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Water Management

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A superior water-management program seeks to provide an optimal balance of water and air in the soil, which allows full expression of genetic potential in plants. The differences among poor, average, and record crop yields generally can be attributed to the amount and timing of the soil's water supply.

Improving water management is an important way to increase crop yields. By minimizing crop-water stress, the producer obtains more benefits from improved cultural practices and realizes the full yield of the cultivars now available. Crops are particularly sensitive to water stress when they are undergoing reproductive growth.

To produce maximum yields, the soil must be able to provide water as it is needed by the crop. But the soil seldom has just the right amount of water for maximum crop production; a deficiency or a surplus usually exists. A good water-management program seeks to avoid both extremes through a variety of measures. These measures include draining waterlogged soils, making more effective use of the water-holding capacity of soils so that crops will grow during periods of insufficient rainfall, increasing the soil's ability to absorb moisture and conduct it down through the soil profile, reducing water loss from the soil surface, and irrigating soils with low water-holding capacity.

In Illinois, the most frequent water-management need is improved drainage. Close to 10 million acres of land have tile drainage, and another several million acres have some form of surface drainage system. Initial efforts in the 1800s to artificially drain Illinois farmland made our soils among the most productive in the world. Excessive water in the soil limits the amount of oxygen available to plants and thus retards growth. This problem occurs where the water table is high or where water ponds on the soil surface. Removing excess water from the root zone is an important first step toward a good water-management program. A drainage system should be able to remove water from the soil surface and lower the water table to about 12 inches beneath the soil surface in 24 hours and to 21 inches in 48 hours. In most Illinois soils, this is equivalent to removing 3/8 inch of water from the soil profile in 24 hours.

The Benefits of Drainage

A well-planned drainage system provides a number of benefits: better soil aeration, more timely field operations, less flooding in low areas, higher soil temperatures, less surface runoff, better soil structure, better incorporation of herbicides, better root development, higher yields, and improved crop quality.

Soil aeration. Good drainage ensures that roots receive enough oxygen to develop properly. When the soil becomes waterlogged, aeration is impeded and the amount of oxygen available is decreased. Oxygen deficiency reduces root respiration and often the total volume of roots developed. It also impedes the transport of water and nutrients through the roots. The roots of most nonaquatic plants are injured by oxygen deficiency, and prolonged deficiency may result in the death of some cells, entire roots, or, in extreme cases, the whole plant. Proper soil aeration also will prevent rapid losses of nitrogen to the atmosphere through denitrification.

Timeliness. Because a good drainage system increases the number of days available for planting and harvesting, it can enable you to make more timely field operations. Drainage can reduce planting delays and the risk that good crops will be drowned or left standing in fields that are too wet for harvest. Good drainage may also reduce the need for additional equipment that is sometimes necessary to speed up planting when fields stay wet for long periods.

Soil temperature. Drainage can increase soil surface temperatures during the early months of the growing season by 6 to 12 °F. Warmer temperatures assist germination and increase plant growth.

Surface runoff. By enabling the soil to absorb and store rainfall more effectively, drainage reduces runoff from the soil surface and thus reduces soil erosion.

Soil structure. Good drainage is essential in maintaining the structure of the soil. Without adequate drainage the soil remains saturated, precluding the normal wetting and drying cycle and the corresponding shrinking and swelling of the soil. The structure of saturated soil will suffer additional damage if tillage or harvesting operations are performed on it.

Herbicide incorporation. Good drainage can help avoid costly delays in applying herbicide, particularly postemergence herbicide. Because some herbicides must be applied during the short time that weeds are still relatively small, an adequate drainage system may be necessary for timely application. Drainage may also help relieve the cool, wet-stress conditions that increase crop injury by some herbicides.

Root development. Good drainage enables plants to send roots deeper into the soil so that they can extract moisture and nutrients from a larger volume of soil. Plants with deep roots are better able to withstand drought.

Crop yield and quality. All of the benefits previously mentioned contribute to greater yields of higher-quality crops. The exact amounts of the yield and quality increases depend on the type of soil, the amount of rainfall, the fertility of the soil, crop-management practices, and the level of drainage before and after improvements are made. Of the few studies that have been conducted to determine the benefits of drainage, the most extensive in Illinois was initiated at the Agronomy Research Center at Brownstown. This study evaluated drainage and irrigation treatments with Cisne and Hoyleton silt loams.

Drainage Methods

A drainage system may consist of surface drainage, subsurface drainage, or some combination of both. The kind of system you need depends in part on the ability of the soil to transmit water. The selection of a drainage system ultimately should be based on economics. Surface drainage, for example, would be most appropriate where soils are impermeable and would require too many subsurface drains to be economically feasible. Soils of this type are common in southern Illinois.

Surface Drainage

A surface drainage system is most appropriate on flat land with slow infiltration and low permeability and on soils with restrictive layers close to the surface. This type of system removes excess water from the soil surface through improved natural channels, human-made ditches, and shaping of the land surface. A properly planned system eliminates ponding, prevents prolonged saturation, and accelerates the flow of water to an outlet without permitting siltation or soil erosion.

A surface drainage system consists of a farm main, field laterals, and field drains. The farm main is the outlet serving the entire farm. Where soil erosion is a problem, a surface drain or waterway covered with vegetation may serve as the farm main. Field laterals are the principal ditches that drain adjacent fields or areas on the farm. The laterals receive water from field drains, or sometimes from the surface of the field, and carry it to the farm main. Field drains are shallow, graded channels (with relatively flat side slopes) that collect water within a field.

A surface drainage system sometimes includes diversions and interceptor drains. Diversions, usually located at the bases of hills, are channels constructed across the slope of the land to intercept surface runoff and prevent it from overflowing bottomlands. These channels simplify and reduce the cost of drainage for bottomlands.

Interceptor drains collect subsurface flow before it resurfaces. These channels may also collect and remove surface water. They are used on long slopes that have grades of 1% or more and on shallow, permeable soils overlying relatively impermeable subsoils. The locations and depths of these drains are determined from soil borings and the topography of the land.

The principal types of surface drainage configurations are the random and parallel systems (**Figure 11.1**). The random system consists of meandering field drains that connect the low spots in a field and provide an outlet for excess water. This system is adapted to slowly permeable soils with depressions too large to be eliminated by smoothing or shaping the land.

The parallel system is suitable for flat, poorly drained soils with many shallow depressions. In a field that is cultivated up and down a slope, parallel ditches can be arranged to break the field into shorter lengths. The excess water thus erodes less soil because it flows over a smaller part of the field before reaching a ditch. The side slopes of the parallel ditches should be flat enough to permit farm equipment to cross them. The spacing of the parallel ditches will vary according to the slope of the land.

For either the random or parallel systems to be fully effective, minor depressions and irregularities in the soil surface must be eliminated through land grading or smoothing.

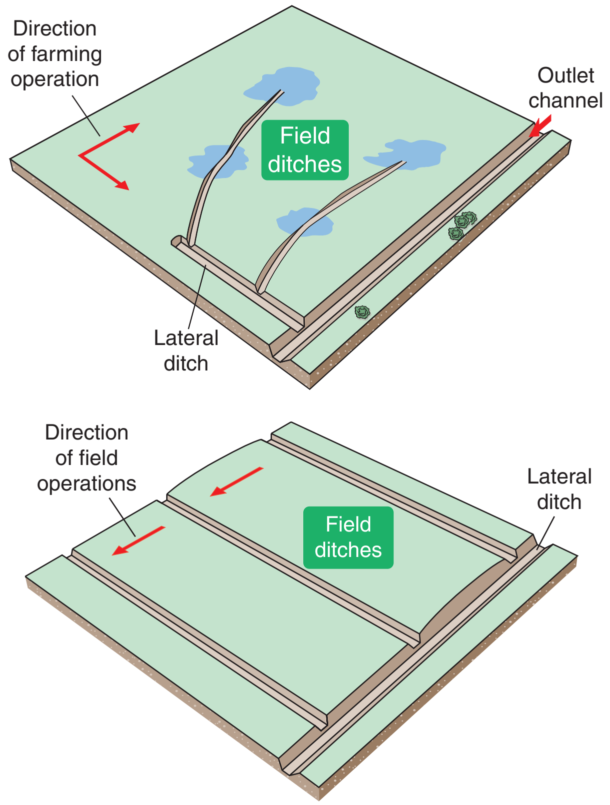

Figure 11.1. Types of surface drainage systems: random ditches (top); parallel ditches (bottom).

Bedding is another surface drainage method that is used occasionally. The land is plowed to form a series of low, narrow ridges that are separated by parallel, dead furrows. The ridges are oriented in the direction of the steepest slope in the field. Bedding is adapted to the same conditions as the parallel system, but it may interfere with farm operations and does not drain the land as completely. It is not generally suited for land that is planted in row crops because the rows adjacent to the dead furrows will not drain satisfactorily. Bedding is acceptable for hay and pasture crops, although it will cause some crop loss in and adjacent to the dead furrows.

Subsurface Drainage

Many of the deep, poorly drained soils of central and northern Illinois respond favorably to subsurface drainage. A subsurface drainage system is used in soils permeable enough that the drains do not have to be placed too closely together. If the spacing is too narrow, the system will not be economical. By the same token, the soil must be productive enough to justify the investment. Because a subsurface drainage system functions only as well as the outlet, a suitable one must be available or constructed. The topography of the fields also must be considered because the installation equipment has depth limitations,

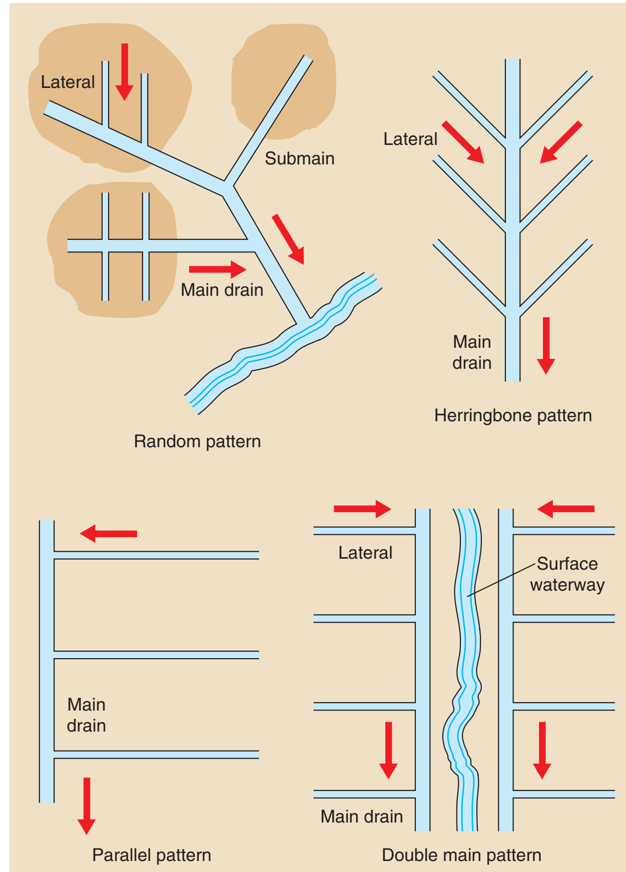

Figure 11.2. Types of subsurface drainage systems. The arrows indicate the direction of water flow.

and a minimum amount of soil cover is required over the drains.

Subsurface systems are made up of an outlet or main, sometimes a submain, and field laterals. The drains are placed underground, although the outlet is often a surface drainage ditch. Subsurface drainage conduits are constructed of clay, concrete, or plastic.

There are four types of subsurface systems: random, herringbone, parallel, and double-main (**Figure 11.2**). A single system or some combination of systems may be chosen according to the topography of the land.

For rolling land, a random system is recommended. The main drain is usually placed in a depression. If the wet areas are large, the submains and lateral drains for each area may be placed in a gridiron or herringbone pattern to achieve the required drainage.

With the herringbone system, the main or submain is often placed in a narrow depression or on the major slope of the land. The lateral drains are angled upstream on either side of the main. This system sometimes is combined with others to drain small or irregular areas. Because two laterals intersect the main at the same point, however, more drainage than necessary may occur at that intersection. The herringbone system may also cost more because it requires more junctions. Nevertheless, it can provide the extra drainage needed for the heavier soils found in narrow depressions.

The parallel system is similar to the herringbone system, except that the laterals enter the main from only one side. This system is used on flat, regularly shaped fields and on uniform soil. Variations are often used with other patterns.

The double-main system is a modification of the parallel and herringbone systems. It is used where a depression, frequently a natural watercourse, divides the field in which drains are to be installed. Sometimes the depression may be wet due to seepage from higher ground. A main placed on either side of the depression intercepts the seepage water and provides an outlet for the laterals. If only one main were placed in the center of a deep and unusually wide depression, the grade of each lateral would have to be changed at some point before it reaches the main. A double-main system avoids this situation and keeps the grade lines of the laterals uniform.

The advantage of a subsurface drainage system is that it usually drains soil to a greater depth than surface drainage. Subsurface drains placed 36 to 48 inches deep and 80 to 100 feet apart are suitable for crop production on many medium-textured soils in Illinois. When properly installed, these drains require little maintenance, and because they are underground they do not obstruct field operations.

More specific information about surface and subsurface drainage systems can be obtained from the *Illinois Drainage Guide (Online)* at www.wq.uiuc.edu/dg. This website addresses the planning, design, installation, and maintenance of drainage systems for a wide variety of soil, topographic, and climatic conditions.

Deciding to Drain

For the producer, the decision to install or improve a drainage system is a practical one, based on principles of good economics and good husbandry. If the benefits outweigh the associated costs, then drainage makes good sense. However, the cost–benefit analysis is not always clear-cut. The associated expenses include material costs, installation costs, and maintenance costs. There may also be other expenses, such as increased hauling costs associated with the increased yield that comes from drainage. Even more difficult to grasp and to quantify are the hidden costs associated with water quality degradation.

Many tools have been developed to help determine the practicability of drainage. The *Illinois Drainage Guide (Online)*, for example, includes an economic analysis calculator (click the link at left for “Economic Considerations,” then “Economic Analysis”) that can be used to determine the profitability of a drainage system. It provides many measures of profitability, but they are all consistent with each other and are but a reflection of user preference. The measures of profitability used in the guide are listed here:

- The **net present value (NPV)** is the present value of the expected future cash flows minus the initial cost. A positive NPV value is indicative of a profitable system.
- The **profitability index (PI),** also known as the benefit–cost ratio, is the ratio of the net present value to the initial capital investment. If the NPV is positive, then the PI is greater than 1.0, indicating that the benefits of a system outweigh the costs.
- The **internal rate of return (IRR)** is the rate at which the future cash flow, discounted back to the present, equals its price. It can be viewed as the interest rate that results in an NPV of 0 or a PI of 1. If the IRR exceeds the interest rate at which capital can be obtained, then the system is profitable.
- The **discounted payback time (DPT)** is the length of time it takes to recover the cost of an initial investment, with regard to the time value of money. For this measure, the value of future income is discounted by the cost of obtaining capital, that is, the interest rate charged on a loan.
- The **undiscounted payback time (UPT)** is the length of time it takes to recover the cost of an initial investment, without regard to the time value of money. In effect, the UPT is the same as evaluating the DPT under the assumption that the cost of capital, the interest rate, is 0.

Drain spacing plays an important role in determining the cost of a subsurface drainage system. A typical drainage system in the Midwest is designed with a drainage coefficient of 3/8 inch, meaning it is designed to remove 3/8 inch of water in 24 hours, when the water table is initially at the soil surface. This drainage coefficient can be achieved with different combinations of depth and spacing. In Drummer Silty clay loam, for example, a 3/8-inch drainage coefficient can be achieved by installing drains 60 feet apart at a depth of 2.5 feet, or by installing drains 100 feet apart at a depth of 5 feet. The system with the more closely spaced laterals would be more expensive. In general, for a given depth, yield will increase with decreased drain spacing up to a point, beyond which it is insensitive to decreases in spacing. In fact, computer simulations indicate that in some soils in some locations, it is possible to place drains so close together that yield is adversely affected. Field experiments are being conducted to determine if these simulations are reflected in reality. The objective is to determine the spacing that maximizes profitability.

Drainage Strategy

Once the decision has been made to incorporate drainage into a farm management plan, a good strategy is to start with fields or sections of fields that will benefit most from drainage. The proceeds from this exercise can then be applied to areas with lesser benefit until the desired coverage is achieved. It is important to remember that there may be situations in which the yield increase does not justify drainage, and the best option is not to install a drainage system in that field or section of a field. Under most conditions, drainage makes economic sense on most hydric soils. However, if the mains are too costly, if the outlets are distant and inaccessible, or if the soil is such that iron ochre or sedimentation would reduce the life of a drainage system to an uneconomic level, it is best not to install a drainage system.

Drainage Installation

The price of drain installation is dependent on many factors, including the equipment used in installation, the size of the job, the time of year when the system will be installed, the contractor's pricing structure, and the level of competition in the county or region. These factors make it worthwhile to obtain quotes from two or more drainage contractors. Different contractors have different pricing structures and business strategies.

The choice of a drainage contractor can significantly affect the profitability of a drainage system. Improper backfilling or grade reversals during installation can dramatically reduce the system's life, though problems may not show up in the first few years. So it is best to select a contractor with a good reputation who will provide a performance guarantee. Take care to select someone who emphasizes quality rather than speed of installation. While it is possible to move through the field relatively quickly with modern drainage equipment, problems such as excessive tile stretch and grade reversals can be minimized by reducing the speed of travel to recommended levels.

Some producers choose to install their own drainage systems. If that is your preference, getting some training on installation techniques is recommended. Such training is often offered by state extension services, trade associations, and equipment manufacturers. It is also strongly recommended that lasers be used in all drain installations. Because of the small slopes at which drains are typically installed, there is not much room for error, so using a properly calibrated laser system is essential.

Conservation Drainage

All across the Midwest, research is being conducted on management practices that improve drain outflow water quality without adversely affecting crop yield. Conservation drainage, as these practices are collectively termed, is the optimization of drainage systems for production, environmental, and water supply benefits. In light of the importance of drainage to agriculture in the region, conservation drainage practices (CDPs) should reduce nutrient transport from drained land without adversely affecting drainage performance or crop production. In Illinois, cost-share funds are available for one such practice, drainage water management.

In drainage water management, often referred to as controlled drainage, a control structure is placed at the outlet of a tile system to control the outlet level. This practice can be used to raise the water level after harvest, thereby reducing nitrate loading from tile effluent, or to retain water in the soil during the growing season. The normal mode of operation in Illinois is to set the water table control height to within 6 inches of the soil surface on November 1 and to lower the control height to the level of the tile on March 15. Thus, water is held back in the field during the fallow period. In experiments in Illinois, reductions were measured of up to 45% for nitrate and 80% for phosphate.

The water control structure in a drainage water management system effectively functions as an in-line weir, allowing the drainage outlet elevation to be artificially set at levels ranging from the soil surface to the bottom of the drains, as shown in **Figure 11.3.**

Types of structures in common usage are shown in **Figure 11.4.** The water table level is controlled with these structures by adding or removing "stop logs" or by using float mechanisms to regulate the opening and closing of a flow valve. There are many variations in the shapes and sizes of structures. Flashboard structures may be either manually operated or automated to adjust the outlet elevation on fixed dates or in response to rainfall patterns.

Drainage water management practices can target agronomic goals, environmental (water quality) goals, or both. The drainage outlet elevation can be set at or close to the soil surface between growing seasons to recharge the water table, temporarily retaining soil water containing nitrate in the soil profile, where it may be subject to attenuating and nitrate transforming processes, depending on soil

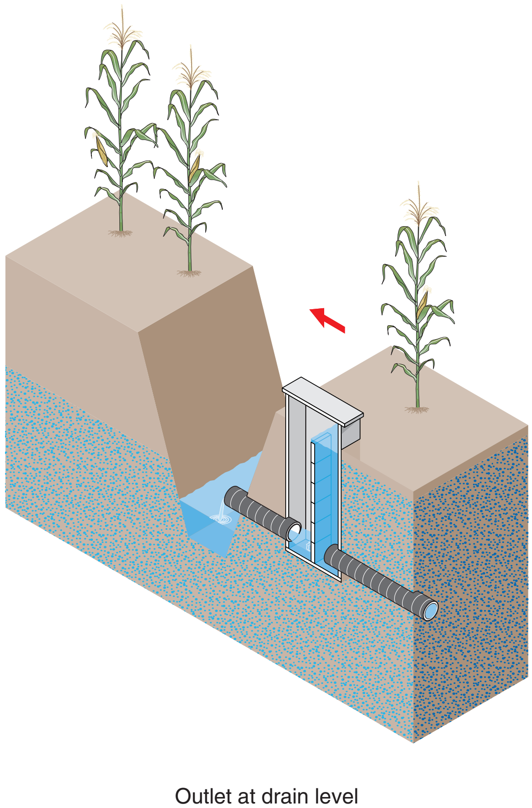

Figure 11.3. Using control structures to manipulate drain outlet levels.

temperature and microbiological activity. In addition, it is possible to raise the outlet elevation after planting to help increase water availability to then-shallow plant roots, and to raise or lower it throughout the growing season in response to precipitation conditions. In some soils, water may even be added during very dry periods to reduce crop loss from drought; this related practice is termed subirrigation. However, the drain spacing for subirrigation may be half to a third of the recommended value for drainage to maintain a water table at a proper depth to reduce deficit crop stress without increasing excess water stress.

In the 2004 crop year, Illinois farmers reported yield increases of 5 to 10 bushels an acre for corn and 3 to 6 bushels an acre for soybean due to the implementation of drainage water management. However, these are only anecdotal reports; research on the yield benefits of this practice is in the early stages, and any benefits may vary by soil and climate. The practice can also be used to benefit wildlife by creating ponded conditions in some fields during the fallow period, providing temporary aquatic habitats for migrating birds.

More information on drainage water management can be found in the regional bulletin *Drainage Water Management for the Midwest,* available online at www.ces.purdue.edu/extmedia/WQ/WQ-44.pdf. In addition, the *Illinois Drainage Guide (Online)* at www.wq.uiuc.edu/dg includes a template for creating a drainage water management plan in the format required by the Illinois NRCS cost-sharing program (click "Related Information" in the left-hand navigation column to go to the relevant portion of the guide).

Benefits of Irrigation

During an average year, most regions of Illinois receive ample rainfall for growing crops, but, as shown in **Figure 11.5,** rain does not occur when crops need it the most. From May to early September, growing crops demand more water than is provided by precipitation. For adequate plant growth to continue during this period, the required water must be supplied by stores in the soil or by irrigation. During the growing season, crops on deep, fine-textured soils may draw upon moisture stored in the soil if the normal amount of rainfall is received throughout the year. But if rainfall is seriously deficient or if the soil has little capacity for holding water, crop yield may be reduced. Yield reductions are likely to be most severe on sandy soils or soils with claypans. Claypan soils restrict root growth, and both types of soils often cannot provide adequate water during the growing season.

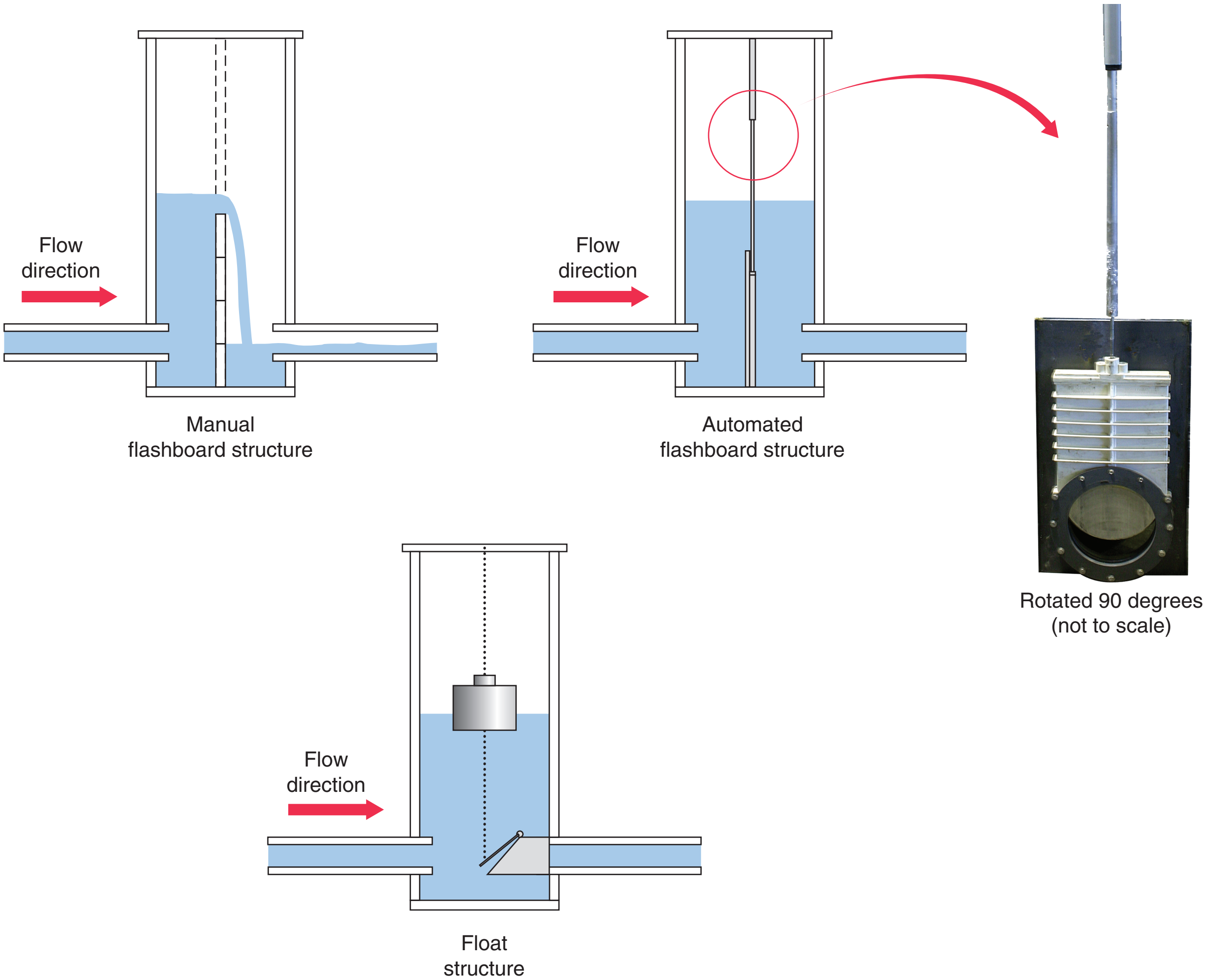

Figure 11.4. Types of water table control structures.

To prevent crop-water stress during the growing season, more and more producers are using irrigation. It may be appropriate where water stress can substantially reduce crop yields and where a supply of usable water is available at reasonable cost. Irrigation is still most widely used in the arid and semiarid parts of the United States, but it can be beneficial in more humid states, including Illinois. Almost yearly, Illinois corn and soybean yields are limited by drought to some degree, even though the total annual precipitation exceeds the water lost through evaporation and transpiration.

With current cultural practices, a good crop of corn or soybeans in Illinois needs at least 20 inches of water. All sections of the state average at least 15 inches of rain from May through August. Satisfactory yields thus require at least 5 inches of stored subsoil water in a normal year.

Crops growing on deep soil with high water-holding capacity, that is, fine-textured soil with high organic matter content, may do quite well if precipitation is not appreciably below normal and if the soil is filled with water at the beginning of the season.

Sandy soils and soils with subsoil layers that restrict water movement and root growth cannot store as much as 5 inches of available water. Crops planted on these soils suffer from inadequate water every year. Most of the other soils in the state can hold more than 5 inches of available water in the crop-rooting zone. Crops on these soils may suffer from water deficiency when subsoil water is not fully recharged by about May 1 or when summer precipitation is appreciably below normal or poorly distributed throughout the season.

Water stress delays the emergence of corn silks and shortens the period of pollen shedding, thus reducing the time of overlap between the two processes. The result is incomplete kernel formation, which can have disastrous effects on corn yields.

Corn yields may be reduced by as much as 40% when visible wilting occurs on four consecutive days at the time

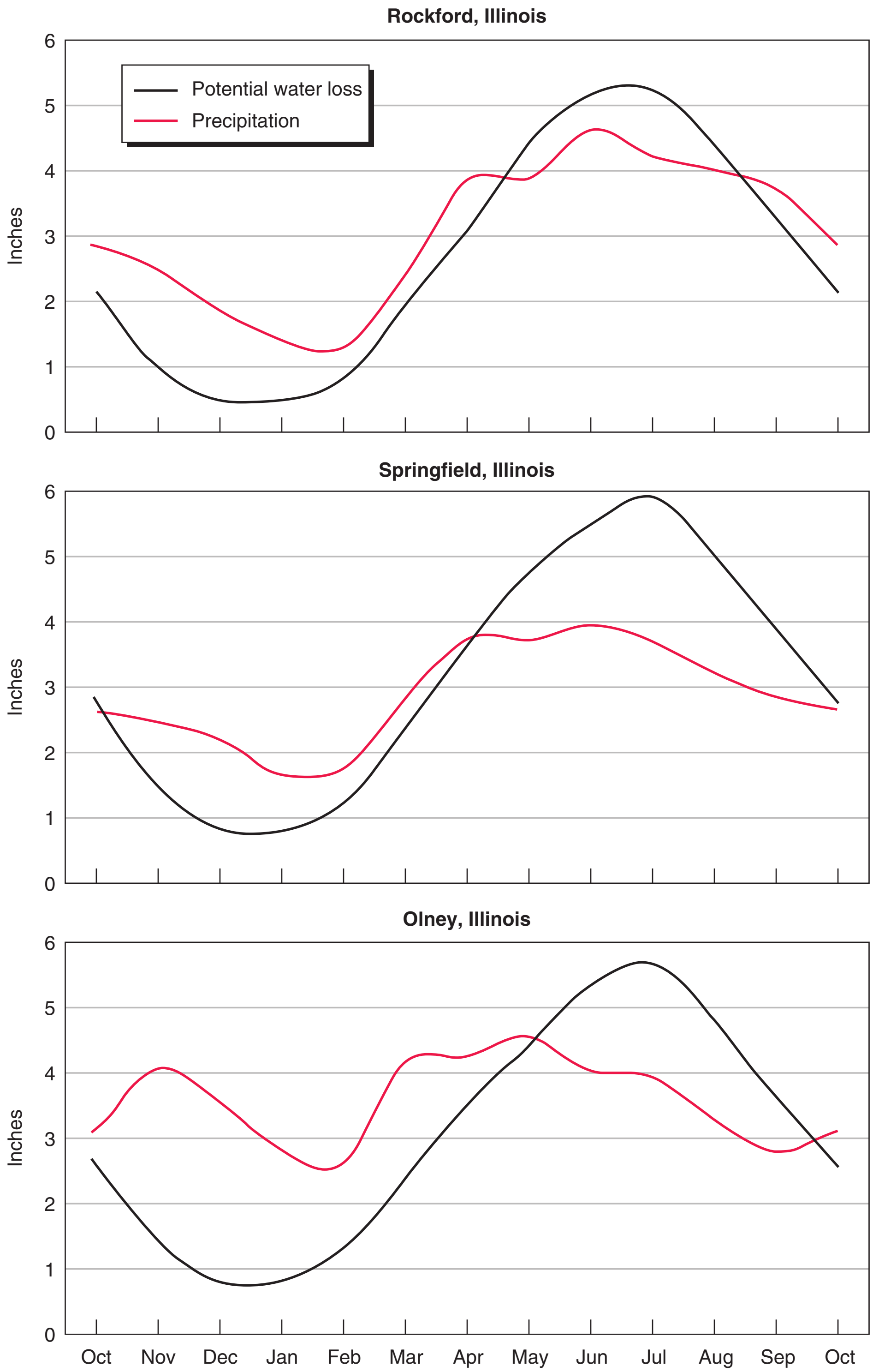

Figure 11.5. Average monthly precipitation and potential moisture loss from a growing crop in three regions of Illinois.

of silk emergence. Studies have also shown that severe drought during the pod-filling stage causes similar yield reductions in soybeans.

Increasing numbers of farmers are installing irrigation systems to prevent the detrimental effects of water deficiency. Some years of below-normal summer rainfall and other years of erratic rainfall distribution throughout the season have contributed to the increase. As other yield-limiting factors are eliminated, adequate water becomes increasingly important to ensure top yields.

Most of the development of irrigation systems has occurred on sandy soils or other soils with correspondingly low levels of available water. Some installations have been made on deeper, fine-textured soils, and other farmers are considering irrigation of such soils.

Deciding to Irrigate

The need for an adequate water source cannot be overemphasized when one is considering irrigation. If a producer is convinced that an irrigation system will be profitable, an adequate source of water is necessary. In many parts of Illinois, such sources do not currently exist. Fortunately, underground water resources are generally good in the sandy areas where irrigation is most likely to be needed. A relatively shallow well in some of these areas may provide enough water to irrigate a quarter section of land. In some areas of the state, particularly the northern third, deeper wells may provide a relatively adequate source of irrigation water.

Some farmers pump their irrigation water from streams, a relatively good and economical source if the stream does not dry up in a droughty year. Impounding surface water on an individual farm is also possible in some areas of the state, but this water source is practical only for small acreages. However, an appreciable loss may occur both from evaporation and from seepage into the substrata. Generally, 2 acre-inches of water should be stored for each acre-inch actually applied to the land.

A 1-inch application on 1 acre (1 acre-inch) requires 27,000 gallons of water. A flow of 450 gallons per minute provides 1 acre-inch per hour. So a 130-acre center-pivot system with a flow of 900 gallons per minute can apply 1 inch of water over the entire field in 65 hours of operation. Because some of the water is lost to evaporation and some may be lost from deep percolation or runoff, the net amount added is less than 1 inch.

The Illinois State Water Survey and the Illinois State Geological Survey (both located in Champaign) can provide information about the availability of irrigation water. Submit a legal description of the site planned for development of a well and request information regarding its suitability for irrigation-well development. Once you decide to drill a well, the Water Use Act of 1983 requires you to notify the local Soil and Water Conservation District office if the well is planned for an expected or potential withdrawal rate of 100,000 gallons or more per day. There are no permit requirements or regulatory provisions.

An amendment passed in 1987 allows Soil and Water Conservation Districts to limit the withdrawals from large wells if domestic wells meeting state standards are affected by localized drawdown. The legislation currently affects Kankakee, Iroquois, Tazewell, and McLean counties.

The riparian doctrine, which governs the use of surface waters, states that you are entitled to a reasonable use of the water that flows over or adjacent to your land as long as you do not interfere with someone else's right to use the water. No problem results as long as water is available for everyone. But when the amount of water becomes limited, legal determinations become necessary regarding whether someone's water use interferes with someone else's rights. It may be important to establish a legal record to verify the date on which the irrigation water use began.

Assuming that it will be profitable to irrigate and that an assured supply of water is available, how do you find out what type of equipment is available and what is best for your situation? University representatives have discussed this question in various meetings around the state, although they cannot design a system for each individual farm. Your local University of Illinois Extension advisor can provide a list of dealers located in and serving Illinois. This list includes the kinds of equipment each dealer sells, but it will not supply information about the characteristics of those systems.

If you contact a number of dealers to discuss your individual needs in relation to the type of equipment they sell, you will be in a better position to determine what equipment to purchase.

Subsurface Irrigation

Subirrigation can offer the advantages of good drainage and irrigation using the same system. During wet periods, the system provides drainage to remove excess water. For irrigation, water is forced back into the drains and then into the soil.

This method is most suitable for land where the slope is less than 2%, with either a relatively high water table or an impermeable layer at 3 to 10 feet below the surface. The impermeable layer ensures that applied water will remain where needed and that a minimum quantity of water will be sufficient to raise the water table.

The free water table should be maintained at 20 to 30 inches below the surface. This level is controlled and maintained at the head control stands, and water is pumped accordingly. In the event of a heavy rainfall, pumps must be turned off quickly and the drains opened. As a general rule, to irrigate during the growing season requires a minimum of 5 gallons per minute per acre.

The soil should be permeable enough to allow rapid water movement so that plants are well supplied in peak consumption periods. Tile spacing is a major factor in the cost of the total system and is perhaps the most important single variable in its design and effectiveness. Where subirrigation is suitable, the optimal system will have closer drain spacings than a traditional drainage system.

Fertigation

The method of irrigation most common in Illinois, the overhead sprinkler, is the one best adapted to applying fertilizer along with water. Fertigation permits nutrients to be applied to the crop as they are needed. Several applications can be made during the growing season with little or no additional application cost. Nitrogen can be applied in periods when the crop has a heavy demand for both nitrogen and water. Corn uses nitrogen and water most rapidly during the 3 weeks before tasseling. About 60% of the nitrogen needs of corn must be met by silking time. Generally, nearly all the nitrogen for the crop should be applied by the time it is pollinating, even though some uptake occurs after this time. Fertilization through irrigation can be a convenient and timely method of supplying part of the plant's nutrient needs.

In Illinois, fertigation appears to be best adapted to sandy areas where irrigation is likely to be needed even in the wettest years. On finer-textured soils with high water-holding capacity, nitrogen might be needed even though water is adequate. Neither irrigating just to supply nitrogen nor allowing the crop to suffer for lack of nitrogen is an attractive alternative. Even on sandy soils, only part of the nitrogen should be applied with irrigation water; preplant and sidedress applications should provide the rest of it.

Other problems associated solely with fertigation include possible lack of uniformity in application, loss of ammonium nitrogen by volatilization in sprinkling, loss of nitrogen and resultant groundwater contamination by leaching if overirrigation occurs, corrosion of equipment, and incompatibility and low solubility of some fertilizer materials.

Irrigation Scheduling

Experienced irrigators have developed their own procedures for scheduling applications, whereas beginners may have to determine timing and rates of application before feeling prepared to do so. Irrigators generally follow one of two basic scheduling methods, each with many variations.

The first method involves measuring soil water and plant stress by taking soil samples at various depths with a soil probe, auger, or shovel and then measuring or estimating the amount of water available to the plant roots; inserting instruments such as tensiometers or electrical resistance blocks into the soil to desired depths and then taking readings at intervals; or measuring or observing some plant characteristics and then relating them to water stress.

Although in theory the crop can utilize 100% of the water that is available, the last portion of that water is not actually as available as the first portion that the crop takes from the soil. Much like with a sponge that is half wrung-out, the water remaining in the soil following 50% depletion is more difficult to remove than the first half.

The 50% depletion figure is often used to schedule irrigation. For example, if a soil holds 3 inches of plant-available water in the root zone, we could allow 1-1/2 inches to be used by the crop before replenishing the soil's water with irrigation.

Management Requirements

Irrigation will provide maximum benefit only when it is integrated into a high-level management program. Good seed or plant starts of proper genetic origin planted at the proper time and at an appropriate population, accompanied by optimal fertilization, good pest control, and other recommended cultural practices, are necessary to ensure the highest benefit from irrigation.

Farmers who invest in irrigation may be disappointed if they do not manage to irrigate properly. Systems are so often overextended that they cannot maintain adequate soil moisture when the crop requires it. For example, a system may be designed to apply 2 inches of water to 100 acres once a week. In two or more successive weeks, soil moisture may be limited, with potential evapotranspiration equaling 2 inches per week. If the system is used on one 100-acre field one week and another field the next week, neither field may receive much benefit. This is especially true if water stress comes at a critical time, such as during pollination of corn or soybean seed development. Inadequate production of marketable products may result.