SDSU Extension

iGrow Corn

BEST MANAGEMENT PRACTICES

Chapter: 30

Managing High Water Tables in Corn Production

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Poorly drained areas frequently require drainage to optimize crop growth. In these areas, high water content can drown crops, delay seeding, increase N fertilizer loss, increase crop disease, and slow seed germination. These areas often are small depressional zones in large, relatively flat fields or lower elevational areas in fields with rolling topographies. Individualized drainage systems need to be developed based on a field's topography. In addition, many poorly drained fields have high salt concentrations. This chapter addresses high water table management.

Lowering High Water Tables with Subsurface Drainage

Approximately 25% of the farmable acres in the U.S. have some form of artificial drainage. Subsurface (tile) drainage is used to remove excess soil water and salts using drainage pipes or tiles installed below the soil surface (Fig. 30.1). 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 typically are installed below the root zone at depths ranging from 2.5- to 4-feet. The drain line outlets generally are streams or open ditches.

Figure 30.1 Water flowing from the outlet of a subsurface drain. (Photo courtesy of Lynn Betts, USDA Natural Resources Conservation Service)

Subsurface drainage is used to enable timely 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 for extended periods from excess precipitation.

By removing excess water from the root zone (Fig. 30.2), salts are flushed from the root zone, and the risk of soil compaction from field operations is reduced. Since soils with subsurface drainage 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 systems.

Along with improved yield, subsurface drainage tends to reduce surface runoff and peak flows by

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encouraging increased water infiltration into soil. Zucker and Brown (1998) reported that subsurface drainage reduced surface runoff from 29% to 65%, and peak flows were reduced from 15% to 30%.

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 phosphorous losses may be reduced up to 45% (Zucker and Brown, 1998). However, subsurface drainage can increase nitrate export. The nitrate concentration in drainage water frequently exceeds the drinking water standard (10 mg/L). There are several emerging practices designed to maintain the benefits of drainage, while reducing negative environmental impacts (Chapter 31).

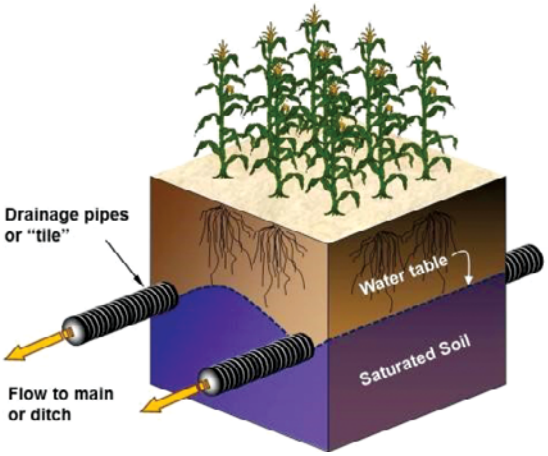

Figure 30.2 Subsurface drainage removes excess water from the root zone via pipes or "tile" buried beneath the soil surface. (Illustration courtesy of Gary Sands, University of Minnesota)

South Dakota drainage law currently (2016) delegates regulatory authority of drainage to the county level. Therefore, a first step in any drainage project is to consult with the county drainage board (in many counties, the board of county commissioners is also the drainage board) about permitting requirements. Note that 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 also 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 guidelines from neighboring states (e.g., Minnesota and Iowa).

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 cost of the drainage system over its lifetime. Although the actual lifetime of a well-designed drainage system may be 50 to 100 years, its economic lifetime often is 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 provide 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 corn yields by 20 to 30 bushels per acre (Zucker and Brown, 1998), and data based on 20 years of yield records from Ontario showed yield increases of 26 bushels per acre (29% increase) on average for corn (Irwin, 1999). Additional information is available in Hofstrand (2010).

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 the bottom of the outlet is at least 1 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 vegetation. 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 whether 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 also must meet all legal and regulatory requirements for drainage outlets. In general, the drainage should occur through a natural or established watercourse and should not alter substantially 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 often are 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 traditionally have been used to remove ponded water from closed depressions or potholes through a subsurface drainage system. By providing a direct connection to water at the surface, however, these intakes serve as a shortcut for sediment, nutrients, or other pollutants to travel to downstream surface water bodies. Several alternative practices exist for removing ponded surface water that can eliminate the need for traditional surface intakes. Often a more intense set of closely spaced laterals or a buried coil of tile in the low spot will drain water quickly enough that a surface intake is not needed. A rock or "blind" inlet is another option that eliminates the need for a riser and filters out sediment before it enters the drain. Open intakes that are flush with the soil surface, in particular, should be avoided because they provide no protection from sediment entering the system. Commercial low-velocity inlets with wicks are available that filter out sediment before it enters the drainage system. More traditional slotted or perforated risers allow for some settling of sediments before water enters the intake. A permanent grass buffer should be established around the riser to trap sediment and other pollutants before they reach the intake.

If surface intakes are added to a subsurface drainage system, the system should be large enough to accommodate the concentrated flow entering from the surface. Surface intakes can be a source of weakness in the drainage system because hitting an intake with farm implements can damage the connecting line. Offsetting the intake on a short lateral line helps protect the main line.

Drainage Coefficient

The drainage system should be designed to remove excess water from the active root zone within 24 to 48 hours of excess precipitation to prevent crop damage. The rate at which the drainage system removes water from the soil is commonly called the drainage coefficient and is a measure of the system capacity. The drainage coefficient typically is expressed as the depth of water removed in a 24-hour period (inches/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.

Table 30.1 Typical drainage coefficients for humid regions. *(ASAE EP260.5 standard)*

	No Surface Inlets	Blind Surface Inlets	Open Surface Inlets
Mineral Soils	*(inch/day)*	*(inch/day)*	*(inch/day)*
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

Typical drainage coefficients for humid regions are shown in Table 30.1. Skaggs (2007) developed equations for estimating a drainage coefficient to maximize profit based on growing-season rainfall. Based on these equations, design drainage coefficients for eastern South Dakota range from 1/6 to ½ inches per day (greatest in the far southeast and decreasing to the north and west). In addition to this guidance, the choice of an appropriate drainage coefficient should be made based on local conditions, experience, and judgment. 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.

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.

Table 30.2 Typical drain spacing and depths for parallel drains for various soils. ***(ASABE EP260.5 standard)***

Soil Type	Permeability	Drain Spacing (ft) for:			Drain Depth (feet)
		Fair Drainage (¼ inch/day)	Good Drainage (⅜ inch/day)	Excellent Drainage (½ 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

As shown in Figure 30.2, 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 farther apart, whereas shallower drains need to be closer together to achieve the same drainage coefficient. Table 30.2 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 iGrow Drainage Calculators (http://www.igrowdrainage.org) include a drain-spacing calculator that can help with these decisions.

Drains typically are 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 with 3- to 6-inch diameter pipes and 2.5 feet for mains with pipes 8-inches or more in diameter. 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. 30.3). Main lines are run through natural low areas toward the outlet, and lateral lines may be added to provide drainage for larger wet areas. 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.

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

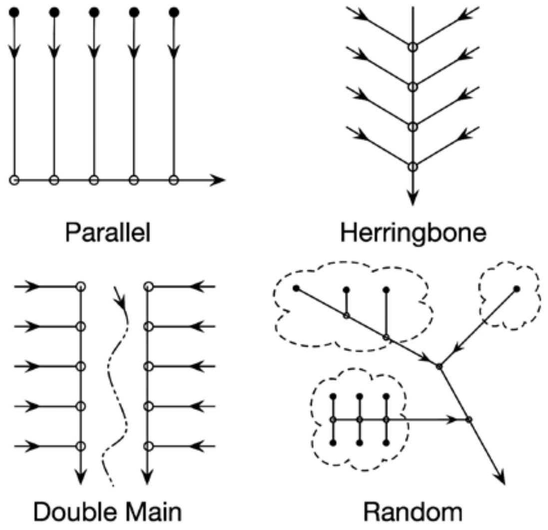

Figure 30.3 Typical drainage system layout options for lowering a water table.

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 30.3 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").

Table 30.3 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 EP260.5 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

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. Humps or dips in the pipe from reversals in grade must always be avoided.

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 material (e.g., corrugated plastic or smooth-wall, plastic or concrete). To determine the required flow that the pipe must handle the following equation can be used:

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

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 3/8-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. 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 (e.g., http://www.igrowdrainage.org).
- Drainage contractors and engineers.

Installation Considerations

In addition to a good design, the quality of installation also is important in determining how well a drainage system will perform. Once a drainage system is installed, correcting problems is difficult and expensive. To ensure that the drainage installation is done on grade and is of high quality an experienced and reliable contractor should be selected. 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 critical. 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, outlet blockages, and erosion damage around the outlet.

Saline Seeps

Drainage can be used to help manage high salt concentrations (Chapter 32). In South Dakota, excess water can result in a gradual buildup of salts in the surface soil. 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. If a crop in the recharge area does not use the water, 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 (see Chapter 31 for additional information).

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Acknowledgements

Support for this document was provided by South Dakota State University, SDSU Extension, South Dakota Corn Utilization Council, SD Water Resources Institute, USDA-NRCS, and USGS. Thanks to Gary Sands, University of Minnesota, for providing illustrations and helpful comments.

Supported in part by:
SOUTH DAKOTA
CORN UTILIZATION COUNCIL
A GROWING INVESTMENT

Hay, C., and T. Trooien. 2016. Chapter 30: Managing High Water Tables in Corn Production. In Clay, D.E., Carlson, C.G. Clay, S.A., and E. Byamukama (eds). iGrow corn: Corn Best Management Practices. South Dakota State University.

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