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Texas Agricultural Extension Service

Irrigation Systems for Forage Crops

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Irrigation Systems for Forage Crops

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Several types of irrigation systems can be chosen for irrigating forage crops for grazing or hay production. Factors to consider include water supply, water quality, soils, topography, field shape, energy cost and labor requirement.

Forage crops respond similarly to whatever irrigation method is used. One exception is the utilization of a salty irrigation water source which could cause leaf burn from sprinkler application but not flood irrigation. The differences in gross water applied by various irrigation methods stem from their inherent efficiencies. However, the **net** water use by a forage will be the same whether water is applied with flood or drip irrigation.

Water Requirements

The highest water use amounts for most forage crops and most locations in Texas will occur from June to August. Peak water use can be assumed to be 0.25 to 0.50 inches per day for Texas. It is helpful to express water requirements in terms of gallons per minute per acre, as shown below to better visualize well capacity requirements:

Well Capacity, gpm/acre =
Peak Water Use, inches/day × 18.95

Therefore, the daily peak water use amounts during the hottest part of the summer will be equivalent to a well capacity of about 5 to 10 gpm/acre. However, irrigation systems are almost always designed at levels much smaller than the peak use rate in order to save investment costs and allow more acreage to be cultivated when the water supply is limited. Design well capacity can be reduced because of:

- **Soil storage.** A large amount of water can be stored in the soil. During the cooler months the system delivers more than the crop needs. In the hot months when the system can no longer keep up with water use, the soil storage is drawn upon and supplies part of the demand. This reservoir quantity depends on the soil type and depth of roots. Alfalfa, for example, can root down more than 5 feet.
- **Rainfall probability.** The system capability can be further reduced from the peak use requirements because rainfall might be expected. Usually, the amount of reduction is based on the 75 percent probability amount; i.e., the water received in the lowest one-quarter years.
- **Acceptable reduction in yields.** Maximum per acre yields are not always the optimum economic yields. The water can purposely be stretched and below maximum potential yields be accepted. Since forage yields are generally linear with regard to actual water use (i.e., each inch of crop consumptive use produces the same amount of forage), total yields often remain the same despite lower per-acre yields because of the increased area farmed. During wetter years this mode will be advantageous.

Figure 1 shows crop water use by alfalfa from Arizona data. For example, assume an operator has irrigation water equivalent to 5 gpm/acre (0.26 inches per day), which is shown on the graph. The shaded portion above this line represents the amount of shortage; this needs to be supplied either by rainfall or by water stored in the soil, or else some yield reduction will occur.

Factors in Choosing a System

A number of factors should be studied before making your decision as to what type irrigation system to select.

1. **Amount of water.** This factor, as already mentioned, determines the maximum acreage in the system. However, it will also influence the method of delivery. Flood irrigation, which is a sound method for forage crops, requires large heads of water, ideally at least 1000 gpm. Less water than this will probably require some type of pressurized system.
2. **Cost of energy and depth of pumping water level.** As the cost of water increases through higher costs of energy and/or deeper pumping depths, there is more incentive to use more efficient types of irrigation systems. The amount of water to be applied is also very important. This determines the acceptable ratio between the up front investment cost versus annual operating costs.

The energy costs to pump water will be based on total lift and operating pressure. A good estimate for determining the expected cost per acre-inch of the water is \$0.01 per foot of lift and \$0.03 per psi of pressure (based on energy at \$0.07 per KWH). Thus, if a manager has to lift water 250 feet and needs to run 50 psi at the well, the expected cost per inch of water will be: (250 × .01) + (50 × .03) = \$4.00/acre-inch.

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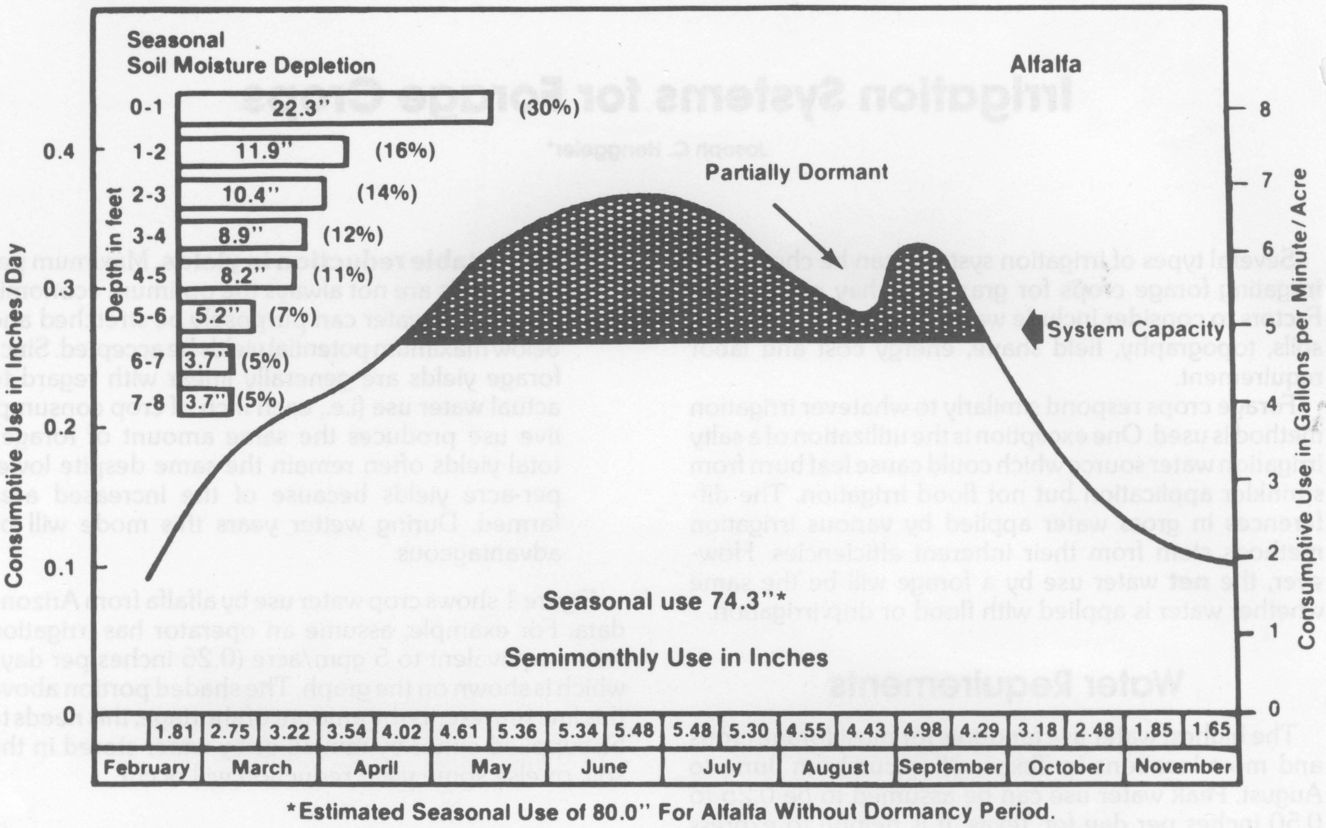

Figure 1. Water use of alfalfa for Mesa, AZ. In a hypothetical case a farmer has 5.0 gpm per acre capacity. Water use below that line (equivalent for 0.26 inches per day) can be met by the system; the shaded area represents water requirement that must be satisfied by rainfall or by moisture stored in the ground. (After Erie et al., 1981.)

3. **Shape of land.** Odd-shaped fields can dictate which type of system must be used.
4. **Land slope.** The slope and undulation of land can also dictate which system to be used.
5. **Soil type.** Soil type must be considered in relation to the type of irrigation system. For example, problems with waterloss can be expected when center pivots are used on clay soils (due to runoff) or when flood irrigation is used on sandy soils (deep percolation).
6. **Energy availability.** If electricity is not currently at the site this can influence the decision on type of irrigation system. In this case the option for center pivots is made less attractive since center pivot towers are usually driven by electric motors.
7. **Quality of water.** Poor quality water can be handled best through flooding, or possibly drip irrigation. Sprinkler systems should be avoided with low-quality water.
8. **Labor considerations.** Some systems require more labor than others. Also, various levels of labor expertise are required for different systems. Cost and availability of labor will be major factors in choosing the right system.
9. **Harvesting.** The type of irrigation will depend upon whether the forage is to be grazed or harvested. Lengths of irrigation run, keep-out periods, swather widths and berms are harvesting considerations. Grazing of the forage presents fewer irrigation problems than harvesting operations.
10. **Financing.** While everyone wants the most economical irrigation system, this is not always possible. Initial capital available for installation and start-up might dictate the type of system to buy.

The economic return period is also very significant. A banker might want to see the economic analysis done on a 2- or 3-year pay back period—usually far short of the life of the equipment—which boils down to less capital and a quicker return. A longer analysis period might have dictated a different type of system to use.

Lending institutions may also influence choice of the type of system based on its liquidity. For instance, a center pivot that can be repossessed might be easier to obtain funding for than a concrete ditch.

Irrigation Systems

A brief description of the various types of irrigation systems follows. Table 1 lists information about each type of system such as estimated cost per acre, labor requirements, etc.

Hand-move sprinklers. The hand-move system is a relatively low cost system to install, especially if used equipment can be found. A mainline with spaced hydrant valves, called risers, is required (Figure 2). The sprinklers are attached to joints of aluminum pipe via a 2- to 3-foot galvanized stem (also called a riser). Pipe size is commonly 2-, 3-, and 4-inch although larger diameters are available. Lengths of each pipe are usually 30 or 40 feet. The joints are gasketed and are quick-coupled together into laterals that can extend for a quarter-mile or more.

The mainline can be either buried PVC pipe or aboveground aluminum pipe. Pressures in the mainline pipe are usually under 75 psi.

Irrigation set time is usually 12 or 24 hours. The amount of moisture applied during an irrigation is usually 3 to 5 inches, which should be enough to last until the crop is watered again.

The joints are removed one at a time and advanced to the next set. Experienced irrigators do not even have to turn off the water to do this. The move is usually 60 feet and the lateral is placed close to the outer wetted edge of the previous set. Some irrigators move over two sets at a time, thus having the two outer wetted edges of the sprinkler pattern just meet. Doing so, they advance down the field twice as fast and when they return they set the lateral at the previously skipped set to achieve the needed depth and overlap.

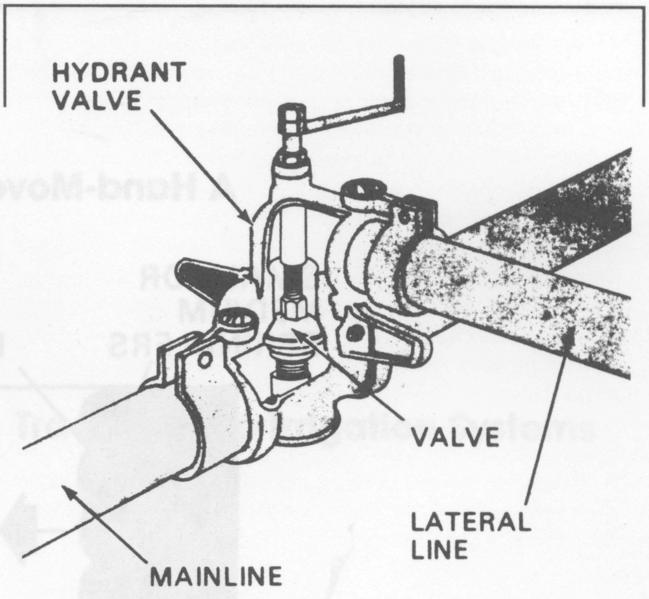

Figure 2. Hydrant valve with quick couplers for easy attachment of the lateral line to the mainline.

The low capital start-up costs for hand-move sprinklers is attractive, but annual operating costs will be high

TABLE 1.—Data on Various Types of Irrigation Systems for Forage Production.

TYPE OF SYSTEM	APPROX. COST ($/acre)	FUEL COSTS	LABOR REQUIRED per IRRIGATION (hrs/acre)	SHAPE OF FIELD	MAXIMUM SLOPE (percent)	MAXIMUM HEIGHT OF CROP (ft)	FIELD SURFACE CONDITIONS	ADAPTABLE TO: CHEMIGATION	ADAPTABLE TO: LIQUID ANNUAL WASTE DISTRIBUTION	EFFICIENCY RANGE (%)
Sprinkler hand-move (used)	100-125	High	.5-1.5	Any shape	20	4	No limit	Yes	Yes	55-75
Sprinkler tractor-move (used)	125	High	.2-.5	Any shape; add more labor for odd shapes	10	4	Smooth enough for tractor operation	Yes	Yes	55-75
Side-roll (used)	175-250	High	.1-.3	Rectangular	10	4	Reasonably smooth	Yes	Yes	50-75
Center Pivot (used)	150-250	Med.-Med. High	.05-1.5	Square	20	8-10	Clear of obstruction	Yes	Yes	55-95
Big Gun, hand-move	100-200	Very High	.5-1.5	Any shape	20	No limit	Reasonably smooth	Yes	Yes	60-70
Big Gun, tractor-move	110-220	Very High	.2-.5	Any shape	5-15	No limit	Reasonably smooth	Yes	Yes	60-70
Flood, furrows (used gated pipe)	50	Low	.2-1.2	Any shape	2	No limit	—	Limited	No	50-75
Flood, basin (lasered)	85-250	Low	.1-1	Any shape	2	No limit	—	Limited	No	80-95

A Hand-Move System Layout

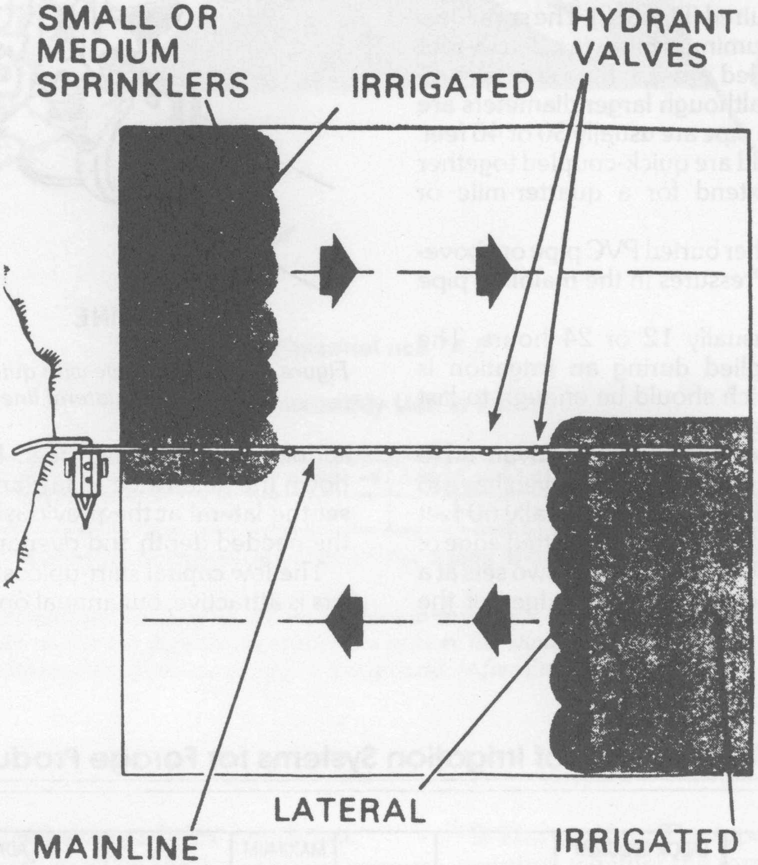

Figure 3. Field layout for a hand-move system using two laterals.

due to pressurization requirements. Operating pressures will be 40 to 65 psi, which itself will cost about one to two dollars per acre-inch. (For example, 5 to 20 dollars out of every ton of alfalfa will go to pay for pressure). Labor requirements will also be high.

The special advantages of hand-move sprinkler systems are their ability to fit odd-shaped fields, low cost and relatively easy management. When little water is required each year, the low investment cost outweighs the higher operating costs.

When two or more laterals are used off one mainline (Figure 3), the irrigator should never have the laterals together at the far end of the mainline because of friction loss. He should start the irrigation sets from both ends and move to the center. After the field is watered, the move back to the first set can involve a great distance and trailers may need to be used.

Tractor-move sprinklers. The tractor-move system is very similar to the hand-move system except that the joints are not broken, but are moved as a unit. This is done by dragging the lateral with a tractor to the next set.

Laterals are equipped with small wheels or skids (Figure 4). Moving directly across the field is no chore, but moving up one set requires a turning point, called a capstan, to pivot the whole line around, as shown in Figure 5.

The laterals are attached to a mainline via a hydrant valve. Each lateral end usually alternates between being the inlet and outer end as the line is moved back and forth across the mainline.

While the energy costs for a tractor-move system will be fairly high, the labor costs will be much lower than the hand-move system.

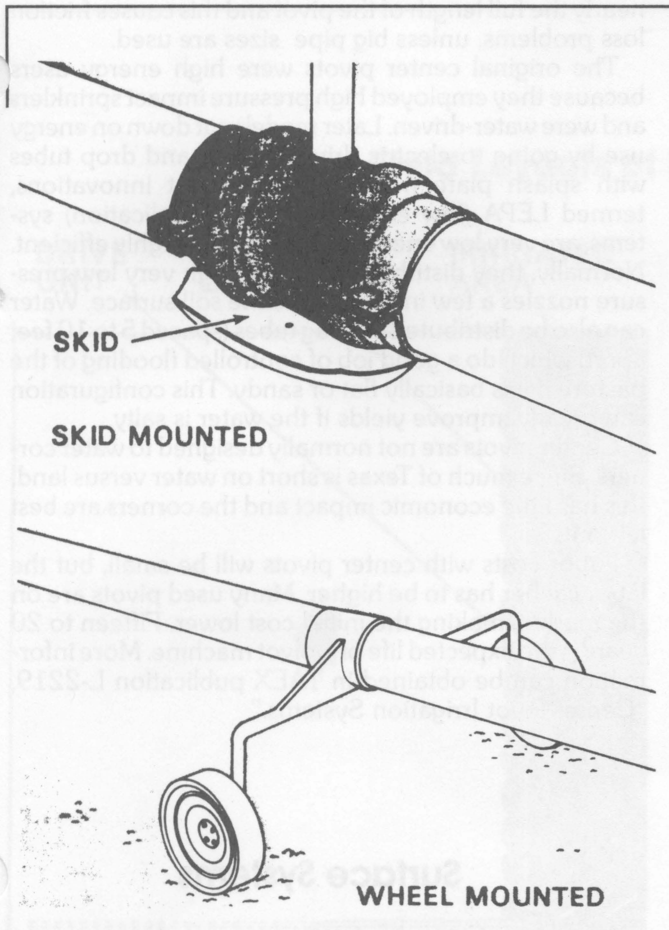

Figure 4. Skid-mounted and wheel-mounted tractor-move systems.

Tractor-Move Irrigation Systems

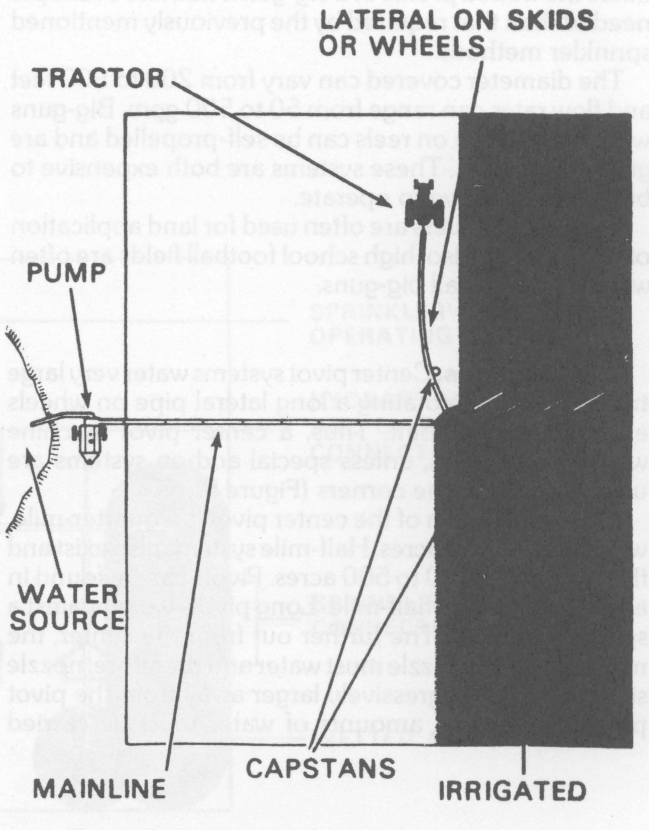

Figure 5. Field layout for a tractor-move system.

Side-roll sprinklers. Side-roll sprinkler systems can cut down labor requirements tremendously. Four- or 5-inch aluminum lines serve both as water distribution laterals and axles for wheels set 40 feet apart. The wheel size is important since they determine spacing to the next set, which will always be a multiple of the wheel circumference. Typical systems will be a quarter mile in length and typical moves are 60 feet, meaning that about 2 acres are watered at a time (Figure 6). After the water is turned off and the lines drained, the whole system is rolled over to the next set by means of a low-torque gas engine.

Livestock can graze alongside a side-roll without causing damage. The problems with side-roll sprinklers are that they are fairly high energy users and that odd-shaped fields cannot be conveniently watered.

In situations where only supplemental water is used and/or labor problems exist, side-rolls may be the best system to choose.

Big-gun sprinklers. Big-gun irrigation systems utilize high water pressure to spray water great distances. The end result is that the initial investment is generally low, but the operating costs will be very high which can be acceptable if only occasional water is required.

Guns can be mounted on either a tripod (Figure 7) or a chassis with wheels. Mainlines are used to bring the water to various sections of a field and then aluminum pipe joints or flexible hose extend from there, via a hydrant, to the gun. After watering, the gun is towed to the next point and the procedure repeated (Figure 8). Since the wetted profile of a big-gun is flat, less overlap is needed than that required by the previously mentioned sprinkler methods.

The diameter covered can vary from 200 to 500 feet and flow rates can range from 50 to 500 gpm. Big-guns with flexible pipe on reels can be self-propelled and are guided by cables. These systems are both expensive to buy and expensive to operate.

Big-gun sprinklers are often used for land application of wastewater. Also, high school football fields are often watered with small big-guns.

Center pivots. Center pivot systems water very large tracts of land by rotating a long lateral pipe on wheels around a pivot point. Thus, a center pivot machine waters only circles, unless special add-on systems are utilized to water the corners (Figure 9).

The usual length of the center pivot is a quarter-mile, which waters 135 acres. Half-mile systems also exist and they can water 450 to 500 acres. Pivots can be found in any length up to a half-mile. Long pivots work against a special problem. The further out from the center, the more area each nozzle must water and therefore, nozzle sizes must be progressively larger away from the pivot point. Thus, large amounts of water must be carried nearly the full length of the pivot and this causes friction loss problems, unless big pipe sizes are used.

The original center pivots were high energy users because they employed high pressure impact sprinklers and were water-driven. Later models cut down on energy use by going to electric driven towers and drop tubes with splash plate nozzles. The newest innovations, termed LEPA (low energy precision application) systems, are very low energy users and also highly efficient. Normally, they distribute water through very low-pressure nozzles a few inches above the soil surface. Water can also be distributed by drag tubes (spaced 5 to 10 feet apart) which do a good job of controlled flooding of the pasture if it is basically flat or sandy. This configuration can greatly improve yields if the water is salty.

Center pivots are not normally designed to water corners. Since much of Texas is short on water versus land, this has little economic impact and the corners are best left out.

Labor costs with center pivots will be small, but the labor caliber has to be higher. Many used pivots are on the market, making the initial cost lower. Fifteen to 20 years is the expected life of a pivot machine. More information can be obtained in TAEX publication L-2219, "Center Pivot Irrigation Systems."

Surface Systems

Flood with furrows. Watering with furrows is the oldest method of irrigation and still the most common in the world today. Water is delivered to either gated-pipe or to a ditch with syphon tubes in it (Figure 10).

Water is delivered to the field's highest end, and gravity advances it to the bottom end. This method of irrigation is the lowest in energy costs but labor requirements will be somewhat high.

The field length should be no longer than a quarter-mile, but sometimes coverage is stretched further. The forage that grows in the furrow ditch will greatly slow down the advance of the water, making the system less efficient.

If tailwater pits at the bottom of the field are used to collect runoff until it can be re-pumped back to the top of the field, the efficiency of the system is greatly improved. Surge flow, a new technology, can also increase furrow irrigation efficiency, as discussed in TAEX publication L-2220, "Surge Flow Irrigation."

Flood with basins. Basin irrigation implies that the water is turned into a larger unit area with small borders surrounding it (Figures 11 and 12). It is allowed to flood the basin and move downslope. Basins can be flat or have raised corrugations on which the crop is grown.

Field Layouts of Sprinkler Systems

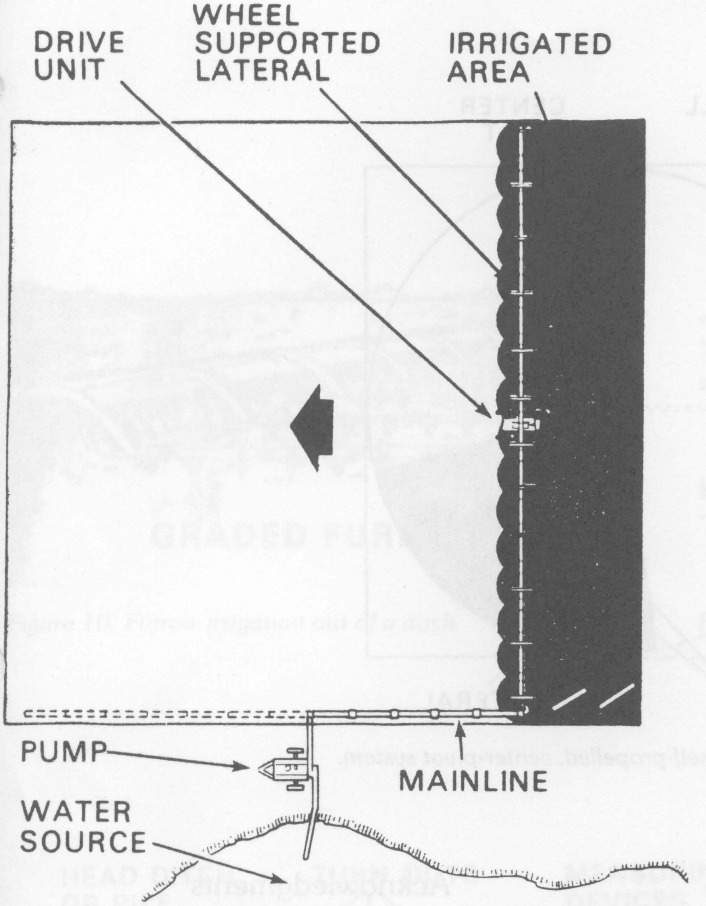

Figure 6. Field layout of a self-move, side-wheel-roll system.

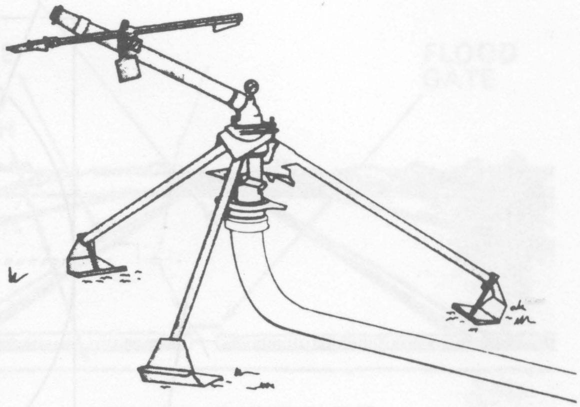

Figure 7. Big-gun sprinkler, hand-move system.

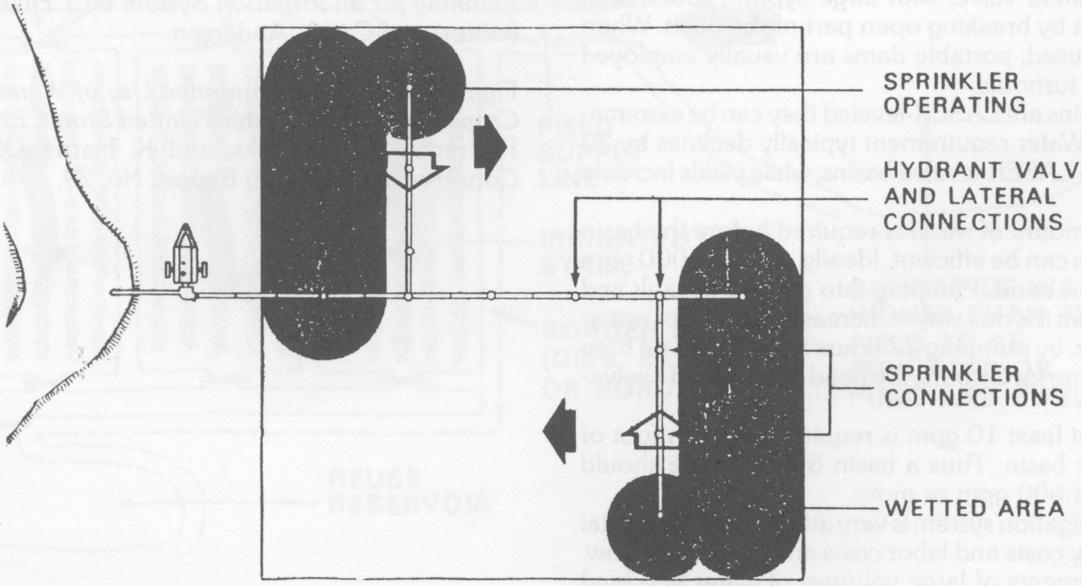

Figure 8. Field layout for a large-sprinkler, hand-move or tractor-move system.

Layout for Center-Pivot System

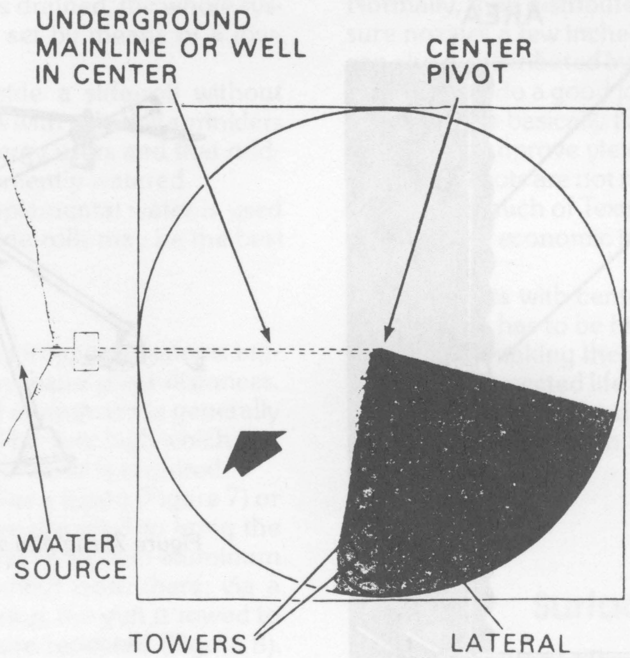

Figure 9. Field layout for a self-propelled, center-pivot system.

The water is delivered via underground PVC pipe, above-ground aluminum pipe or ditch (concrete or dirt). It is turned out into the basin by use of a large hydrant called an alfalfa valve, with large syphon tubes, with gates, or just by breaking open part of the ditch. When ditches are used, portable dams are usually employed close to the turnouts.

When basins are LASER-leveled they can be extremely efficient. Water requirement typically declines by 20 percent with LASER-leveled basins, while yields increase that much.

A large amount of water is required before the basin flood system can be efficient. Ideally, at least 1000 gpm should be on hand. Pumping into a pond or tank and irrigating from it is one way to increase the head of water. For example, by pumping 22 hours into a tank and then flood irrigating for 2 hours, the head is increased twelve-fold.

Usually, at least 10 gpm is required for each foot of width in the basin. Thus a basin 60 foot wide should have at least 600 gpm or more.

A flood irrigation system is very attractive in that initial costs, energy costs and labor costs are all relatively low. *The requirements of large volumes of water and land* that lays flat in at least one direction are essential.

Acknowledgments

All figures in this text (except Figure 1) were taken from *Planning for an Irrigation System* by J. Howard Tuner (editor) and Carl L. Anderson.

Figure 1 is from *Consumptive Use of Water by Major Crops in the Southwestern United States*, Erie, L. J., O. F. French, D. A. Bucks, and K. Harris; USDA/ARS Conservation Research Report, No. 29, 1981.

Surface Irrigation Systems

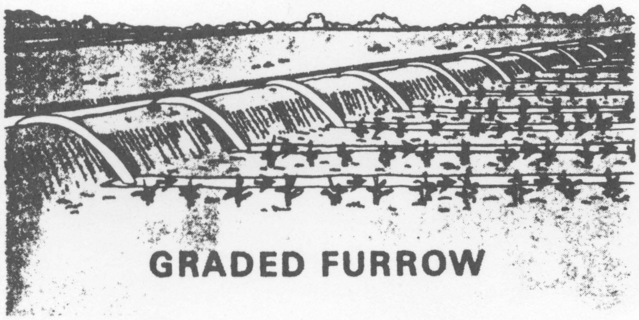

Figure 10. Furrow irrigation out of a ditch.

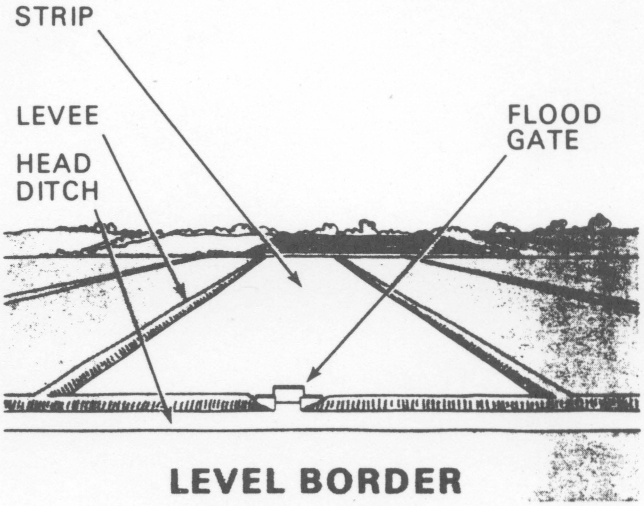

Figure 11. Level border type of surface irrigation.

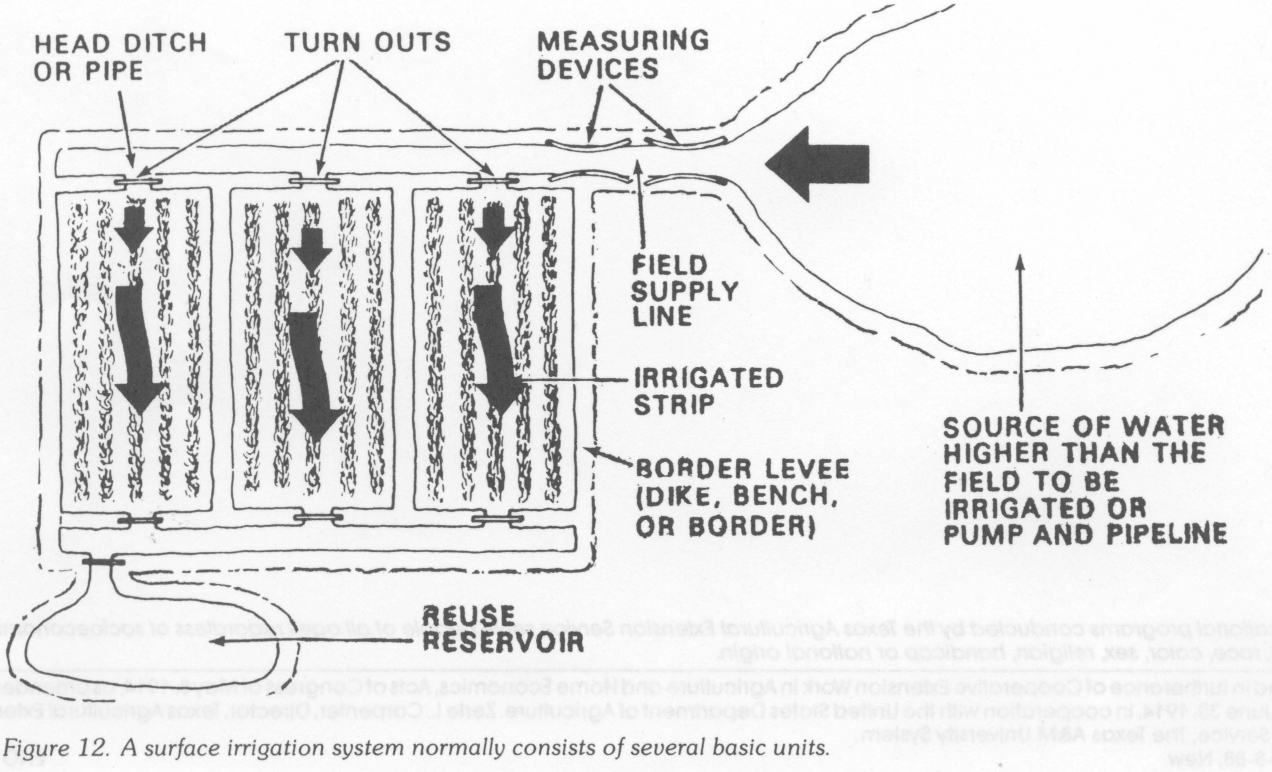

Figure 12. A surface irrigation system normally consists of several basic units.

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