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KEYS TO SUCCESSFUL ADOPTION OF SDI: MINIMIZING PROBLEMS AND ENSURING LONGEVITY

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INTRODUCTION

Since 1989, research studies and demonstration studies at the Northwest and Southwest Research-Extension Centers of Kansas State University have indicated that subsurface drip irrigation (SDI) systems can be efficient, long-lived, and adaptable for irrigating corn and other deep-rooted crops. A survey of all Kansas SDI users in 2003 revealed an estimated 14,000 acres were irrigated with SDI systems (Rogers, unpublished data). Though system usage has grown steadily over the years, SDI systems are currently used on less than 1% of total irrigated acres. The 2006 Kansas Irrigation Water Use Report indicated that 10,250 acres were exclusively irrigated by SDI systems and an additional 8,440 acres were irrigated partially by SDI in combination with another system type, such as an irrigated SDI corner of a center pivot sprinkler or a surface gravity-irrigated field partially converted to SDI.

Many producers have had successful experiences with SDI systems despite minor technical difficulties during the adoption process. In a 2005 survey of SDI users, nearly 80% of Kansas producers indicated they were at least satisfied with the performance of their SDI system, and less than 4% indicated they were not satisfied (Alam & Rogers 2005). However, even satisfied users indicated a need for additional SDI management information. The most noted concern was the damage and repairs caused by rodents. A few systems had failed or had been abandoned after a short-use period due to inadequate design, inadequate management or a combination of both.

Design and management are closely linked in a successful SDI system. Research studies and on-farm producers both indicate that SDI systems result in high-yielding crops and water-conserving production practices only when the systems are properly designed, installed, operated and maintained. A system that is improperly designed and installed will be difficult to operate and maintain and most likely will not achieve high irrigation water application uniformity and efficiency goals. However, proper design and installation does not ensure high SDI efficiency and long system life. An SDI system must also be operated according to design specifications and utilize good irrigation water management procedures to achieve high uniformity and efficiency. An SDI system is also destined for early failure without proper maintenance. This paper will review key factors for successful adoption of SDI for Kansas irrigated agriculture.

MINIMUM SDI COMPONENTS FOR EFFICIENT WATER DISTRIBUTION AND SYSTEM LONGEVITY

SDI system design must consider individual management restraints and goals, as well as account for specific field and soil characteristics, water quality, well capabilities, desired crops, production systems, and producer goals. However, certain basic features are a part of all SDI systems, as shown in Figure 1. The long-term ability of the producer to operate and maintain the system in an efficient manner is seriously undermined if any of the minimum components are omitted during the design process. Minimum SDI system components should not be sacrificed as design and installation cost-cutting measures. If minimum SDI components cannot be included as part of the system, an alternative type of irrigation system or a dryland production system should be considered.

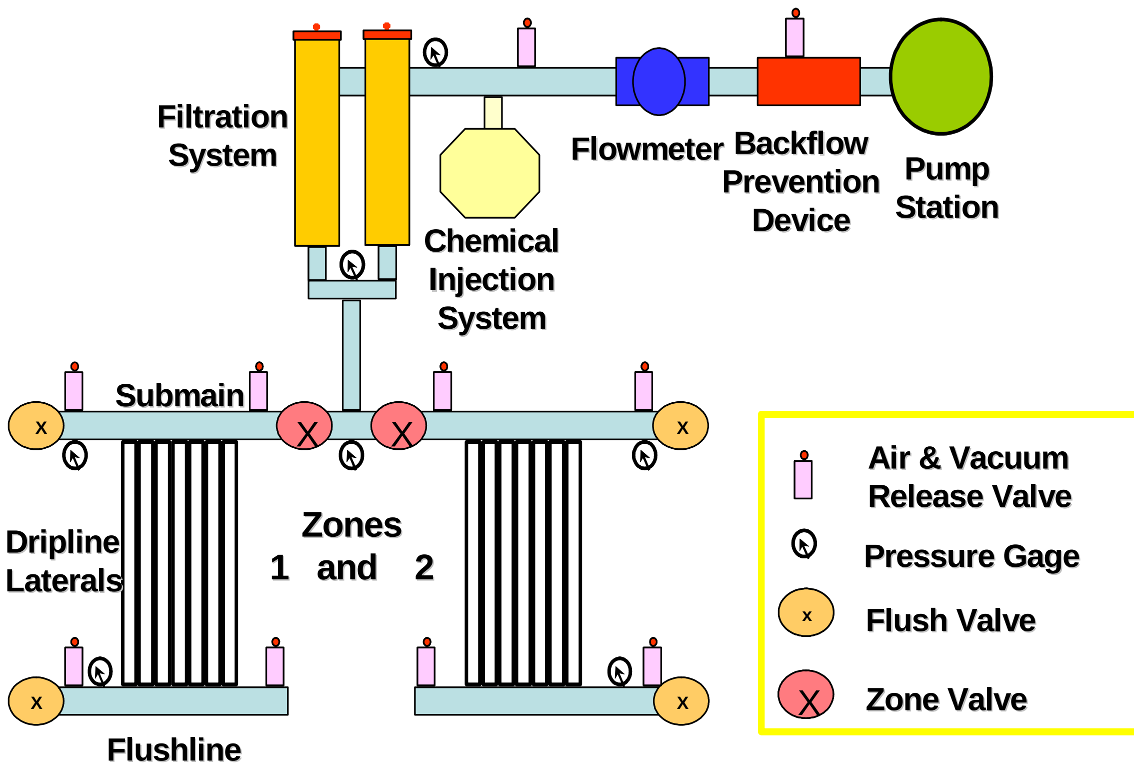

Figure 1. Minimum components of an SDI system. (Components are not to scale) K-State Research and Extension Bulletin MF-2576, Subsurface Drip Irrigation (SDI) Component: Minimum Requirements

Water distribution components of an SDI system include the pumping station, the main, submains and dripline laterals. Sizing requirements for the mains and submains are somewhat similar to underground service pipe to center pivot sprinklers or main pipelines for surface-irrigated gravity systems and are determined by the flow rate and acceptable friction loss within the pipe. In general, the flow rate and friction loss determines the dripline size (diameter) for a given dripline lateral length and land slope. An SDI system consisting of only the distribution components would have no method to monitor system performance and the system would not have any protection from clogging or any methods to conduct system maintenance. Clogging of dripline emitters is the primary reason for SDI system failure. In addition to basic water distribution components, additional components allow the producers to monitor SDI system performance, allow flushing, and protect or maintain performance by injection of chemical treatments. The injection equipment can also be used to provide additional nutrients or chemicals for crop production. A backflow prevention device is required to protect the source water from accidental contamination if backflow should occur.

The actual characteristics and field layout of an SDI system vary from site to site, but irrigators often add additional capabilities to their systems. For example, the SDI system in Figure 2 shows additional valves that allow the irrigation zone to be split into two flushing zones. When the well or pump does not have the capacity to provide additional flow and pressure to meet the flushing requirements for the irrigation zone, splitting the zone into two parts may be an important design feature. The American Society of Agricultural and Biological Engineers (ASABE) recommends a minimum flushing velocity of 1 ft/s for microirrigation lateral maintenance (ASAE EP-405, 2008). This flushing velocity requirement needs to be carefully considered at the design stage, and may dictate larger sizes for submains and flushlines to assure that maximum operating pressures for the driplines are not exceeded (Lamm and Camp, 2007).

Filter systems are generally sized to remove particles that are approximately 1/10 the diameter of the smallest emitter passageway. However, small particles still pass through the filter and into the driplines, and over time, they can clump together. Also, biological or chemical processes produce materials that need to be removed to prevent emitter clogging or a build-up of material at the outlet or distal end of the system. Opening the flushline valves allows water to rapidly pass through the driplines, carrying away any accumulated particles. A good design should allow flushing of all pipeline and system components.

The frequency of flushing is largely determined by the quality of the irrigation water and to a degree, the level of filtration. A good measure of the need to flush is to evaluate the amount of debris caught in a mesh cloth during a flushing event. When only a small amount of debris is found, the flushing interval may be increased. Heavy accumulations of debris, however, mean more frequent flushing is needed.

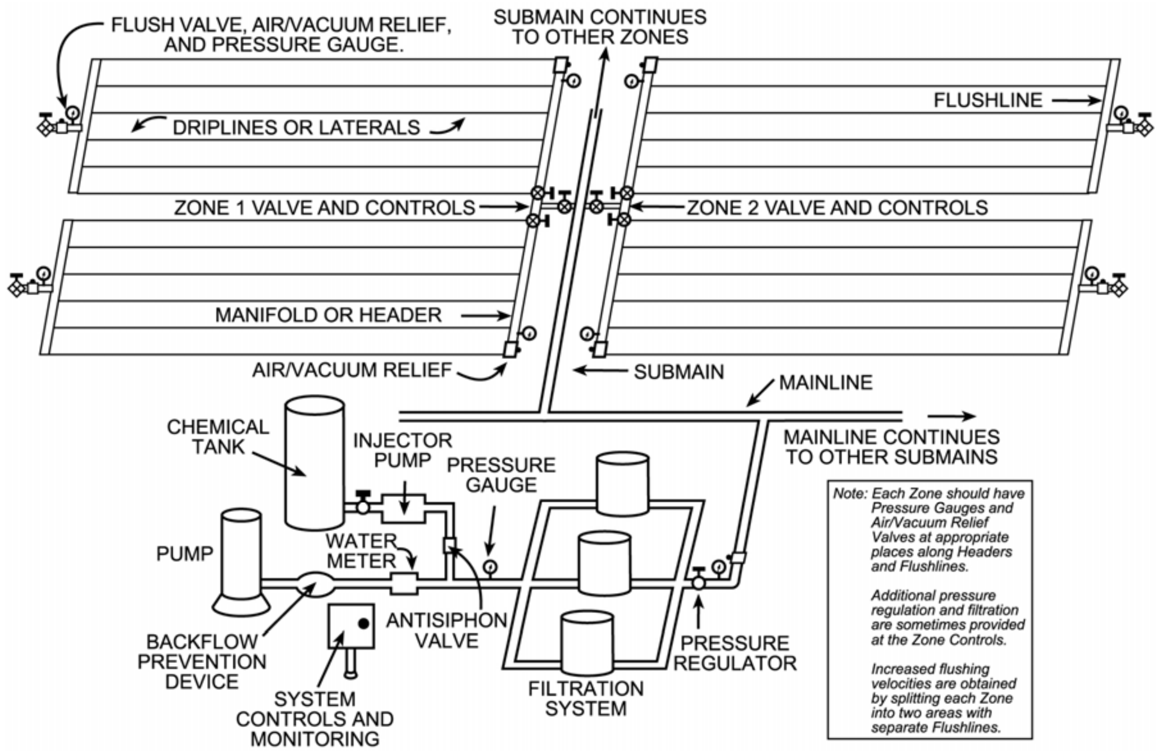

Figure 2. Layout for a well-designed SDI system (Lamm and Camp, 2007).

In SDI systems, all water application is underground. Because no surface wetting occurs in properly installed and operated systems, no visual cues of system operation are available to the manager. Therefore, the flow meter and pressure gauges act as operational feedback cues. The pressure gauges along the submain of each zone measure the inlet pressure to driplines. Decreasing flow rates and/or increasing pressure may indicate clogging, and increasing flow rates with decreasing pressure may indicate a major line leak. The inlet pressure gauges along with those at the distal ends of the dripline laterals at the flushline valve help establish the baseline performance characteristics of the system. Good quality pressure gauges should be used at each of these measurement locations and the gauges should be periodically replaced or inspected for accuracy. The flow rate and pressure measurements should be recorded and retained for the life of the system. A time series of flow rate and pressure measurements can be used as a diagnostic tool to discover operational problems and determine appropriate remediation techniques, as illustrated in Figure 3.

Anomaly A: The irrigator observes an abrupt flowrate increase with a small pressure reduction at the Zone inlet and a large pressure reduction at the Flushline outlet. The irrigator checks and finds rodent damage and repairs the dripline.

Anomaly B: The irrigator observes an abrupt flowrate reduction with small pressure increases at both the Zone inlet and the Flushline outlet. The irrigator checks and finds an abrupt bacterial flare-up in the driplines. He immediately chlorinates and acidifies the system to remediate the problem.

Anomaly C: The irrigator observes an abrupt flowrate decrease from the last irrigation event with large pressure reductions at both the Zone inlet and Flushline outlet. A quick inspection reveals a large filtration system pressure drop indicating the need for cleaning. Normal flowrate and pressures resume after cleaning the filter.

Anomaly D: The irrigator observes a gradual flowrate decrease during the last four irrigation events with pressure increases at both the Zone inlet and Flushline outlet. The irrigator checks and find that the driplines are slowly clogging. He immediately chemically treats the system to remediate the problem.

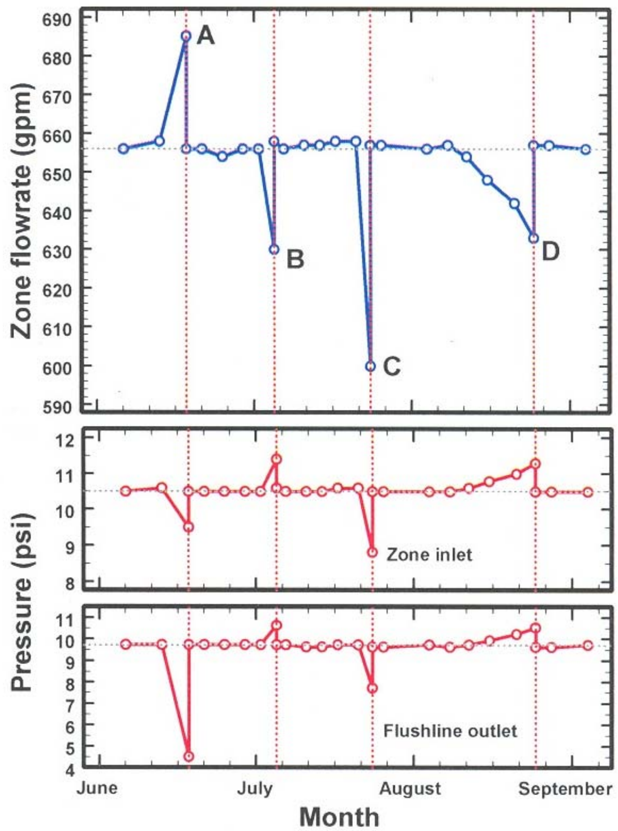

Figure 3. Hypothetical example of how pressure and flowrate measurement records could be used to discover and remediate operational problems (Lamm and Camp, 2007).

FILTRATION SYSTEM

The heart of the protection system for the dripline emitters is the filtration system. The type of filtration system depends on the quality characteristics of the irrigation water and the clogging hazards. The illustration in Figure 1 depicts a pair of screen filters, while Figure 2 shows a series of sand media filters. Screen filters are the simplest type of filtration and provide a single plane of filtration. They are most often used in situations where the water source is relatively clean. Sand media filtration systems, which consist of two or more large pressure tanks with specially graded filtration sand, provide three dimensional filtration and are well-suited for surface water sources. Surface water supplies may require settling basins and/or several layers of bar screen barriers at the intake site to remove large debris and organic matter. Another common type of filtration system is the disc filter which can also be considered as providing three dimensional filtration. In some cases, the filtration system may be a combination of filtration components. For example, a well that produces a large amount of sand in the pumped water may require a cyclonic sand separator in advance of the main filter. Examples of the different types of filters are shown in Figure 4.

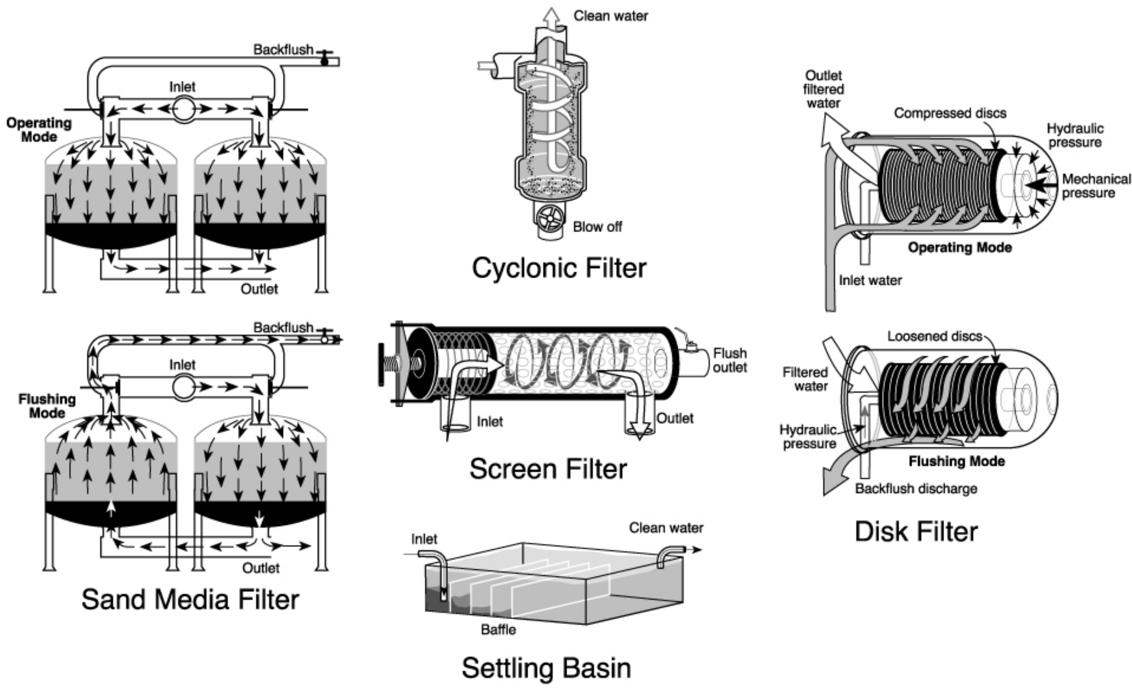

Figure 4. Schematic description of various filtration systems and components. (Courtesy of Kansas State University).

Clogging hazards are classified as physical, biological or chemical. Sand particles in the water represent a physical clogging hazard, and biological hazards are living organisms or life by-products that clog emitters. Water sources that have high iron content are also vulnerable to biological clogging hazards, such as an iron bacteria flare-up within the groundwater well. Control of bacterial growth generally requires water treatment in addition to filtration. Chemical clogging hazards relate to the chemical composition or quality of the irrigation water. As water flows from a well to the distribution system, chemical reactions occur due to changes in temperature, pressure, air exposure, or the introduction of other materials into the water stream. These chemical reactions may form precipitates that result in emitter clogging.

INJECTION SYSTEM

In addition to the protection component, the chemical injection system injects nutrients or chemicals into the water to enhance plant growth or yield. A variety of injectors can be used, but the choice of unit depends on the desired injection accuracy of a material, the rate of injection, and the agrochemical being injected. When a wide variety of chemicals are likely to be injected, then more than one type of injection system may be required. Also, state and federal laws govern the type of injectors, appropriate agrochemicals, application amounts, and required safety equipment that may be used in SDI systems, as illustrated by example in Figure 5.

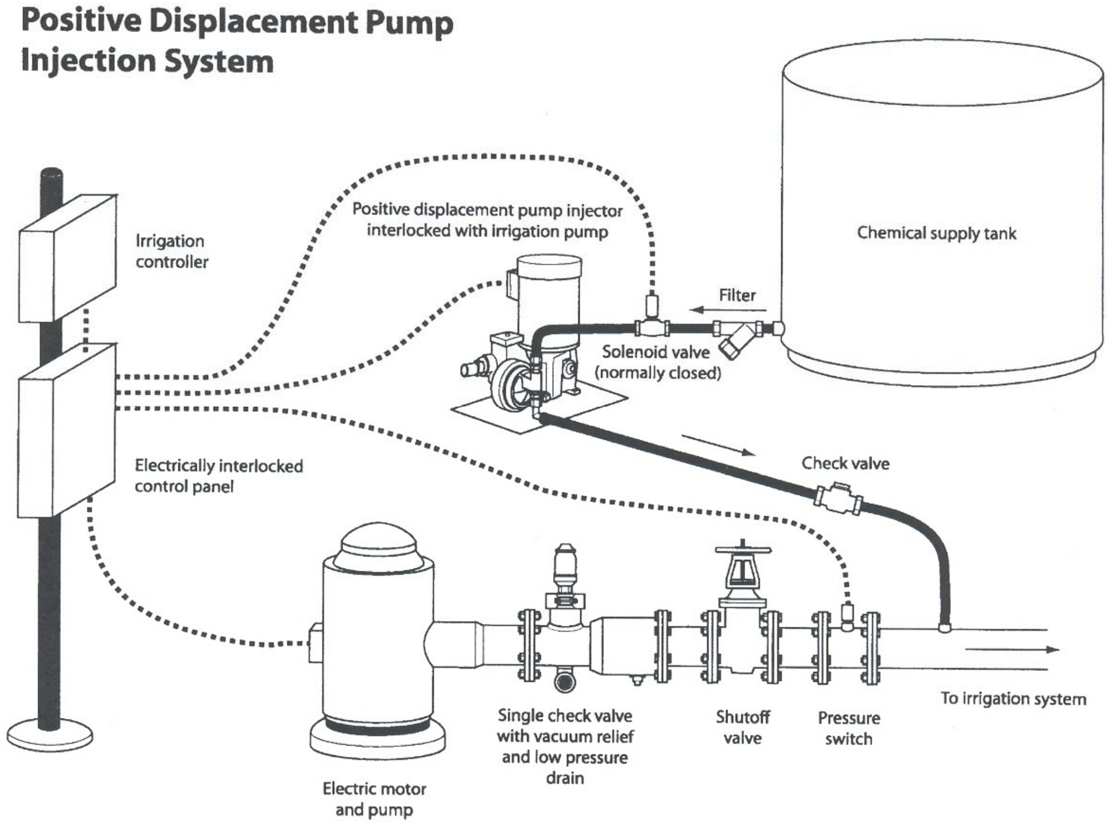

Figure 5. Layout of an Injection System with Safety Interlocks and Backflow Prevention Devices (Courtesy of L.J. Schwankl, Univ. of California-Davis)

Many different agrochemicals can be injected, including chlorine, acid, dripline cleaners, fertilizers, and some pesticides. Producers should avoid injecting any agrochemical into their SDI system without knowledge of the agrochemical compatibility with irrigation water. For example, various phosphorus fertilizers are incompatible with many water sources and may only be injected using additional precautions and management techniques. All applicable laws and labels should be followed when applying agrochemicals.

The injection systems in Figures 1 and 2 have a single injection point located upstream of the main filter, but some agrochemicals may require an injection point downstream from the filter to prevent filter damage. Care needs to be exercised in the location of the injection port to prevent system problems such as corrosion within the filters or chemical precipitation beyond the filter resulting in emitter clogging.

Chlorine is commonly used to disinfect the injection system and minimize the risk of clogging from biological organisms. Acid injection can also lower the pH chemical characteristic of the irrigation water. For example, water with a high pH clogs easily because minerals drop out of solution in the dripline after the water passes through the filter. A small amount of acid added to the water lowers the pH to minimize to potential for mineral clogging.

WATER QUALITY ANALYSIS

Water quality also has a significant effect on SDI system performance and longevity. In some instances, poor water quality causes soil and crop growth problems. However, with proper treatment and management, water high in minerals, nutrient enrichment or salinity can be used successfully in SDI systems. No SDI system should be designed and installed without first assessing the quality of the proposed irrigation water supply.

Clogging prevention is the key to SDI system longevity and requires understanding of the potential problems associated with a particular water source. Table 1 details important water quality information that all designers and irrigation managers should consider in the early stages of the planning process. With this information in mind, suitable management, maintenance plans, and system components, like the filtration system, can be selected.

Table 1. Recommended water quality tests to be completed before designing an SDI system.

1. **Electrical Conductivity (EC)**, a measure of total salinity or total dissolved solids, measured in dS/m or mmho/cm.
2. **pH**, a measure of acidity, where a value of 1 is very acid, 14 is very alkali, and 7 is neutral.
3. **Cations** include Calcium (Ca), Magnesium (Mg), and Sodium (Na), measured in measured in meq/L, (milliequivalent/liter).
4. **Anions** include Chloride (Cl), Sulfate (SO_4), Carbonate (CO_3), and Bicarbonate (HCO_3), measured in meq/L.
5. **Sodium Absorption Ratio (SAR)**, a measure of the potential for sodium in the water to develop sodium sodicity, deterioration in soil permeability and toxicity to crops. SAR is sometimes reported as Adjusted (Adj) SAR. The Adj. SAR value better accounts for the effect on the HCO_3 concentration and salinity in the water and the subsequent potential damage to the soil because of sodium.
6. **Nitrate nitrogen (NO_3 - N)**, measured in mg/L (milligram/liter).
7. **Iron (Fe), Manganese (Mn), and Hydrogen Sulfide (H_2S)**, measured in mg/L.
8. **Total suspended solids**, a measure of particles in suspension in mg/L.
9. **Bacterial population**, a measure or count of bacterial presence in # / ml, (number per milliliter)
10. **Boron*** measured in mg/L.
11. **Presence of oil****

* The boron test would be for crop toxicity concern.

** Oil in water would be a concern for excessive filter clogging. It may not be a test option at some labs and could be considered an optional analysis.

Results for Tests 1 through 7 should be provided in a standard irrigation water quality test package. Tests 8 through 11 are generally offered by Water Labs as individual tests. The test for the presence of oil may be helpful in oil-producing areas of the state or if the well to be used for SDI has experienced surging, which causes existing drip oil in the water column to mix with the pumped water. The fee schedule for Tests 1 through 11 varies from lab to lab and may total a few hundred dollars. The cost is minor, however, in comparison to the value offered by the test in determining proper design and operation of the SDI system.

RODENT MANAGEMENT

Burrowing mammals, principally of the rodent family, can cause extensive leaks that reduce SDI system uniformity. Most rodents avoid digging into wet soil, so dripline leaks presumably are not caused by the animals looking for water. Rather, rodents must gnaw on hard materials, such as plastic, to wear down their continuously growing teeth. The difficulty in determining the actual location of a dripline leak caused by rodents is compounded by the fact that the leaking water may follow the burrow path for a considerable distance before surfacing. Anecdotal reports from the U. S. Great Plains can be used to describe some of the typical habitat scenarios that tend to increase rodent problems. These scenarios include the close proximity of permanent pastures and alfalfa fields, railroad and highway easements, irrigation canals, sandy soils, crop and grain residues during an extended winter dormant period, or absence of tillage.

Cultural practices such as tillage and crop residue removal from around SDI control heads and above-ground system apparatus seem to decrease the occurrence of rodent problems. Some growers have tried deep subsoiling and/or applying poison bait around the SDI system field perimeters as a means of reducing rodent subsurface entry into the field. Isolated patches of residue within a barren surrounding landscape will provide an "oasis" effect conducive to rodent establishment. After the smaller rodents become established, other burrowing predators such as badgers can move into the field, further exacerbating the damage. Caustic, odoriferous, pungent, and unpalatable chemical materials have been applied through SDI systems in attempts to reduce rodent damage, but the success of these trials has been varied. Periodic wetting of the soil during the dormant period has been suggested as a possible means of reducing rodent damage. Deeper SDI depths (18 inches or greater) may avoid some rodent damage (Van der Gulik, 1999). Many of the burrowing mammals of concern in the United States have a typical depth range of activity that is less than 18 inches (Cline et al., 1982).

PRODUCER RESPONSIBILITIES

The decision to invest in an SDI system is ultimately up to the investor. Good judgments require a thorough understanding of the fundamentals of the opportunities and challenges and/or the recommendations from a proven expert. A network of SDI industry support is still in early development in the High Plains region, even though the microirrigation industry is over 40 years old and application in Kansas has been researched since 1989. Individuals considering SDI should carefully determine if the system is a viable option for their situation by taking the following actions:

1. Getting educated before contacting a service provider or salesperson by
    a. Seeking out university and other educational resources. Good places to start are the K-State SDI website at www.oznet.ksu.edu/sdi and the Microirrigation forum at www.microirrigationforum.com. Read the literature or websites of companies as well.
    b. Reviewing minimum recommended design components as recommended by K-State. http://www.oznet.ksu.edu/sdi/Reports/2003/mf2576.pdf
    c. Visiting other producer sites that have installed and used SDI. Most current producers are willing to show their systems to others.

2. Interviewing at least two companies.
    a. Ask for references, credentials (training and experience) and sites (including the names of contacts or references) of other completed systems.
    b. Ask questions about design and operation details. Pay particular attention if the minimum SDI system components are not met. If not, ask why? System longevity is a critical factor for successful adoption of SDI.
    c. Ask companies to clearly define their role and responsibility in designing, installing and servicing the system. Determine what guarantees are provided.

3. Obtaining an independent review of the design by an individual that is not associated with sales. This adds cost but should be minor compared to the total cost of a large SDI system.

SUMMARY AND CONCLUSIONS

Subsurface drip irrigation (SDI) offers a number of agronomic production and water conservation advantages but these advantages are only achieved with proper design, operation, and maintenance. With proper care the SDI system can have an efficient, effective and long life. One necessary change from the current irrigation systems, however, is the need to understand SDI's sensitivity to clogging by physical, biological and/or chemical agents.

Before designing or installing an SDI system, a comprehensive water quality assessment should be conducted on the source water supply. Once this assessment is completed, the system designer can alert the manager of any potential problems that might be caused by the water supply. The old adage "an ounce of prevention is worth a pound of cure" is very appropriate for SDI systems. Early recognition of developing problems and appropriate action can prevent larger problems. While the management needs may seem daunting at first, most managers quickly become familiar with the SDI system and its operational needs.

The SDI operator/manager also needs to understand the need for and function of the various components of the SDI system. Many accessory options are available for SDI systems that can be included during the initial design and installation phases or added at a later time. More importantly, minimum design and equipment features must be included in the basic system. SDI is a viable irrigation system option, but it should be carefully considered by producers before making any financial investment.

OTHER AVAILABLE INFORMATION

The above discussion is a brief summary prepared from materials available through K-State. The SDI related bulletins and irrigation-related websites are listed below:

MF-2361 *Filtration and Maintenance Considerations for Subsurface Drip Irrigation (SDI) Systems http://www.oznet.ksu.edu/sdi/Reports/2003/mf2361.pdf*

MF-2576 *Subsurface Drip Irrigation (SDI) Components: Minimum Requirements http://www.oznet.ksu.edu/sdi/Reports/2003/mf2576.pdf*

MF-2578 *Design Considerations for Subsurface Drip Irrigation http://www.oznet.ksu.edu/sdi/Reports/2003/mf2578.pdf*

MF-2590 *Management Consideration for Operating a Subsurface Drip Irrigation System http://www.oznet.ksu.edu/sdi/Reports/2003/MF2590.pdf*

MF-2575 *Water Quality Assessment Guidelines for Subsurface Drip Irrigation http://www.oznet.ksu.edu/sdi/Reports/2003/mf2575.pdf*

MF 2589 *Shock Chlorination Treatment for Irrigation Wells http://www.oznet.ksu.edu/sdi/Reports/2003/mf2589.pdf*

Related K-State Research and Extension Irrigation Websites:

Subsurface Drip Irrigation http://www.oznet.ksu.edu/sdi

General Irrigation http://www.oznet.ksu.edu/irrigate

Mobile Irrigation Lab http://www.oznet.ksu.edu/mil

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