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Filtration and Maintenance: Considerations for Subsurface Drip Irrigation (SDI)

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All irrigation systems require proper maintenance. Subsurface drip irrigation (SDI) systems are no exception. The basic components of a typical SDI system are shown in *Figure 1*. The major cause of failure in SDI and other microirrigation (low flow) systems is emitter clogging. Because emitters in SDI systems are small and can easily clog, it is important to understand the filtration and maintenance requirements of SDI systems and be proactive to prevent clogging. *Figure 2* shows a cut-away diagram of a typical emitter.

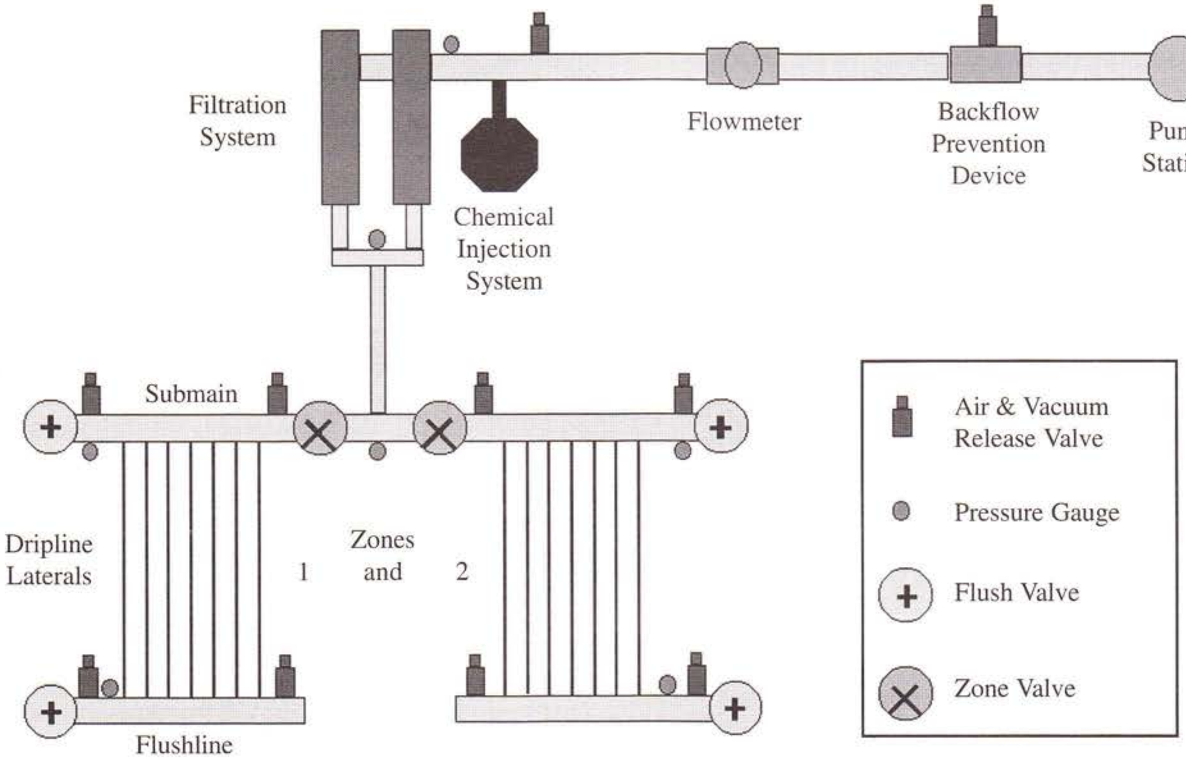

Figure 1. Schematic of subsurface drip irrigation system (courtesy of Kansas State University).

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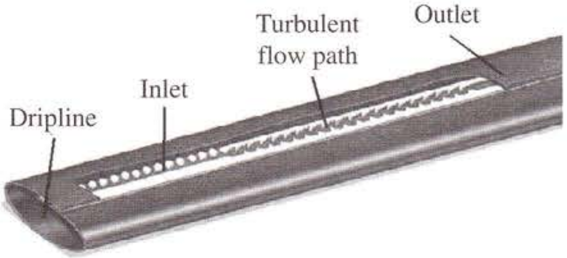

Figure 2. Illustration of dripline emitter (courtesy of T-Systems International).

Causes of Emitter Clogging

Clogging hazards for SDI systems fall into three general categories: physical (sediment), biological or organic (bacteria and algae), and chemical (scale). Frequently, clogging is caused by a combination of more than one of these factors. The source and quality of the water used for irrigation dictate both the type and size of the filtration components as well as the intensity and frequency of system maintenance. The characteristics of the dripline, emitter opening size in particular, play a role in the selection of the filtration system to use. In addition, a water quality analysis is necessary to further define the filtration and maintenance measures required to prevent clogging.

Influence of the Water Source

The type of emitter clogging problems that occur vary with the source of the irrigation water. Water sources can be grouped into two categories: surface or ground water. Both of these water sources present specific clogging hazards.

Algal and bacterial growth are major problems associated with the use of surface water. Individual algae cells and organic residues of algae are often small enough to pass through the filters of an irrigation system. Once in the system, these cells can form aggregates that plug emitters. Residues of decomposing algae can accumulate in pipes and emitters and support the growth of slime-forming bacteria. The resulting slime can plug emitters. Surface water also can contain larger organisms such as moss, snails and other organic debris that must be adequately filtered to avoid plugging problems. In Nebraska, chemical precipitation is not normally a problem when using surface water.

Groundwater, however, often contains high levels of minerals in solution that can, given the right conditions, precipitate and form scale that can clog emitters. In addition to the potential for scale formation, groundwater from shallow wells (< 100 ft) also can produce plugging problems associated with bacteria. Physical clogging problems are generally less severe with ground water. Many SDI users in Nebraska and the rest of the Great Plains irrigate with high-quality groundwater, like that found in the Ogallala aquifer. Using high-quality water reduces but does not eliminate the potential for clogging.

Water Quality Analysis

Knowing the quality of the proposed irrigation water is necessary before designing a SDI system. A comprehensive analysis should include the constituents listed in *Table I*. If the source is groundwater from a relatively deep well (over 100 ft), the analysis for bacteria population may be omitted. Conversely, if the source is surface water, hydrogen sulfide will not be present and can be omitted. *Table 1* provides concentration levels for evaluating water quality in terms of emitter plugging potential. Your SDI dealer and/or Extensions professional can assist in determining what analyses to run.

A water quality analysis usually will list electrical conductivity (EC) in micromhos per centimeter (µmho/cm). To estimate parts per million (ppm) dissolved solids as shown in *Table I*, multiply µmho/cm by 0.64. For example, if the report indicates an EC of 1000 µmho/cm, then the dissolved solids concentration is approximately 640 ppm.

Table I. Criteria for plugging potential of microirrigation water sources.

	Plugging Hazard Based on Concentration		
	Concentration		
Factor	*Slight*	*Moderate*	*Severe*
Physical			
Suspended solids (filterable)[a]	< 50	50 - 100	> 100
Chemical			
pH	< 7.0	7.0 - 7.5	> 7.5
Dissolved solids[a]	< 500	500 - 2,000	> 2,000
Manganese[a]	< 0.1	0.1 - 1.5	> 1.5
Iron[a]	< 0.1	0.1 - 1.5	> 1.5
Hydrogen sulfide[a]	< 0.2	0.2 - 2.0	> 2.0
Hardness[b]	< 150	150 - 300	> 300
Biological			
Total bacteria[c]	< 10,000	10,000 - 50,000	> 50,000

[a] Maximum measured concentration from a representative sample (ppm),
[b] hardness as ppm $CaCO_3$,
[c] colonies per milliliter

Hardness is primarily a measure of the presence of calcium (Ca) and magnesium (Mg), and is another indicator of the plugging potential of a water source. If Ca and Mg are given in ppm rather than hardness, hardness can be estimated by using:

$$Hardness = (2.5 \times Ca + \times (4.1 \times Mg)$$

where Ca and Mg are reported in milligrams per liter or parts permillion (mg/L = ppm). If the analysis reports hardness in grains per gallon, one grain of hardness equals 17.1 ppm or hardness as $CaCO_3$.

Physical clogging hazards

Wells may produce sand that can clog emitters. Physical clogging hazards like sand usually are removed with screen filters. Sizing of screen filters is based on the maximum particle size allowable by the emitter, the quality of the irrigation water, the flow volume between required

Table II. Screen filter mesh sizes and corresponding filter opening diameters.

Mesh	*Diameter*		
Size	*Inches*	*mm*	*Microns*
40	0.017	0.425	425
100	0.006	0.150	150
150	0.004	0.105	105
200	0.003	0.075	75
270	0.002	0.053	53
400	0.0015	0.038	38

Table III. Selected equivalent diameters.

Particle	*Diameter, mm*
Coarse sand	0.50 to 1.00
Fine sand	0.10 to 0.25
Silt	0.002 to 0.05
Clay	<0.002
Bacteria	0.0004 to 0.002
Virus	<0.0004

cleanings, and the allowable pressure drop across the filter. Information about the maximum allowable particle size should be available from the dripline manufacturer. If not, a rule of thumb is remove any particles larger than one-tenth the diameter of the smallest opening in the emitter. *Table II* shows a range of filter mesh sizes and corresponding filter opening diameters. *Table III* shows the equivalent diameters of selected particles. A 200-mesh screen filter will remove particles the size of fine sand and larger and is usually adequate for SDI systems using groundwater in the Great Plains.

Flow rates through screen filters should not exceed 200 gallons per minute per square foot (gpm/ft^2) of effective filter area. The effective filter area is defined as the area of the openings in the filter screen. A 200-mesh screen has 200 openings per linear inch. Generally, a 200-mesh screen with a surface area of about 2.8 square feet will provide 1 square foot of effective filter area. Screen filters should be cleaned (backflushed) when the pressure drop across the filter increases by 3 to 5 psi (pounds per square inch) or as recommended by the manufacturer. Automatic flushing is available on some screen filter systems. *Figure 3* shows a typical screen filter.

Figure 3. Flushable screen filter (courtesy Yardney Water Management Systems, Inc.)

In addition to sand, pump lubrication oil also may cause plugging of screen filters. To avoid filter plugging and to ensure that the pump is adequately lubricated, discuss drip-oil issues with the well driller or well service professional and your SDI system dealer.

Another type of screen filter is the self-cleaning *spin filter.* These filters are continuous-flushing units. Spin filters swirl the water towards the center of the filter. Filtered particles move towards the sides of the filter and to the bottom where they flow out of the filter through an opening on the bottom. A small volume of water continuously flushes the filtered particles out of the system.

In some applications where the water contains a large amount of sand, a sand separator may be required *(Figure 4)*. Sand separators also swirl the water towards the center of the separator using centrifugal action to separate sand and other heavy particles (specific gravity > 1.5) from the water prior to entering the filtration unit. Properly functioning sand separators can remove 70 to 95% of heavy particles with equivalent diameters greater than 0.003 inches.

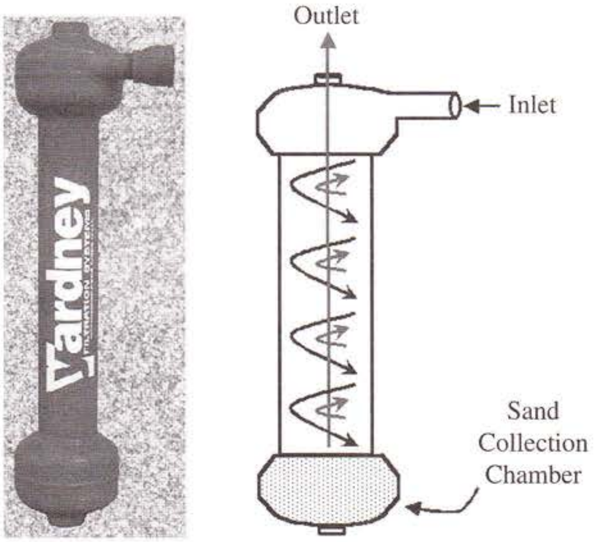

Figure 4. Sand separator (photo courtesy of Yardney Water Management Systems, Inc.)

For surface water with a large silt concentration, a settling basin may be required. In addition, pre-screening of the water to remove debris such as stalks, leaves, and other plant residue may be necessary. When surface water is used, more refined filtration systems like sand media or disc filters may be required.

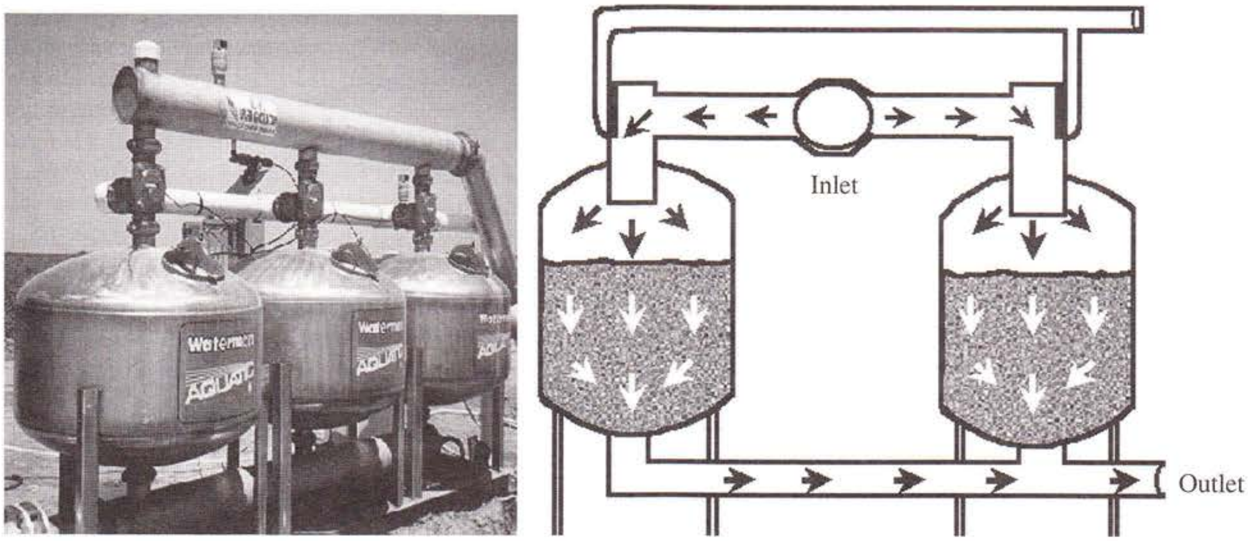

Figure 5. Photo and schematic sand media filter (photo courtesy of Waterman Industries, Inc.)

Table IV. Sand media size and screen mesh equivalent.

Sand No.	*Effective Sand Size (in)*	*Screen Mesh Size*
8	0.059	70
11	0.031	140
16	0.026	170
20	0.018	230
30	0.011	400

Biological clogging hazards

Biological or organic material, such as bacterial slimes and algae, are often filtered with sand media filters *(Figure 5)*. Particle size of the media is selected according to the desired degree of filtration *(Table IV)*. Flow rates for media filters should not exceed approximately 25 (gpm/ft^2) of filter surface area. Lower flow rates should be used with water sources containing greater than 100 ppm of suspended solids to reduce the need for frequent backflushing. Media filters should be backflushed when the pressure drop across the filter reaches about 10 psi or as recommended by the manufacturer. In most installations, multiple filters are necessary to accommodate backflushing while the SDI system continues to operate.

Backflush flow rates depend on the media size; lower flow rates should be used for finer filter media. Automatic backflushing is generally required on media filtration systems. Most manufacturers recommend the use of a screen filter downstream from the media filter to reduce the hazard of escaping filter media clogging emitters.

Disc filters *(Figure 6)* are sometimes used when filtering biological material. They are a hybrid of screen filters and sand media filters. Microscopic grooves between the discs filter unwanted material. Discs within the filters

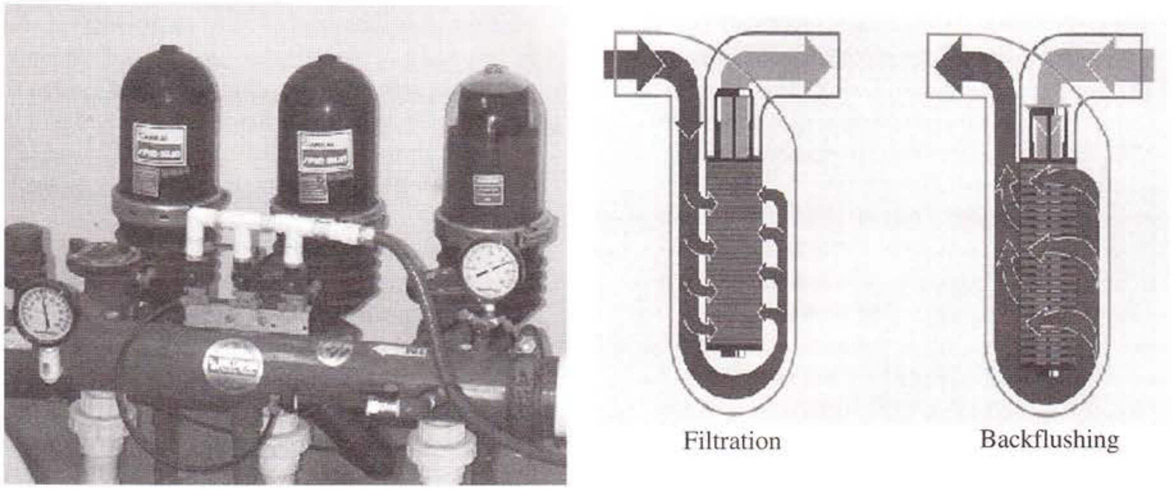
Filtration
Backflushing

Figure 6. Photo and schematic of disc filter (schematic courtesy of Arkal Filtration Systems.)

separate during backflushing. Disc filters require less water than media filters for backflushing; however, required backflushing pressures may be as high as 50 psi. Such high pressures may require the use of a pressure-sustaining valve or booster pump or both. A typical recommended flow rate for filtering with 200-mesh equivalent disk filters is 50 gpm/ft^2 of filter area.

If sand is a particular concern for a given system, one may choose to avoid using disc filters entirely. During backflushing, when the discs are separated, sand may become lodged between discs. If this happens, the effective screen mesh size is reduced and filtration will be less effective. If sand is present, and one still chooses to use a disc filter, consider using a sand separator before the filter unit.

Chlorine injection is commonly used to assure that any unfiltered biological material does not accumulate elsewhere in the SDI system. If the biological load of the irrigation water is severe *(Table I)*, a low concentration (1 to 2 ppm) of chlorine should be injected continuously. If the biological load is slight to moderate, and thus the potential for biological clogging is low, a periodic chlorine shock treatment may be used as an alternative to continuous chlorine injection. A typical chlorine shock treatment uses a concentration of 10 to 30 ppm. For systems that use groundwater, a semiannual chlorine shock treatment likely will be sufficient to prevent biological clogging. The frequency of shock treatments is not, however, set in stone. One should continuously monitor system performance and adapt the maintenance schedule accordingly.

Sodium hypochlorite or liquid bleach (NaOCL) is a safe and easily obtained chlorine source. However, it degrades over time so it should not be stored for long periods before using.

While chlorine injections are effective against biological clogging hazards, injecting chlorine has no effect on scale deposits. There are other commercial materials to dislodge and dissolve scale deposits.

With SDI systems, if the pH of the water is high, concurrent acidification and chlorination may be required. Chlorination for bacterial control is relatively ineffective if the pH of the water is above 7.5, so adding acid may be necessary to lower the pH and increase the biocidal action of the chlorine. Acid and chlorine injection points should be at least 2 to 3 feet apart. Acid and chlorine should ***never*** be combined in the same container because dangerous toxic chlorine gas is released.

When chlorine is injected, a test kit should be used to see that the injection rate is adequate. Color test kits that measure the "free residual" chlorine, which is the primary bactericidal agent, should be used. Common test kits (orthototlidine-type) that one might use to measure the total chlorine content of a swimming pool are not satisfactory for irrigation applications. To ensure the system is adequately treated, the chlorine concentration at the flush outlet farthest from the injection pump should equal the desired treatment concentration.

As was mentioned, most biological clogging hazards are associated with surface water; however very small concentrations of iron (0.1 – 0.3 ppm) in groundwater can pose a biological clogging threat. Certain bacteria can use iron as an energy source. Those bacteria oxidize ferrous iron (+2 charge) to form ferric (+3 charge) iron. As the bacteria grow, they form slimes that may combine with other materials and clog emitters. As with other biological clogging hazards, if iron bacteria do develop, chlorine injections can be used to oxidize or kill the bacteria. The dead bacteria then can be flushed from the system.

Chemical clogging hazards

Two major chemical clogging hazards to SDI systems in the Great Plains are precipitation of calcium carbonate ($CaCO_3$), also called lime or scale, and the formation of iron precipitates. Precipitation of $CaCO_3$ can occur in one of two ways: evaporation of water, leaving the salts, behind, or a change in solubility due to changes in solution characteristics (mainly temperature or pH). Evaporation is not usually a problem in SDI systems, but solubility changes can cause $CaCO_3$ precipitation. As water temperature increases, $CaCO_3$ solubility decreases and lime deposits may occur. Because buried driplines do not get as hot as surface-installed drip irrigation lines, temperature-induced $CaCO_3$ precipitation is not generally a significant problem in SDI systems.

Increased pH (more basic) also decreases $CaCO_3$ solubility, increasing the potential for precipitation. A water analysis can be used to determine the predisposition of the water source to precipitate $CaCO_3$. In many cases, bicarbonate may be present. Bicarbonate can react with naturally occurring calcium in the water to form scale deposits. Continuous acid injection is often used to lower the water's pH (≤ 7.0) and decrease the possibility of $CaCO_3$ precipitation.

If the intent of the acid injection is to remove existing scale buildup within the irrigation system, the pH will have to be lowered even more. When removing existing scale deposits, the release of water into the soil should be minimized as root damage may occur. An acid slug should be injected into the irrigation system and remain in the system for several hours, after which the system should be flushed with irrigation water. Although acid will not normally corrode PVC (polyvinyl chloride) and PE (polyethylene) tubing, it may be corrosive to steel and aluminum.

In addition to the biological oxidation of iron and the associated clogging hazards mentioned previously, iron also can be chemically oxidized (rusted). The oxidized (ferric) iron can form precipitates that block emitters. If iron presents a problem in your operation, there are two common treatment options. The first is to pump the groundwater into a reservoir before pumping it into the SDI system, making sure adequate aeration occurs in the reservoir. The ferrous iron is oxidized and the ferric iron settles out. The second option is to inject a strong oxidizer upstream of the filter (all chemicals should be injected upstream from the filtration system). Chlorine can be used to oxidize ferrous iron. The resulting ferric iron is then filtered before it enters the driplines.

Injecting Chemicals Into An SDI System

Anytime chemicals (including fertilizers) are injected into an irrigation system, certain certifications, procedures, and equipment are required.

Before injecting any chemical, or before mixing any chemicals, one should always perform a "jar test" to evaluate potential plugging hazards.

1. Add drops of the chemical to be injected into a sample of the irrigation water so that the concentration is equivalent to the solution that would be in the system.
2. Cover and place the mixture in a dark, cool environment for at least 12 hours.
3. Direct a light beam at the bottom of the sample container to determine if any precipitates have formed. If no apparent precipitates have formed, the chemical will normally be safe to use with that specific water source.

Concluding Statements

When using SDI systems, it is important to prevent clogging problems before they occur. The best prevention plan includes an effective filtration and water treatment strategy. Depending on the water source and its quality, various combinations of sand separation, filtration, and chemical treatments may be required.

Filtration equipment may be the single item of greatest cost when installing the SDI system. One must resist the temptation to "cut corners." Good filtration will pay for itself by avoiding the costs and extra effort required to repair a damaged system that was not adequately maintained.

To assess SDI system performance and to ensure that components like filters are working correctly, flow meters and pressure gauges must be properly installed to provide feedback to the system operator. Monitoring flow meters and pressure gauges over time can reveal system performance anomalies that may require attention.

No matter how well designed your filtration system is, some "contaminants" will find their way into the driplines. To prevent the accumulation of those contaminants and the resulting emitter clogging, driplines should be flushed periodically. A useful way to provide for system flushing is to connect all the downstream ends of the driplines within a zone to a common flush manifold. Regular flushing is critical to system health and longevity.

Profit margins for crops typically grown in the Great Plains are less than the margins for fruits and vegetables traditionally grown with SDI systems. To make SDI systems in the Great Plains more viable economically, they must last for many years. Prevention of clogging through proper maintenance is therefore critical to successfully using SDI on the Great Plains.

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