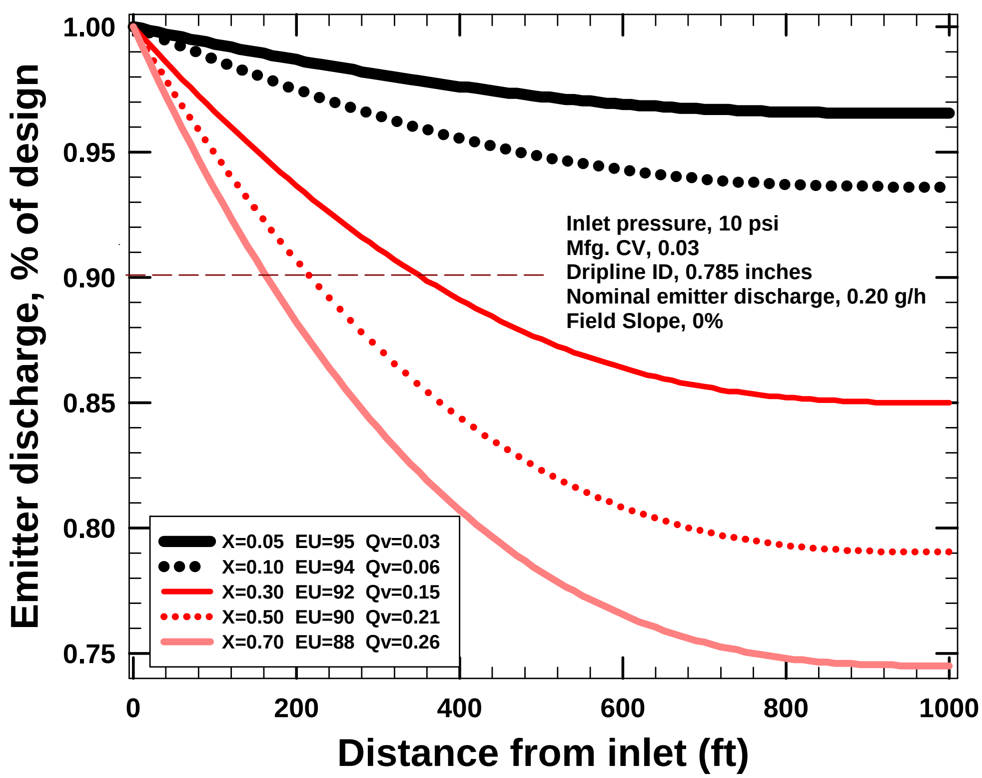

Figure 6. Calculated emitter discharge, emission uniformity (EU), and emitter discharge variation (q_{var}) as affected by the emitter exponent (x). An emitter with an exponent of zero is said to be fully pressure compensating (PC). Results for hypothetical dripline calculated with software from Roberts Irrigation Products (2003).

Hydraulic Considerations for Flushing Velocity

A minimum flushing velocity of 1 ft/s is recommended for microirrigation systems by the American Society of Biological and Agricultural Engineers (ASAE EP405.1, 2003). However, disagreement exists about the recommended flushing velocity for SDI systems, with values ranging from 1 to 2 ft/s (Burt and Styles, 2007). The practical rationale for a higher flushing velocity for SDI is that perhaps it could provide better overall flushing of materials. Many of these systems are used for multiple years and system longevity is very important in determining SDI economic feasibility, especially for lower-valued crops. The required flushing velocity and flushline hydraulics greatly affect the SDI system design. Higher velocities require large supply lines and flushlines and shorter lengths of run to keep the flushing pressures below the maximum allowable dripline operating pressure. The general guideline is that the required flushing velocity be maintained in all segments of the SDI system, but there are locations where this guideline cannot be followed. The water velocity in the flushline at the farthest point from the flush valve is very low because only a single dripline is contributing flow. Decreasing the flushline diameter at this point in the system could help maintain a higher velocity but also increases the downstream pressure on the dripline. It is more important to maintain adequate flushing velocity in the driplines because the emitters are subject to clogging.

Some pressure usually exists on the end of driplines during flushing for SDI systems that use a flushline common to a group of driplines. This downstream pressure represents the sum of elevation changes between the dripline and the point where the water exits the flush valve, friction losses in the flushline, friction losses in the flush valve, and the friction losses associated with the dripline/flushline connection. It is difficult to design for a dripline downstream pressure during flushing of less than 1 psi and values of 3 psi are reasonable under some circumstances. Downstream pressures that are greater than 3 psi during flushing will often require driplines with higher maximum allowable operating pressure or that the designer must reduce dripline length and/or emitter discharge rates. The inlet pressure during flushing often has more restriction on design dripline length and emitter discharge rate than system uniformity (Figure 7). Adjustable pressure regulators or other design characteristics may be required to accommodate the higher inlet pressure requirements during flushing.

The required flowrate during flushing can be considerably higher than the nominal dripline flowrate (Figure 8). This may require larger pipe size (mains, submains and headers), adjustments to the pumping plant to provide the larger flow, and/or splitting the normal irrigation zone into more than one flushing zone.

Conclusions

Careful consideration must be given to the hydraulic design of SDI systems because of the complex manner in which the different factors interact. An improperly designed SDI system is less forgiving than an improperly designed center pivot sprinkler system. Water distribution problems may be difficult or impossible to correct for an improperly designed SDI system. The SDI system must also be properly designed to ensure system longevity. Minimizing investment costs through cheaper designs can be a double-edged sword, as a cheaper system may increase operating costs and/or possibly increase the chance of system failure.

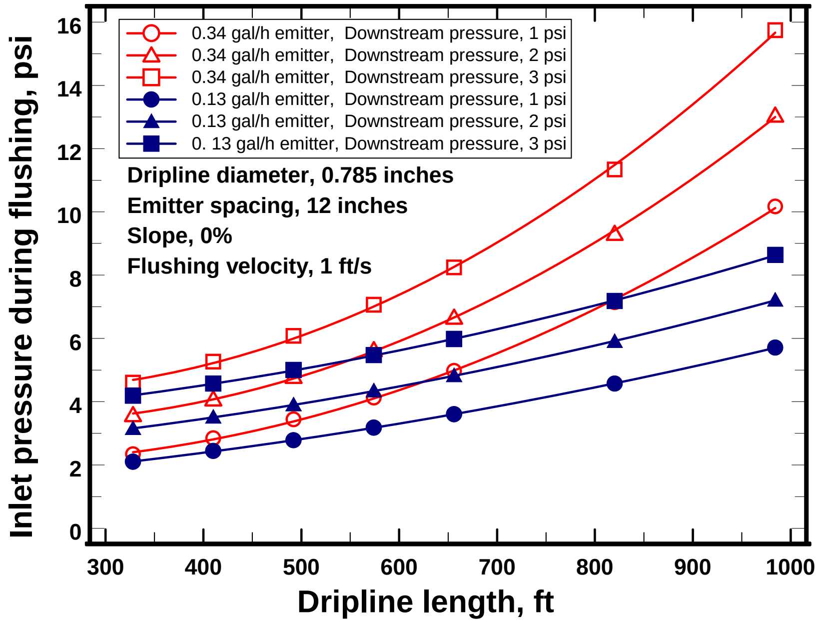

Figure 7. Required inlet pressure to maintain a 1 ft/s dripline flushing velocity, as affected by the nominal emitter discharge rate, dripline length, and downstream pressure. Results for hypothetical dripline calculated with software from Toro Ag Irrigation (2002).

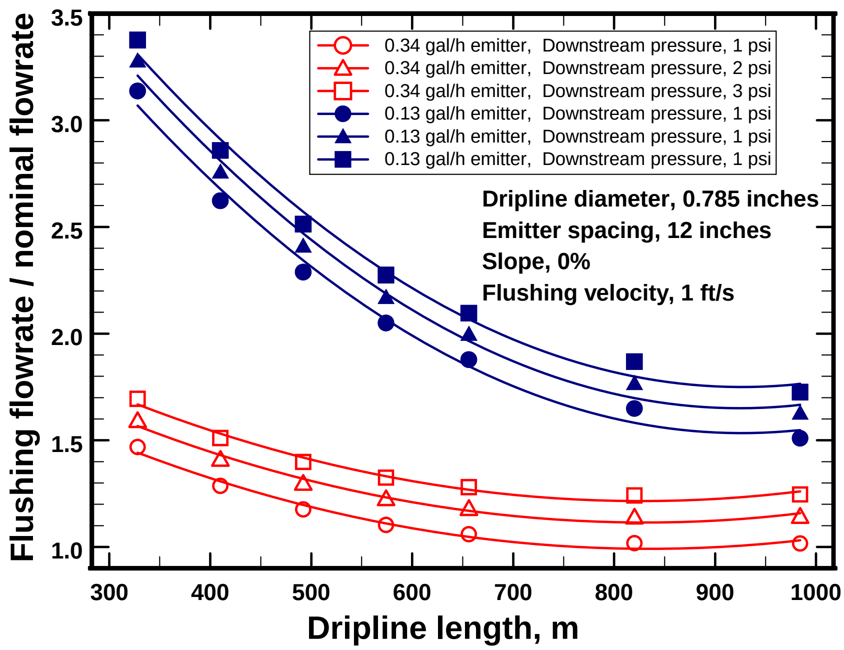

Figure 8. Ratio of required flushing flowrate to nominal design flowrate to maintain a 1 ft/s dripline flushing velocity as affected by nominal emitter discharge rate, dripline length, and downstream pressure. Results for hypothetical dripline calculated using software from Toro Ag Irrigation (2002).

Acknowledgements

[1] Mention of tradenames is for informational purposes only and does not constitute endorsement by the authors or by the institutions they serve.

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