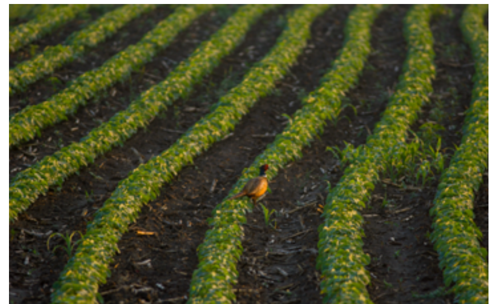
iGrow Soybean
BEST MANAGEMENT PRACTICES



Chapter 47: Managing High Water Tables and Saline Seeps in Soybean Production

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Poorly drained areas frequently require drainage to optimize crop growth. In these areas, high water contents can drown crops, delay seeding, increase the loss of N fertilizer, increase crop diseases, and slow seed germination. These areas may be small depressional areas in relatively large flat fields or lower elevation areas in rolling fields. Based on a field's topography, individualized drainage systems need to be developed. In addition to having high water contents, many poorly drained fields have high salt concentrations. This chapter will address the management of high water tables and the basic reclamation principles for saline seeps.

Figure 47.1. Water flowing from the outlet of a subsurface drain.
(Photo courtesy of Lynn Betts, USDA Natural Resources Conservation Service)

Lowering high water tables with subsurface drainage

Subsurface (tile) drainage is used to remove excess soil water and salts using drainage pipes or tiles installed below the soil surface (Fig. 47.1). Since the 1970s, perforated polyethylene tubing has become the most popular material for drainage pipes. Historically, cylindrical clay or concrete sections, or "tiles," were used, so the customary terms "tiling" and "tile drainage" are still used to describe subsurface drainage. Drains are typically installed just below the root zone at depths of 2.5 to 4 feet. The outlets for the drain lines are generally streams or open ditches.

Subsurface drainage is used to enable timelier planting, harvesting, and other field operations and to increase crop yields. Many South Dakota soils have poor natural drainage, and without artificial drainage they would remain waterlogged from excess precipitation for extended periods.

Approximately 25% of the farmable acres in the U.S. have some form of artificial drainage. By removing excess water from the root zone (Fig. 47.2), salts are flushed from the root zone, and the risk of soil compaction from field operations is reduced. Since soils with subsurface drainage will dry out and warm up faster in the spring than undrained soils, subsurface drainage can enhance the ability to implement no-till and minimum tillage.

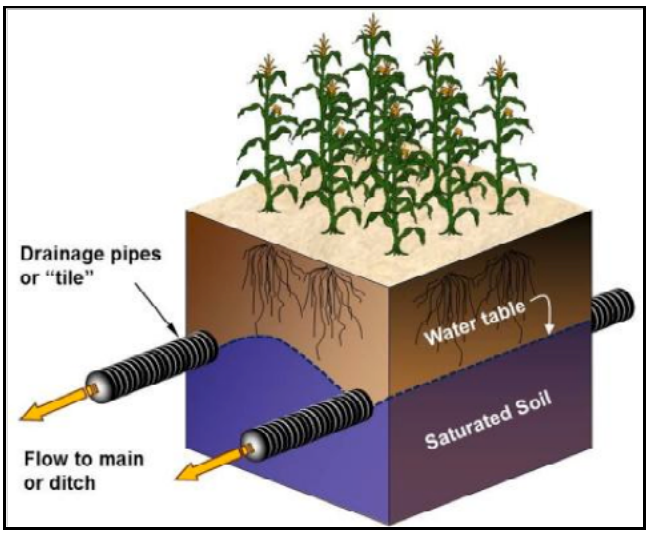

Figure 47.2. Subsurface drainage removes excess water from the root zone via pipes or "tile" buried beneath the soil surface. (Illustration courtesy of Gary Sands, University of Minnesota)

Along with improved yields, subsurface drainage tends to reduce surface runoff and peak flows by encouraging increased infiltration of water into the soil. Zucker and Brown (1998) reported that subsurface drainage reduces surface runoff by 29% to 65%, peak flows are reduced by 15% to 30%, and total outflows (surface runoff plus subsurface drainage) are similar. Other studies have shown modest increases (5% to 10%) in total outflows from the addition of subsurface drainage.

The impacts of subsurface drainage on water quality can be both positive and negative. Because subsurface drainage reduces surface runoff, sediment and nutrient losses from surface runoff are also reduced. Sediment loss reductions range from 16% to 65%, and losses of phosphorous may be reduced up to 45% (Zucker and Brown, 1998). However, subsurface drainage can increase nitrate export. Nitrate losses from subsurface drainage vary widely, but concentrations of nitrate in drainage water frequently exceed the drinking water standard and may lead to local or regional water quality problems.

Conservation drainage constitutes a set of established and new designs and practices designed to maintain the benefits of drainage, while reducing negative environmental impacts. This is an active area of research, and a number of conservation drainage demonstration projects are being implemented in the Midwest. These practices include:

1. **Drainage water management (controlled drainage).**
   Water control structures are used to raise or lower the outlet elevation to manage the water table depth. By restricting the water movement in the drains at times when drainage is not needed, the overall volume of water flow is reduced, more soil moisture is available for the growing crop when it can be used, and nitrate export is reduced.

2. **Denitrifying bioreactors.**
   Outflow from the drainline is intercepted near the outlet and the water is routed through a trench filled with wood chips or other carbon-rich media. Bacteria growing on the chips remove nitrate from the water by converting it to harmless nitrogen gas. A bypass pipe ensures that the capacity of the drainage system is not reduced. Bioreactors are typically located near field edges so little or no land needs to be taken out of production and the wood chips may last 10 to 20 years with little maintenance.

3. **Constructed wetlands.**
   Drain water is discharged into a wetland constructed near the field edge. Within the wetland, nitrate is removed from the drain water, water movement is slowed, and biomass can be produced for other uses. Depending on local conditions, the wetland may take up production ground.

4. **Saturated buffers.**
   Drain water is distributed with a subsurface manifold parallel to the receiving waterway. Nitrate is removed from the water as it flows through the soil/wetland system to the waterway.

5. **Shallow drainage.**
   Drain lines are installed shallower than standard drainage systems. The shallower drains intercept and remove less water than deeper drains. Shallower drains may have to be installed with closer spacing to gain adequate crop benefits.

South Dakota drainage law delegates regulatory authority of drainage to the county level. So, an important first step in planning any drainage project is to consult with the county drainage board (in many counties, the board of county commissioners is also the drainage board). Other states have different governing authorities for regulating drainage activities. In addition to county regulations, the Swampbuster provisions introduced in the 1985 Food Security Act (Farm Bill) discourage the drainage of wetlands for agricultural use. Therefore, local USDA Farm Service Agency and Natural Resources Conservation Service offices must be consulted about drainage plans. Draining wetlands can result in the loss of farm program benefits.

When preparing a drainage plan, it is useful to gather background information from county soil surveys, topographic maps, aerial photos, climate data, local water management authorities, and drainage guides from neighboring states (e.g., Minnesota and Iowa). Obtaining detailed data (topographic surveys and soils characterizations) for areas to be drained is also useful.

Economics

A primary goal of subsurface drainage is increased profit for the producer. Because installing a subsurface drainage system involves a significant investment, an economic feasibility study should be conducted before installation. Factors that should be considered are expected yield response, impact on equipment and material costs, and costs of the drainage system over the life of the drainage system. Although the actual lifetime of a well-designed drainage system may be 50 to 100 years, the economic lifetime of the drainage system is often assumed to be 20 to 30 years.

Estimating values to use in the economic analysis, particularly yield response, is difficult. Comparisons of combine yield monitor data from poorly drained and adequately drained areas of a field may give some indications of potential yield response when drainage improvements are made. Other potential sources of information include neighboring producers who have installed drainage systems and drainage contractors.

As examples of yield increases following drainage, results from an 11-year study in Ohio indicated that subsurface drainage increased soybean yields by 7 to 14 bushels per acre (Zucker and Brown, 1998), and data based on 20 years of yield records from Ontario showed yield increases of 8 bushels per acre (26% increase) for soybeans (Irwin, 1998).

Additional information is available in Hofstrand (2010) and online calculators.

- Prinsco at http://www.prinsco.com/article.cfm?ID=96
- Advanced Drainage Systems at http://www.ads-pipe.com/en/documentlisting.asp?documenttypeID=40

Drainage outlet

Subsurface drainage systems perform only as well as the outlet, so good drainage design should begin by ensuring there is a suitable outlet. Typically, the drainage outlet is the lowest point in the drainage system. At the outlet, water is delivered to a natural or manmade open channel that is deep enough so that that the bottom of the outlet is at least one foot above the normal low-water level in the waterway. Proper maintenance is needed to prevent drainage ditches from becoming clogged by sediment and/or by vegetation growth. Consequently, erosion and weed control are essential to ensure that these systems continue to function effectively.

Any existing drainage outlet should be checked to see if it can handle additional water, and if it is deep enough to allow the planned additional field drains to be placed at the desired depth. Pumped outlets may be considered where there is an otherwise adequate outlet that is not deep enough to allow for gravity drainage. The outlet should be protected from rodents or other small animals, washout, and erosion.

In addition to the physical requirements for an outlet described above, the outlet must also meet all legal and regulatory requirements for drainage outlets. In general, the drainage should occur through a natural or established watercourse and should not substantially alter the flow such that it causes unreasonable harm downstream. In many cases, downstream notification or approval may be required as part of the regulatory process. Regardless, drainage problems are often not limited to a single property, so working with neighbors to address drainage problems can result in more effective solutions and less potential for disputes.

Surface intakes

Surface intakes can be used to remove ponded water from closed depressions or potholes through the subsurface drainage system. If surface intakes are added to a subsurface drainage system, the system should be sized to accommodate the concentrated flow entering from the surface. Surface intakes can be a source of weakness in the drainage system, so offsetting them on a short lateral will help protect the main line.

By providing a direct connection to water at the surface, these intakes can serve as a shortcut for sediment, nutrients, or other pollutants to travel to downstream surface water bodies. Open intakes that are flush with the surface, in particular, should be avoided for this reason. Slotted or perforated risers allow for some settling of sediments before water enters the intake. A permanent grass buffer should be provided around the riser to trap sediment and other pollutants before they reach the intake. Rock or “blind” inlets are another option that eliminates the need for a riser by filtering out sediment before it enters the drain.

Drainage coefficient

The drainage system should be designed to remove excess water from the active root zone to prevent crop damage within 24 to 48 hours of excess precipitation. The rate at which the drainage system can remove water from the soil is commonly called the drainage coefficient, and it is a measure of the system capacity. The drainage coefficient is typically expressed as the depth of water removed in a 24-hour period (inch/day). Because drain spacing and sizing will be determined by the drainage coefficient, the choice of a drainage coefficient is an economic as well as an agronomic decision.

If surface inlets will be used to directly drain water from the surface through the drain pipes, a larger drainage coefficient should be used to account for the additional water coming from the surface. Typical drainage coefficients for humid regions are shown in Table 47.1. Choice of an appropriate drainage coefficient should be made based on local conditions, experience, and judgment. Because South Dakota is in a transition zone from humid to semiarid regions, a smaller drainage coefficient of ¼ inch per day may be an appropriate choice.

Table 47.1. Typical drainage coefficients for humid areas. (ASAE EP480 standard)

Soils	No Suface Inlets (inch/day)	Blind Surface Inlets (inch/day)	Open Surface Inlets (inch/day)
Mineral Soils			
Field crops	⅜-½	½-¾	½-1
High value crops	½-¾	¾-1	1-1 ½
Organic Soils			
Field crops	½-¾	¾-1	1-1 ½
High value crops	¾-1 ½	1 ½-2	2-4

Drain depth and spacing

The depth and spacing of parallel drains necessary to achieve a certain drainage coefficient are determined in large part by the hydraulic conductivity (permeability) of the soil and the depth to a low permeability barrier. For single targeted drains, the hydraulic conductivity and depth to the barrier will determine the effective distance from the drain that will be adequately drained given the depth of the drain. Depth and spacing should be considered simultaneously when trying to achieve a desired drainage coefficient.

As shown in Figure 47.2, the water table will be highest midway between two parallel drains and lowest at the drains themselves. The depth and spacing are chosen to maintain a minimum depth to the water table midway between the drains. The height that the water table will reach above the drains will be less for drains spaced more closely together. Therefore, deeper drains can be spaced further apart, whereas shallower drains need to be closer together to achieve the same drainage coefficient. Table 47.2 lists general drain depth and spacing recommendations based on soil type. More specific depth and spacing recommendations should be based on measured soil properties or drainage experience with similar soils and conditions. The SDSU Drain Spacing Calculator can help with drain spacing decisions. http://climate.sdstate.edu/water/DrainSpacingCal.html

Table 47.2. Typical drain spacing and depths for parallel drains for various soils. (Wright and Sands, 2001)

Soil Type	Permeability	Drain Spacing (ft) for:			Drain Depth (feet)
		Fair Drainage (1/4 inch/day)	Good Drainage (3/8 inch/day)	Excellent Drianage (1/2 inch/day)	
Clay loam	Very low	70	50	35	3.0-3.5
Silty clay loam	Low	95	65	45	3.3-3.8
Silt loam	Moderately low	130	90	60	3.5-4.0
Loam	Moderate	200	140	95	3.8-4.3
Sandy loam	Moderately high	300	210	150	4.0-4.5

Drains are typically placed 3 to 4 feet deep. If possible, drains should be placed above shallow, low permeability layers. The minimum depths to avoid damage from heavy equipment are 2 feet for laterals (3 to 6 inch diameter pipes) and 2.5 feet for mains (8 inches or greater diameter pipes). Ideally drainage systems would have uniform depth, but field topography and the layout design will determine actual drain depths.

System layout

The layout of the drainage system, along with the design decisions made above, will determine the uniformity of drainage for the field or area. Drainage system layout is chosen to best match field topography, outlet location, and drainage needs of the field. Topography will dictate what layout options are practical.

There are several layout options available for drainage systems (Fig. 47.3). The layout may be complex or as simple as a single drain line from a wet spot in the field. Parallel drainage systems are used to drain large areas or entire fields of regular shape and uniform soils. Herringbone systems are typically used in relatively narrow depressions such as those along shallow drainageways. Double main systems are used where a larger or deeper drainageway divides the field. Targeted drainage systems are used where there are isolated wet areas that require drainage. Mains are run through natural low areas toward the outlet, and laterals may be added to provide drainage for larger wet areas.

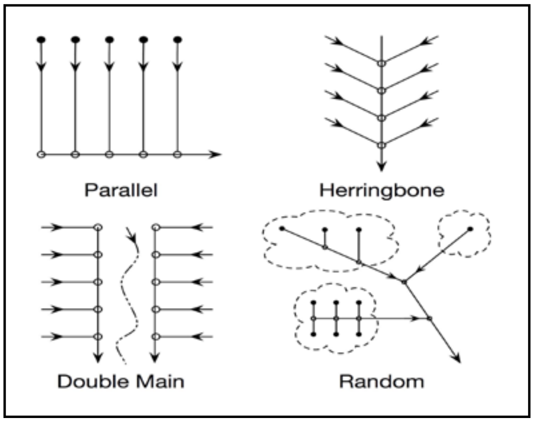

Figure 47.3. Typical drainage system layout options for lowering a water table.

For any layout pattern, a general guideline to follow when laying out the system is to align laterals along the field contours to the extent possible. This allows the laterals to act as interceptors of water as it moves down the slope. Collectors or mains are then placed on steeper grades or in swales to allow for a more uniform lateral gradeline.

Drain grades and envelopes

Drainage systems should be designed such that both minimum and maximum grade recommendations are followed. This is to ensure that flow velocities are within an acceptable range. The grade should be sufficient to prevent sediments from accumulating in the drains and shallow enough to prevent excessive pressure that could result in erosion of soil around the drain. Drains in stable soils (clay content greater than 25% to 30%) can be placed on shallower grades. Soils lower in clay with more fine sands and silt require steeper grades.

Table 47.3 lists the minimum recommended grades for various pipe sizes depending on whether fine sands and silts are likely to be a problem. In addition to minimum grades, the use of drain envelopes should be considered for soils high in fine sands and silts, particularly if shallower grades must be used. Materials used for drain envelopes include gravel, synthetic fiber membranes, and pre-wrapped geotextiles (or "socks").

To prevent problems with excessive pressures and velocities, mains should not be placed on grades greater than 2% where practical. When steeper grades must be used, additional precautions should be taken, which may include the use of pressure relief wells. Large changes in grade, particularly steep-to-flat, should be avoided to prevent the risk of blowouts. Reversals in grade must always be avoided.

Table 47.3. Minimum recommended grades (% or ft/100 ft) for drainage pipes where CPE is corrugated polyethylene plastic pipe and smooth refers to smooth wall plastic pipe or concrete or clay tile. (ASAE EP480 standard)

Inside diameter of drain (inch)	Drains not subjected to fine sand or silt (min. velocity of 0.5 ft/s)		Drains subjected to fine sand or silt (min. velocity of 1.4 ft/s)	
	CPE	Smooth	CPE	Smooth
3	0.10	0.08	0.81	0.60
4	0.07	0.05	0.55	0.41
5	0.05	0.04	0.41	0.30
6	0.04	0.03	0.32	0.24

Drain pipe sizing

The recommended size of drainage pipe depends on the area to be drained, the chosen drainage coefficient, the grade on which the pipe is laid, and the pipe materials (corrugated plastic or smooth-wall, plastic or concrete, pipe). To determine the required flow that the pipe must handle the following equation can be used:

$$Q\ (\text{cfs}) = \frac{\text{Area (acres)} \times \text{DC (inches/day)}}{23.8}$$

Where Q is the required flow rate (capacity) in cubic feet per second (cfs), the area to be drained is in acres, and the drainage coefficient (DC) is in inches per day. For example, the flow capacity needed to drain 40 acres with a ⅜ inch drainage coefficient is: 40 acres x 0.375 inch/day ÷ 23.8 = 0.63 cfs.

To size the outlet, the total area to be drained by that outlet should be used. For sizing individual laterals, only the area drained by the lateral is used. If future expansion of the drainage system is likely, the outlet should be sized to accommodate that expansion. Once the required flow is calculated, the pipe size (diameter) necessary to carry that flow can be determined based on the grade and the pipe material. Figure 47.4 can be used to determine necessary pipe size for corrugated plastic pipe. Other sources for determining necessary pipe size include:

- Manufacturer’s literature.
- Slide calculators from drain pipe manufacturers (e.g., Prinsco, Hancor, and ADS).
- Web-based calculators:
    - http://www.extension.umn.edu/AgDrainage/online calculator.html
    - http://www.prinsco.com/article.cfm?ID=98
    - http://www.ads-pipe.com/en/documentlisting.asp?documenttypeID=40
- Drainage contractors and engineers.

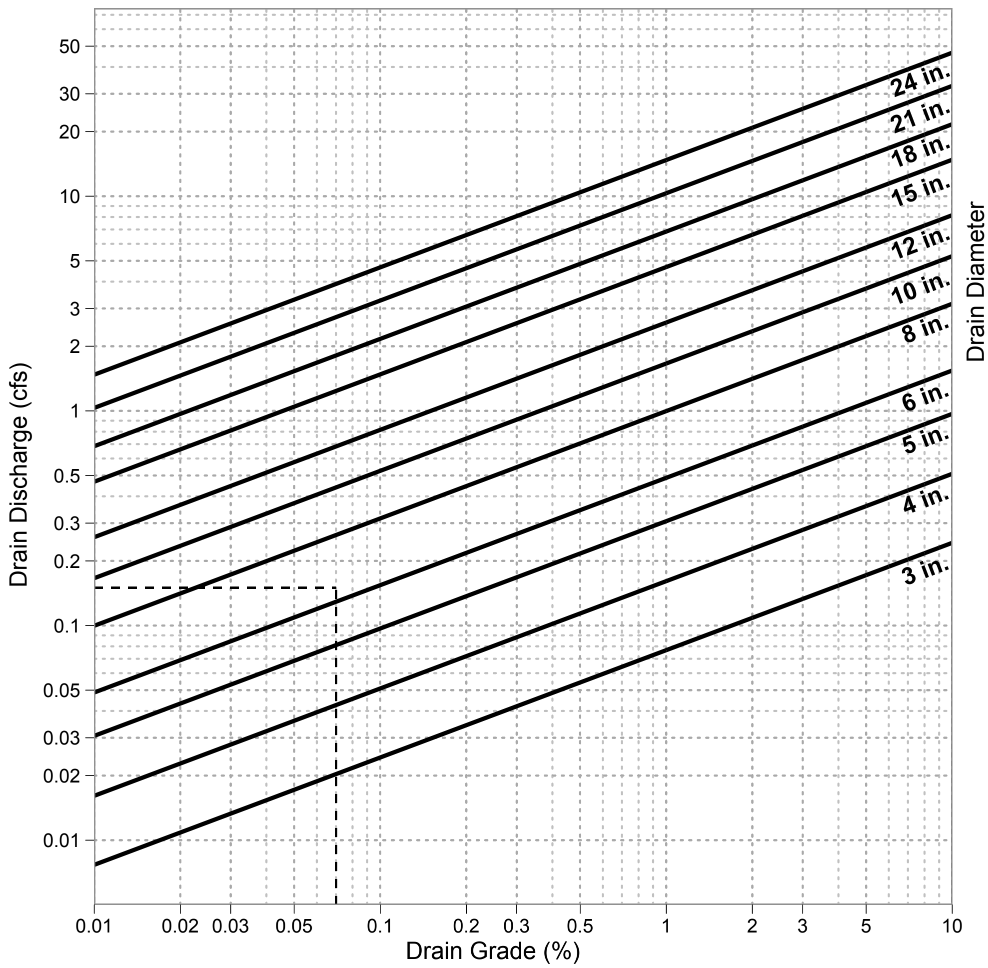

Figure 47.4. Chart for determining the required diameter of corrugated plastic pipe based on the pipe grade (in percent) and the design drain discharge (in cubic feet per second).

The solid black lines represent the discharge of a pipe of the size indicated that is flowing full based on the drain grade. The space between the solid black lines represents the range of pipe capacity for the pipe size indicated between the solid lines.

For drain grade and discharge combinations that do not fall directly on one of the solid lines, the next larger commercial pipe size would be chosen. For example, the required drain size for a drain grade of 0.07% and a design discharge of 0.15 cfs would be an 8-inch pipe (dashed black lines).
(Adapted from ASAE EP480 standard)

Installation considerations

In addition to a good design, the quality of installation is also important in determining how well a drainage system will perform. Once a drainage system is installed, correcting any problems is difficult and expensive. It is, therefore, important to make sure that drainage installation is done on grade and is of high quality. An experienced and reliable contractor can be an asset in achieving a quality installation. The equipment used for installation can also influence the quality of installation. Tractor mounted and pull-type plows can perform well, but good grade control can be more difficult to manage.

Shallow or flat grades, in particular, have a smaller margin for error, so accurate grade control is especially important under those conditions. As-built plans showing the dimensions and locations of all drains should be prepared following or during (such as those created by GPS systems) installation and kept as part of the farm records. These plans will facilitate any future expansion or required maintenance of the drainage system. Problems to watch for following installation include wet spots in the field where drains were installed, sedimentation at the outlet, blockages of the outlet, and erosion damage around the outlet.

Saline seeps

Another problem caused by excess water is the saline seep. A saline seep is the discharge location for shallow groundwater. The water also carries any soluble salts or nutrients that it encountered in the soil. Over time, the seep area becomes too wet and too saline, either reducing crop performance or preventing crop growth. Additional information on the management of saline soils is available in Chapter 48.

Saline seeps start when water from rain or snowmelt enters the soil in a recharge area. This recharge area is often located some distance from the seep and must be higher in the landscape (Fig. 47.5). If the water is not used by a crop in the recharge area, it eventually drains downward and leaves the root zone. If the water draining downward reaches a layer of high lateral permeability, then the water can move laterally in that layer. If the topography is such that the zone of high lateral permeability intersects or approaches the soil surface, the water will re-emerge on the soil surface as a saline seep.

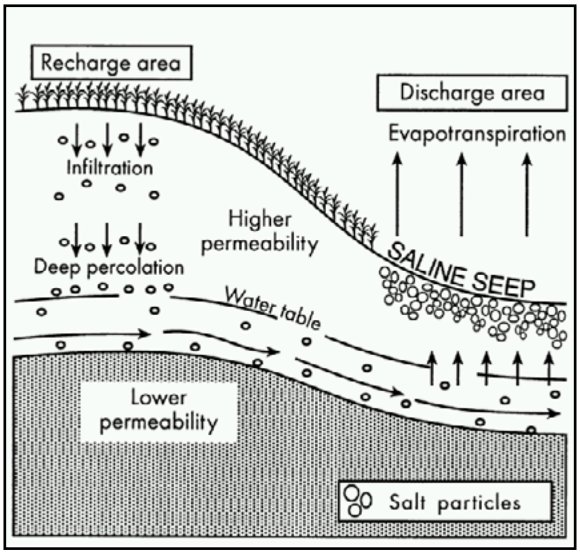

Figure 47.5. A diagram showing saline seep hydrology. Water moves from the recharge area, through the zone of lateral permeability, and back to the soil surface in the discharge area (which is the seep). As it moves through the soil, the water dissolves and carries soluble salts and nutrients.

Figure 1 of Mankin and Koelliker (2000). Originally published in Applied Engineering in Agriculture 16(2): 129-133. Reprinted with permission of the American Society of Agricultural and Biological Engineers, St. Joseph, MI.

As the water moves through the soil, it dissolves salts and soluble nutrients. If and when the water reappears on the soil surface, those salts and nutrients arrive with the water and are deposited on the soil surface. Magnesium and sodium salts are often found in seep areas. Seep areas with high sodium salts must be managed carefully (Chapter 48). Saline seeps can also have high nitrate-nitrogen concentrations.

The excess water in the seep can prevent access by equipment and reduce the plant root effectiveness. The salts interfere with water uptake and reduce or even prevent plant growth. Sodium salts can cause problems with the soil itself, reducing infiltration rates. Nitrate-nitrogen is a vital crop nutrient and can be used by growing plants. High nitrate concentration in these areas generally is not a concern unless it gains entry to a drinking water supply and causes nitrate-nitrogen concentrations in excess of the maximum contaminant level of 10 mg/L (ppm).

Control of a saline seep starts in the recharge area. The precipitation that falls on the recharge area must be prevented from leaving the root zone. That is, the crop (vegetation) water use must be increased in the recharge area so water is used up before it can drain out the bottom of the root zone. Crop water use can be increased with greater cropping intensity. One strategy for increasing the cropping intensity is annual cropping instead of fallow.

Another strategy is planting alfalfa in the recharge area. This is a good option because alfalfa has a high water use each growing season, and alfalfa has deep roots, using water and nutrients deeper in the soil profile, when compared to small grain crops. Planting alfalfa may not be required for the entire recharge area. In the central Great Plains, planting one-third of the recharge area to alfalfa has been shown to reduce water movement to a seep by one-half or more.

Any crop rotation that decreases the amount of time the recharge area is fallow will help reduce or eliminate the active mechanism supporting a saline seep. When the increased cropping intensity in the recharge area has effectively controlled the water, the seep area will respond in one or two years, depending on the weather. More rainfall will cause greater leaching in the seep, reducing the time until the area is fit again for crop production.

When the water is effectively controlled in the recharge area, some management practices in the seep area can hasten reclamation. Straw mulch has been shown to be effective at increasing the rate of salt removal from the seep area. Other practices that conserve soil water in the seep area will increase the rate of salt removal by increasing the water drainage and leaching.

Interceptor drains have been tried to reclaim saline seeps. However, the intercepted saline water poses a disposal problem. In addition, the interceptor drainage strategies have been shown to be less successful at reducing water and salt flow to the seep.

Irrigation has been used to impose downward water movement in the seep itself, moving water and salts downward and out of the root zone. This can be effective in moving salts out of the root zone, especially if accompanied by artificial drainage within the seep area. However, the drain water disposal issue is still a problem, and resalinization can occur during the non-growing (and non-irrigating) season.

In summary, saline seeps are caused by excess water coming from a location higher in the landscape. Reduction or reclamation of the saline seep starts with intensified cropping in the recharge area.

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