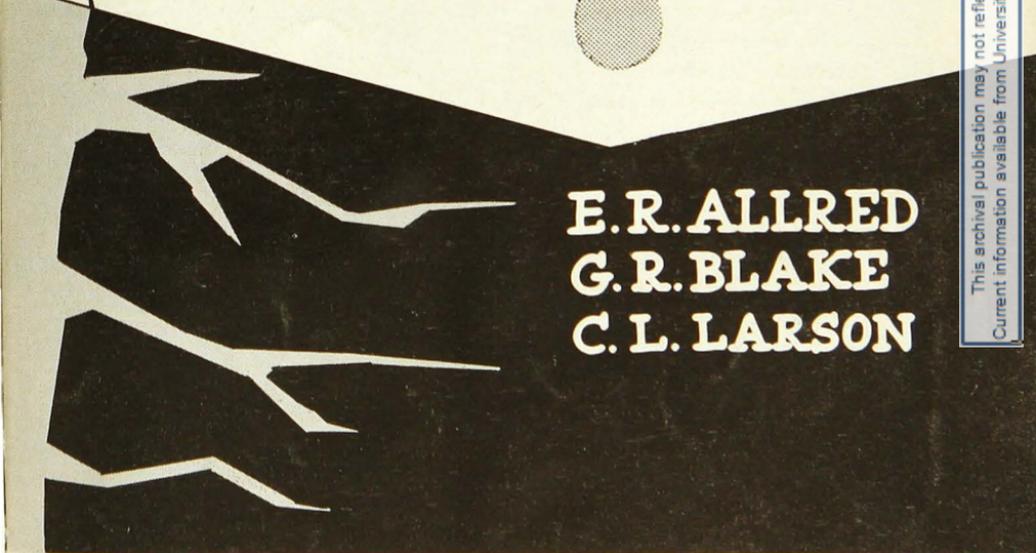


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PLANNING *for* IRRIGATION *in* Minnesota



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Photographs for the figures indicated are used through the courtesy of the following: University of California, Davis (fig. 3); W. R. Ames Co. (fig. 4); M. Lee Gustafson (fig. 5); Food Machinery and Chemical Corp. (fig. 7); Irrigation Pump Co. (fig. 9); Fairbanks-Morse & Co. (fig. 13); and Construction Machinery Co. (figs. 17, 18).

PLANNING FOR IRRIGATION IN MINNESOTA

E. R. Allred, G. R. Blake, and C. L. Larson¹

MINNESOTA GROWING SEASONS are usually quite favorable, but there have been years when irrigation would have meant better yields on many farms. Even during wet years short drouths may handicap crop growth. On heavy soils, short drouths usually do not cause severe crop losses. Many farms located in heavy soil areas have never known a complete crop failure. On the other hand, crops grown in light soils seldom escape at least partial damage from lack of moisture.

This bulletin is primarily intended for persons who are considering irrigation on their farms. No attempt is made to include the technical data necessary to design an irrigation system. A reliable manufacturer's representative or other trained technician should make such a design.

WHY IRRIGATE?

How valuable irrigation is depends upon the value of the crop and the conditions under which it is grown. Here are the principal benefits from irrigation.

Drouth insurance—Many Minnesota farmers consider irrigation as an insurance against drouth. Annual precipitation varies from 19 inches in the northwest to 32 inches in the extreme southeast, averaging about 25 inches. Most of the major crops are grown from May through August when over half of the annual precipitation normally occurs. The value of irrigation as drouth insurance depends on the value of the crop. It is questionable if irrigation can be justified in Minnesota solely on the basis of drouth insurance where low-value crops are grown.

Increased production—For top yields, crops need the right amount of moisture. When prices are high and stable,

the benefits from increased yields may justify irrigating field crops, such as alfalfa, pastures, and corn as well as the higher valued truck crops.

Early maturity—Irrigation may speed up maturity of market fruits and vegetables, enabling the grower to get the higher prices usually paid for a short time before local produce floods the market.

Improved quality—During some seasons irrigation brings higher returns by improving the quality of the crop.

Protection against frost—When designed for it, a sprinkler irrigation system can be used to reduce the risk faced with certain crops which are susceptible to serious frost damage during the early spring. Protecting against frost through sprinkling is most successful with low-growing crops, such as strawberries. The increased weight of the ice on the plant may damage high-growing crops, bushes, and trees. To obtain such protection the water must be applied con-

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tinuously until all traces of ice have disappeared. Protection of large areas of low-valued crops is usually impractical because of the cost.

Purchasing an irrigation system is an important step toward providing ideal growing conditions. However, it is not

a complete solution to production problems. Water is only one of the factors necessary for high crop yields. During some years poor germination, low fertility, plant diseases, or poor management may be the limiting factors of production rather than lack of moisture.

Soils and Irrigation

STORAGE CAPACITY

The storage capacity of different soils depends primarily on their texture—that is, the relative proportion of clay to silt and sand. Fine-textured soils have greater storage capacities than sandy soils.

Field capacity—When soils are thoroughly wetted, the excess water drains into the ground water. Drainage greatly decreases after 24 to 48 hours, and the soil holds an amount of water called its field capacity. This amount varies for different soils. If there is no crop growing on the soil it will remain moist under the surface few inches for rather long periods.

Permanent wilting percentage—If a crop is growing on the soil and it receives no additional water, the moisture supply is slowly depleted until finally the plant wilts and dies. The amount of water then remaining in the soil is called the permanent wilting percentage.

The amount of **available water** that can be stored in the soil for use by the crop is defined by the field capacity and the permanent wilting percentage.

When a crop has used about half the available water from a soil, plant growth begins to slow down. By the time two-thirds to three-quarters of the available water has been used, plants will wilt on hot afternoons and growth is seriously slowed down. Many vegetable crops benefit from irrigation when about half to two-thirds of the available water has been used.

Table 1 shows the amount of available water that can be stored in each

foot of depth. If half the available water is removed from the surface 3 feet of a loam soil we can add about 3 inches of water without appreciable loss by drainage (one inch for each foot of depth). If the crop is a shallow rooting one, and 50 percent of the available water has been removed to 2-foot depth, then a loam soil will hold about 2 inches of water.

MOVEMENT OF WATER

Gravity draws the water in wet soils downward. After soil moisture is at field capacity, movement nearly ceases. Consequently if a plant uses water, the soil about its roots gets dry and remains dry until rain or irrigation. Water doesn't flow in from the sides. It will flow in from below only if there is a water table near the root zone. Movement up from a water table greater than 3 feet is extremely limited.

Because movement of water is very slow in soils drier than field capacity, if a dry soil is wetted down from above the moisture content of the soil will be raised to field capacity as far as it penetrates. If an insufficient amount of water is added to bring the entire

Table 1. Available water storage capacity of soils

Texture	Inches available water per foot of soil
Loamy sand	0.6-1.0
Sandy loam	1.0-1.3
Loam	1.7-2.3
Silt loam	2.0-2.8
Silty clay loam	2.5-3.5
Clay	2.0-3.0

root zone to full capacity, there will remain a dry zone below the wetted part. A wet soil surface doesn't guarantee moisture at the root zone unless sufficient water is added to penetrate to the desired depth. For this reason, crops following alfalfa will often suffer from drouth unless the fall, winter, and spring precipitation is sufficient to recharge the subsoil with water. A probe or soil sampling tube helps tell penetration depth.

Since water in wet soils (during application) moves straight down and also because it moves very little at field capacity (when application ceases), an uneven application of water at the soil surface will result in an uneven distribution of moisture within the soil. For this reason, regardless of the irrigation method used, a uniform application of water to the soil surface is highly desired.

Most water leaves the soil by transpiration through plant leaves. Some also evaporates from the soil surface. This loss, however, is small once the surface is dry. Unnecessary stirring or cultivation only exposes moisture that will be lost by evaporation.

DEPTH TO WHICH CROPS CAN GET WATER

Plants growing in soil at the field capacity will remove large amounts of water from the surface foot of soil and progressively less from subsequent depths to the maximum rooting depth. If a crop roots 48 inches deep, therefore, the surface foot will become very

dry, the second foot not so dry, the third foot will remain fairly moist, and the moisture content of the fourth foot will approach that of the field capacity. If the dry period continues, the plant will gradually extend its roots deeper.

The rooting depth of any crop, therefore, is variable, and depends on the time since the last water application. Even so, some plants can use water at greater depths much more efficiently than others. Each crop, therefore, has a relative rooting depth from which it can supply its needs sufficiently to maintain a high growth rate.

Relative rooting depths are maintained regardless of the length of the dry period. Potatoes, for example, even under drouth will not root as deeply as corn. Table 2 gives the effective rooting depth of different crops.

The root extension of all crops will be restricted by a water table. Even sluggish drainage, though the water table is deep, will greatly restrict the rooting depths of most crops.

HOW MUCH AND HOW OFTEN?

The amount of water and the frequency with which it is applied depends on the season, the kind of crop, and its stage of growth. Crops with shallow roots will require frequent irrigation. As little as 1 inch will sometimes be sufficient to restore the soil moisture reservoir. Less frequent, heavier applications of water will be necessary for crops which root deeply, especially in midsummer when plants are growing fastest.

Table 2. Effective rooting depths of various crops in well-drained soils

Very shallow (18 inches)	Shallow (24 inches)	Moderately deep	Deep	Very deep
onions	potatoes	soybeans	tomatoes	alfalfa
radishes	celery	spring grains	asparagus	trees
lettuce	peas	sugar beets	corn	
spinach	red clover	brome grass	sweet clover	
ladino clover	timothy	orchard grass	birdsfoot trefoil	
white clover		cabbage	parsnips	
bluegrass		snap beans	lima beans	
		broccoli		
		peppers		

"How much" and "how often" for some shallow-rooted vegetable crops may be approximately 1 inch every 6 or 7 days. For deeper rooting field crops—such as tomatoes, corn, or beans—the amount will be nearer 2 to 3 inches every 14 to 16 days.

The tendency with sprinkler irrigation systems is to add too little at each application. This can be wasteful of resources and will often fail to stimulate crop growth as expected. Do not add less than 1 or 1½ inches of water in a single application. Smaller applications result in wetting too near the surface. This allows for large evaporation losses and does not penetrate to the bulk of plant roots.

On fine-textured soils having high storage capacities and on a crop such as corn that removes water to a considerable depth, applying 3 to 4 inches of water every 3 or even every 4 weeks would supply the crop's needs. However, this practice does not allow completion of the irrigation cycle in a practical length of time. A compromise is often necessary between complete soil moisture reservoir recharge and system capacity.

APPLICATION RATE DEPENDS ON SOIL PERMEABILITY

The rate at which water will run into soils varies greatly with soil type, amount of vegetative cover, and previous tillage practices. Bare soil will usually have a much lower infiltration rate than one with a cover of vegetation or plant residues. Recently plowed soils will take in water rapidly. If the soil has been compacted by intensive cultivation, the infiltration rate will be lowered. This is often true for vegetable crops where cropping and traffic are intense.

Soils one or more years away from plowing will usually have relatively low permeability. Pastures and hay lands are in this category. However, the vegetative cover associated with hay crops aids water infiltration and slows runoff.

Infiltration rates will also depend on soil texture. Generally, the finer the soil texture, the lower the infiltration rate. The structure of the soil will greatly modify this, however.

The majority of soils have infiltration rates somewhat less than an inch per hour. Infiltration rates of ¼ to ½ inch per hour are much more realistic.

When water is first added to dry soils, the infiltration rate may be as great as 5 or even 10 inches per hour. However, as more water is added, this rate declines rapidly at first and begins to level off after a few tenths of an inch have been added. It is not uncommon to find an infiltration rate of two-thirds of an inch per hour for the first inch, one third of an inch per hour for the second inch, and a quarter of an inch per hour for succeeding amounts.

Whatever estimate is used in the design of an irrigation system, it is necessary to check for runoff once the system is in use. Some adjustment in the application rate will be required for each field and for each crop to prevent runoff and erosion, no matter what standards are used in preliminary estimates of the infiltration rate.

SOIL RESPONSE TO IRRIGATION

Sandy soils can usually be more successfully irrigated than finer textured ones. Fine-textured soils often have relatively low infiltration rates. Sometimes it takes several hours of sprinkling to get an inch of water into the soil. If there is a deficit of 3 or 4 inches, as may be the case in fine-textured soils, a long sprinkling period is required. With a long sprinkling period, some damage may occur to the crop in hot weather because of restricted aeration in the wet soil.

Sandy soils, on the other hand, drain very rapidly and are usually not poorly aerated even while water is being applied. Furthermore, fine-textured soils tend to puddle on the surface. As a result, infiltration greatly decreases after about half an inch to one inch of water has been added.

Another difficulty with fine-textured soils is that they tend to be sticky and wet for about one or two days after the water has been applied, making it hard to go into the field and move pipe. If this difficulty is ignored, there is considerable damage to the soil structure from traffic on wet soil. With pasture crops, this difficulty would, of course, be less severe. In the United States, much of the irrigation on finer textured soils is done by flooding. Fine-textured soils can be irrigated, however, provided the difficulties are properly recognized.

Peat and muck soils are frequently irrigated, especially where high value crops are grown. These soils respond well to irrigation because they tend to dry out quickly. Also, by keeping the moisture content at a high level blowing of these soils can be reduced to a minimum. Many peat lands, however, are underlain by a shallow water table which makes irrigation unnecessary. Sub-surface irrigation (discussed on page 8) is often used successfully on peat and muck soils.

CROP RESPONSE TO IRRIGATION

Most irrigating in Minnesota is done near cities on small fruits and vegetables. But interest has been growing in the irrigation of field crops, such as alfalfa, pastures, and corn. This has occurred largely in areas having light-textured soils.

The decision to irrigate will depend on whether or not the type of farming planned will justify the investment. The fact that a crop is responsive to irrigation, however, does not always mean it can be irrigated economically.

Vegetable crops respond well to irrigation because they are frequently grown in either peat or sandy soils, and many have relatively shallow root systems. Since vegetables have critical water requirements, moisture deficiencies must be avoided. Such deficiencies retard growth, reduce yield, and cause a marked lowering of quality.

Small fruits also respond favorably to irrigation. For best quality and maximum yields, small fruits must have ample moisture, especially during and immediately following blossoming.

Corn has the ability to recover well from drouths during early stages of its growth. Such drouths tend to delay maturity but do not affect yields greatly. However, if a moisture deficiency occurs during the silking or tasseling stages, yields will be seriously reduced.

Potatoes and most other root crops are extremely sensitive to soil moisture content. If there is a moisture shortage at any time during the growing season—especially while the tubers are being set—quality and yield will be seriously affected.

Sugar beets, though sensitive to moisture deficiency, are deep rooting. They can, therefore, get considerable water from the soil. Also, they are usually grown in fine-textured soils having large water storage capacities.

Alfalfa uses large amounts of water. With its deep rooting system, it is capable of withdrawing water from greater soil depths. This permits the addition of large amounts of water per application. It can best be irrigated after each hay crop is removed, unless rainfall makes that unnecessary.

Pastures and grasses, in general, have remarkable recovery power from drouth. If soil moisture is depleted, pasture growth will slow up but little permanent damage will occur. Application of water following a drouth will result in good pasture growth.

IRRIGATION TAKES SOUND SOIL MANAGEMENT

While supplemental irrigation may be a great asset on some soils and crops, research has shown that there are some inherent dangers in it. Awareness of these dangers is important to prevent

soil deterioration. To be successful, irrigation must go hand in hand with sound soil management.

In humid regions, there is some danger of over-irrigation, especially if an irrigation is followed by rain. Over-irrigation can exclude air from about plant roots and may hinder growth while new rootlets are being formed.

It has been shown, too, that the crumb structure of soil (which gives it desirable tilth) is often damaged by water. The result is that the soil is more sticky and has a tendency to crust more easily. Such conditions create a less desirable plant root environment. The problem

may be aggravated if the moisture content of the soil is higher than usual when cultivated or tilled, because soils are much more subject to compaction when wet or moist than when dry. Avoid, whenever possible, driving over the land with farm equipment when the soil is wet.

Soil erosion can be as serious with irrigation as with summer rain. On sloping lands, contour planting and other conservation practices are even more important when extra water is added. It is important to keep the application rate low enough to avoid erosion.

What Methods Are Used?

SURFACE METHODS

With surface irrigation, the water is applied across the surface of the soil in the form of a thin sheet, or as a small furrow stream. As a result, the land must slope gently in the direction of flow. To establish such a slope, land smoothing is usually necessary. If land smoothing has to be done, get technical advice on how to set the proper grades and avoid exposure of undesirable subsoils.

Some farms, mostly in the Red River Valley, can be adapted to surface methods. However, because a large portion of the agricultural land in Minnesota has irregular topographic features, surface irrigation is not common.

SUB-SURFACE METHODS

With sub-surface irrigation, water is applied to the root zone from a point below the ground level. This is done either by deep ditches or underground, porous pipelines. In either method the water is admitted into the subsoil in order to cause a quick rise, then lowering, of the groundwater table.

Successful sub-irrigation requires a highly permeable surface soil, uniform topographic conditions, moderate slopes,

and an impervious subsoil at a depth of 6 to 10 feet.

These requirements are frequently met in peat or muck soil areas. As a result, it is more practical and less costly in most cases to use sub-surface irrigation on these lands. Since drainage is always required to grow crops on peat soils, a common practice in some areas is to combine sub-surface irrigation with controlled drainage. This can be done by installing dams or gates in the drainage system so that the water table can be raised or lowered at will. A pump and a water supply may be needed to pump water into the drainage system for irrigation.

SPRINKLER METHODS

Various factors favor the use of sprinkler irrigation over other methods in Minnesota. The irregular-shaped topography in most areas is one. Another is the fact that irrigation is largely confined to the application of small amounts of water to special crops during critical periods. Also, a sprinkler system requires no land preparation and can be installed on short notice.

Sprinkler irrigation methods are of three general types—overhead oscillating pipe, perforated pipe, and ro-

tating sprinkler systems. The water is carried through pipes located either above ground or buried. Aboveground pipe may be permanently or semi-permanently installed, or it may be portable. Where portability is desired, lightweight aluminum pipe is most commonly used. Transite (cement-asbestos), iron, steel, and plastic pipe are used for permanent and for underground lines. Figure 1 shows the typical layout of a sprinkler irrigation system and identifies the main parts of the system.

Portability in an irrigation system is achieved by using a coupler which makes it possible to assemble and disassemble the pipe quickly. Some of the couplers most commonly used are shown in figure 2. There are some differences in coupler design, depending upon the manufacturer.

In most respects, couplers are basically similar; all employ replaceable rubber or other flexible gaskets to form a tight seal between the coupler and the pipe when pressure is applied. Upon release of the pressure in the line this seal is broken, thus permitting the water to drain from the pipe so that it can be moved more easily.

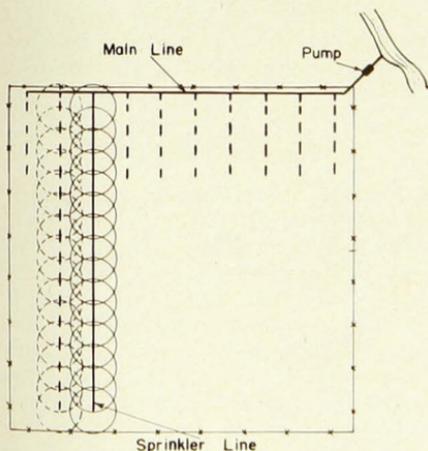


Fig. 1. Component parts of a sprinkler irrigation system.

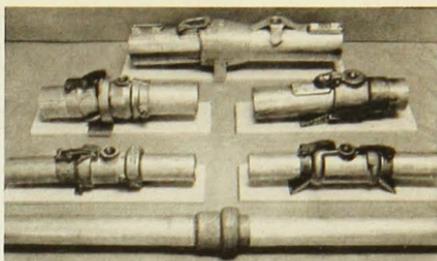


Fig. 2. Various types of quick-couplers for portable irrigation systems.

Overhead Oscillating Pipe System

In the oscillating pipe system shown in figure 3, the main line delivers the water from the pump to the sprinkler line. It may be located either above or below the ground surface. The sprinkler lines, consisting of $\frac{3}{4}$ - to $1\frac{1}{2}$ -inch steel pipe, are coupled together and supported 4 to 8 feet above ground by wooden or metal posts, spaced about 15 feet apart.

Water is sprayed through small, fixed nozzles, spaced from 2 to 3 feet apart along the sprinkler line. During operation the entire sprinkler line is slowly oscillated through an arc of about 120 degrees by means of a hydraulic oscillator. Roller supports fitted on top of the posts assist in this movement.

The sprinkler lines of an oscillating pipe system are generally spaced 50 feet apart and run at right angles to the direction of the main. When operating at a pressure of 30 to 40 p.s.i. (pounds per square inch) and without wind interference, the water is sprayed about 25 feet each way from the nozzles. Under these conditions the system will deliver approximately 1 inch depth of water during each 8-hour run.

An oscillating pipe system is considered permanent since the various lines are not usually moved from one part of the farm to another. It has a uniform distribution of water and a fine spray action. The gentle spray makes it well suited for frost control purposes



Fig. 3. Oscillating pipe system in operation.

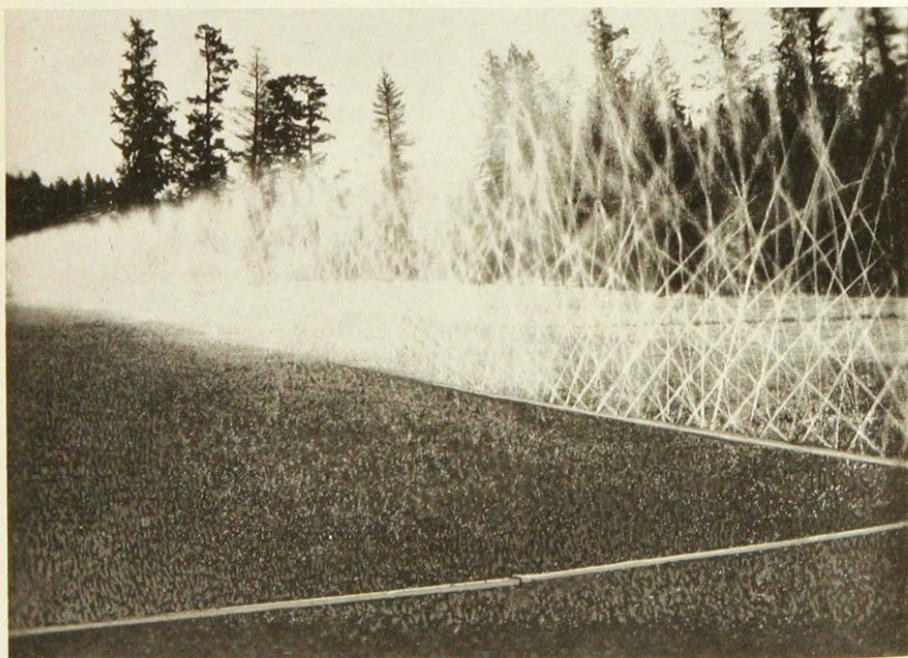


Fig. 4. Perforated pipe system in operation.

and for use on tender crops such as spinach, lettuce, berries, and flowers.

The disadvantages of the system are its high initial cost, hindrance to field operations, and small width of coverage. Such systems are generally found only on small acreages, where high value truck or fruit crops are grown.

Perforated Pipe

The main line of a perforated pipe system (figure 4), is usually located above ground and runs across one end of the area being irrigated. The perforated sprinkler line is available in 2- to 6-inch sizes, and is usually located at right angles to the main.

The system operates at pressures from 10 to 20 p.s.i. and distributes the water about 20 feet on each side of the pipe. Perforations are spaced along the sprinkler line to give an even distribution of water. The size of the perforations determines the rate of application.

The use of the perforated pipe method is most popular with nurseries and truck farms. With its even distribution of water, the truck farmer growing a variety of crops in small plots is able to irrigate these crops independently of each other. Also, smaller power units may be used with the perforated pipe system since the operating pressures are low. For the same reason, a perforated pipe system usually has slightly lower operating and first costs than other types.

Perforated pipe systems are not commonly used on large acreage where a single crop is being grown because of the narrow width of strip irrigated from each setting. Another major disadvantage of this system is that it is difficult to apply the water at rates slower than $\frac{3}{4}$ inch per hour. This is not objectionable on light-textured soils, but cannot be permitted on heavier soils where infiltration rates are low.

Also, such low-pressure systems can't be used on steep or irregular areas because large changes in elevation along the line will cause variations in pres-

sure. This results in an irregular-shaped wetted area.

Rotating Sprinkler System

The rotating sprinkler system (figure 5) is the most common type of sprinkler irrigation in Minnesota. In most cases the pipes are placed directly on the ground surface and are moved from one setting to the next by hand. Flow from the sprinkler line occurs through a sprinkler head, which is raised a short distance above the ground surface by a riser pipe. The height of the riser varies with the crop irrigated but is normally from 2 to 4 feet. Taller risers can be used for high-growing crops but must have some means of support in order to maintain an upright position.

Rotating sprinklers are available for flows ranging from 2 g.p.m. (gallons per minute) at 15 pounds pressure to 600 gpm at 100 pounds pressure. For a given installation, a sprinkler is chosen to furnish a favorable distribution pattern and to deliver water to the soil at the desired rate. Rotating sprinkler heads may be equipped with one or more nozzles. The operating characteristics of a given sprinkler are determined by the water pressure and size of nozzles.

The sprinklers most commonly used in Minnesota are of the spring reaction type, shown in figure 6. Such sprinklers rotate slowly, requiring from 20 to 60 seconds per revolution.

The spacing of the sprinklers along the lateral line of a rotating sprinkler system, and the distance this line can be moved for each setting, depends upon the sprinkler size and the operating pressure. For uniform distribution a considerable amount of overlapping is necessary.

Mechanically Moved Systems

To reduce labor costs, sprinkler systems are sometimes designed to be moved mechanically instead of by hand. Of these, the wheel-move, tractor-



Fig. 5. Rotating sprinkler system in operation.

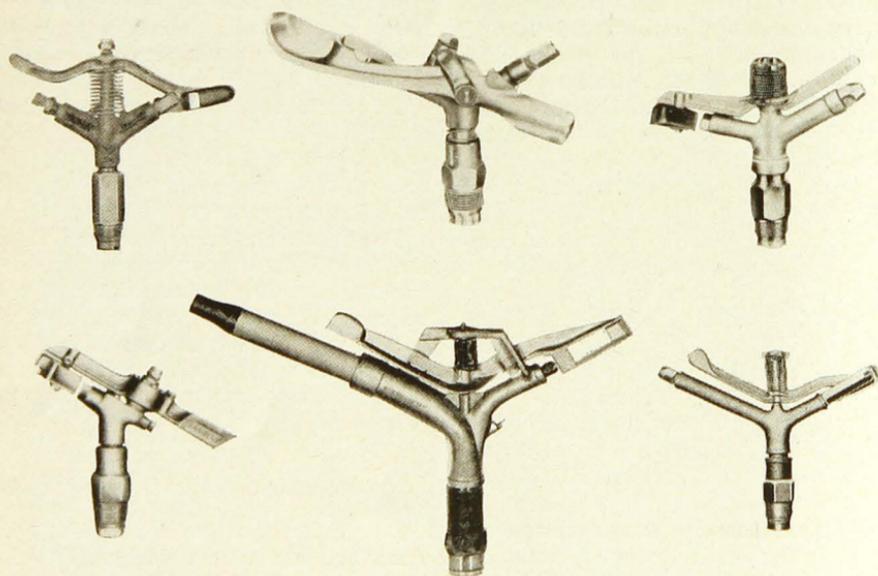


Fig. 6. Various sizes and types of rotating sprinklers.

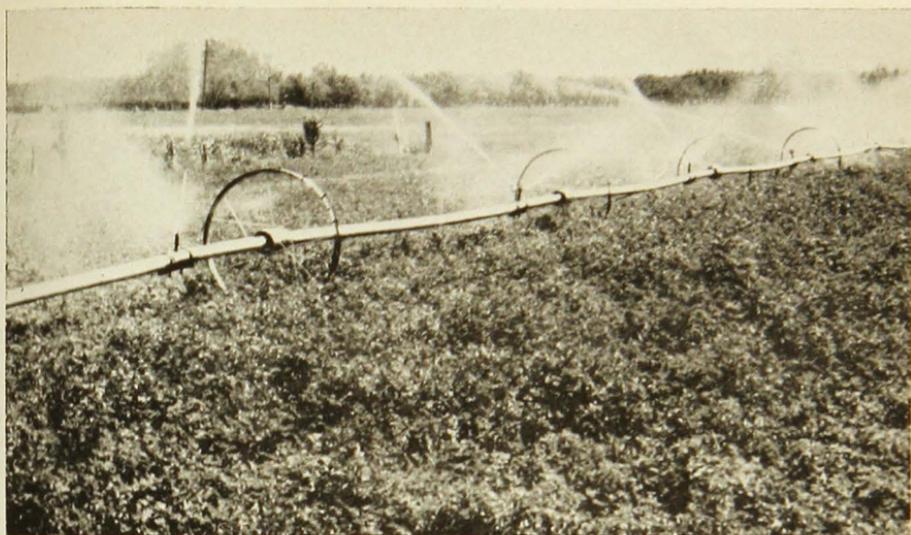


Fig. 7. Wheel-move irrigation system.

move, and trailer-mounted boom sprinklers are most common. Although the initial cost of mechanically moved systems is greater than for hand moved systems, the savings in labor may more than offset the increased cost.

Because mechanically moved systems are not dismantled for each move, rigid couplers are used. For this reason it is both difficult and expensive to convert a hand-move type of system to one which can be moved by mechanical means.

Wheel-move systems usually have 4-foot diameter wheels spaced from 20 to 40 feet along the sprinkler line (figure 7). The pipe lengths are joined at the hubs of the wheels and the sprinkler line is rolled as a unit from one setting to the next. Wheel-move systems are best adapted for irrigation of pastures, forage crops, and low-growing truck crops. Crops higher than 2 feet tend to interfere with the movement of the pipe.

With the tractor-move system, the entire sprinkler line is pulled by hitching a tractor to one end of the line. Skids or small diameter wheels are used to fa-

cilitate moving. Tractor-move systems are most commonly used on pastures or other crops where the equipment can be moved without causing extensive damage (figure 8). On crops subject to damage, "lanes" are usually provided through which the tractor can pull the sprinkler line. The distance between these "lanes" depends upon the width of coverage of the sprinkler.

Trailer-mounted boom sprinklers are gaining some popularity for irrigation in Minnesota. These sprinklers are built in a flat Y-shape, measuring from 170 to 210 feet from tip to tip (figure 9). Small nozzles located along each leg of the boom distribute the water be-



Fig. 8. Tractor-move irrigation system.



Fig. 9. Boom-type system used to irrigate corn.

neath the sprinkler and also provide the hydraulic force required to rotate the boom. A large nozzle at each tip distributes water to an area beyond the end of the boom. Depending on the size of the sprinkler and the operating pressure, a single boom sprinkler may irrigate up to $4\frac{1}{2}$ acres per setting. For this reason one such sprinkler is usually sufficient on the average farm.

The boom sprinkler is moved from place to place by hitching a tractor to the trailer. Pipe is removed from the trailer to extend the main to the new position.

Boom-type sprinklers are especially suited to the irrigation of tall-growing crops. However, they are difficult to maneuver in small fields, and are not adapted for use on steep slopes.

Requirements of a Good Water Supply

Before investing in an irrigation system, make certain that your water source will prove satisfactory. Regardless of the source chosen, three important requirements must be met:

1. The water must be of suitable quality for irrigation.
2. A legal permit must be obtained to use the water.
3. A sufficient amount of water must be available at all times.

WATER QUALITY

Some waters contain chemical salts which are injurious to plants. A small

amount of such salts in the water is not harmful. Water samples taken from some deep wells of the western and northwestern counties of Minnesota contain appreciable amounts of these salts. Largely because of the small amount of irrigation water required each year, however, most of these waters have not proven seriously objectionable.

Water from ponds, lakes, and streams throughout the state are generally found to be of high quality for irrigation. Should a reasonable doubt exist concerning water quality, send a sample to a commercial chemist for analysis.

LEGAL USE OF WATER FOR IRRIGATION

As in most other states, Minnesota farmers are required by law to obtain a permit before they can legally use water for irrigation. Write the Division of Waters, State Conservation Department, State Office Building, St. Paul 1, for an application form. After the form is returned, the Conservation Department grants or denies the permit, depending on each individual case. It is important that you obtain a use permit before you purchase an irrigation system.

AMOUNT OF WATER NEEDED

The water supply for an irrigation system must be sufficient to cover the land during a long drouth. No investment should be made until an adequate water supply has been established. If the amount of water is limited, it is better to irrigate a small acreage rather

than doing an inadequate job on a large area.

The exact amount of water needed for an irrigation system cannot be determined until the system is completely designed—since the pumping rate will depend upon the area irrigated, crop requirements, rate of application, and the number of hours of operation per day. Since irrigation requires large amounts of water, one tends to overestimate the number of acres that can be irrigated from a given source of water.

Under Minnesota conditions you should allow about 10 gallons per minute for each acre of land to be irrigated. This figure is based on the assumption that you irrigate 16 hours per day. If you plan to operate the system 12 hours per day use 14 gallons per minute and for eight hours allow 20 gallons per minute per acre. These figures are rough estimates and should be used for preliminary planning only.

Possible Sources of Irrigation Water

A water supply must be both adequate and dependable. If more than one source is available, preliminary cost estimates should be made to determine which should be used. In most cases the source nearest the field is best.

If you're considering natural ponds or farm ponds, be sure they are large enough to irrigate the land area and that they will not go dry during dry spells. A pond should contain about $1\frac{1}{2}$ acre-feet of water for each acre of land irrigated. To determine the approximate volume of water in a pond, estimate its surface area (in acres) and its greatest depth (in feet).

Then multiply the surface area by one-half the greatest depth to get acre-foot volume. Technical advice on building farm ponds can be obtained from soil conservation technicians.

Excavated dugouts, abandoned rock quarries, and gravel pits are some-

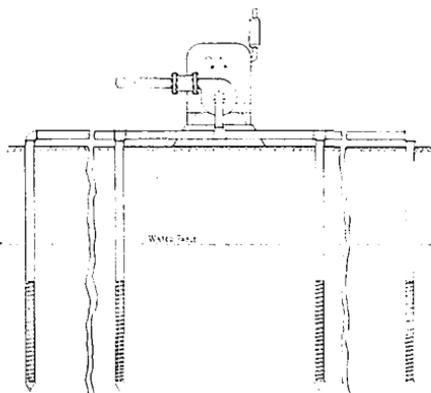


Fig. 10. A series of small well points (2-inch diameter) pumped from a centrally located pumping unit.

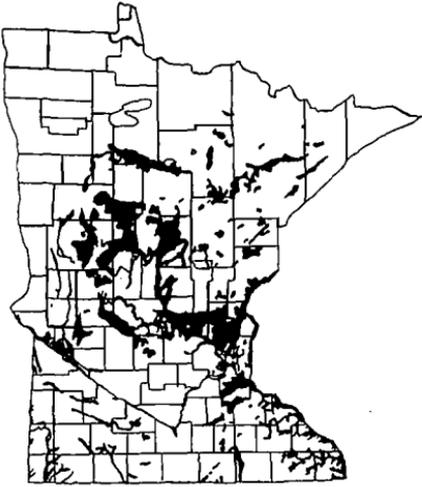


Fig. 11. Location of shallow water-bearing sand and gravel deposits in Minnesota.

times used as a source of irrigation water. Don't attempt the construction of a dugout until tests have been made to show the position and seasonal fluctuations of the groundwater table and the permeability of the subsoil.

Small farm reservoirs are occasionally used as a temporary means of storing the flow from wells, springs, or creeks. By collecting the limited but continuous flow from a well or stream, sufficient water may be made available for irrigation. To be sure of an ample supply of water during hot, dry spells, a continuous flow of about 7 gallons per minute is needed from the stream or spring for each acre of land to be irrigated.

If groundwater is being considered, be sure you have a dependable supply before investing in equipment. Don't be misled by the fact that water appears in a dug hole at a short distance from the ground surface. Such a condition indicates the presence of a water table at that point but you may not be able to pump it fast enough to meet the needs. Consult your local well-driller for his advice on groundwater supplies in your area.

Most farms pumping from groundwater sources use small well points driven into shallow beds of sand or gravel. For irrigation purposes, 2-inch diameter points as shown in figure 10 are most common. If the yield of a single 2-inch point is insufficient to meet the irrigation needs, additional rather than larger points are generally used. The well points are connected together and pumped as a unit. The total pumping lift from a well point should not exceed 20 feet.

Figure 11 shows the location of known deposits of shallow water-bearing sand and gravel in Minnesota. Conditions in the shaded areas are most favorable toward the use of well points.

Irrigation wells are sometimes drilled instead of driven. Drilled wells for irrigation vary from 6 to 24 inches in diameter and from 30 to 200 feet in depth. The availability of water from deep wells varies widely throughout the state. In some areas porous formations furnish abundant quantities of water. In other areas where granite is exposed or covered with a relatively thin layer of drift, groundwater supplies are limited. The availability of groundwater for deep wells is indicated in figure 12.

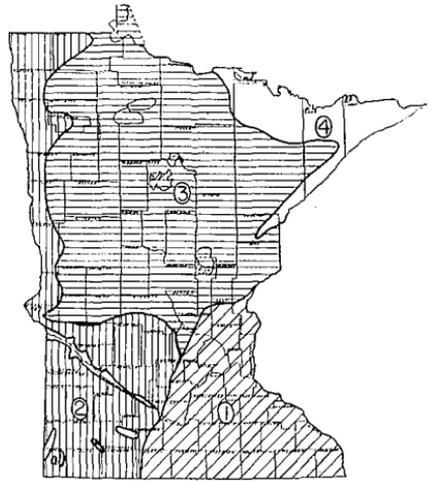


Fig. 12. Groundwater supplies from deep wells in order of availability. (Area 1, most favorable; Area 4, most difficult.)

Selecting an Irrigation System

A well-designed irrigation system requires the use of technical data and knowledge. For this reason the equipment should be purchased through a reputable dealer and one familiar with irrigation requirements. If the products of several reputable manufacturers are available in your vicinity, select that system handled by the dealer best able to give you dependable service.

TYPES OF PUMPS AVAILABLE

The centrifugal pump (figure 13) is most common in irrigation work be-

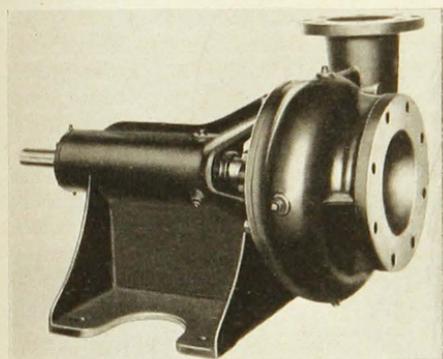


Fig. 13. Centrifugal pump commonly used for irrigation.

cause it is rugged, simple to operate, requires little maintenance, is available in a wide range of sizes, and is relatively inexpensive. For these reasons, the centrifugal pump should be given first consideration. It is ideally suited for pumping from lakes, ponds, streams, and shallow wells. For best performance the suction lift with centrifugal pumps should not exceed 15 feet.

Centrifugal pumps are usually connected directly to the power shaft of the motor or engine to prevent loss of power from slippage. Where it is impossible to do so, however, the connection can be made by V-belts and pulleys or by a gear arrangement.

A deep well turbine pump is a centrifugal pump in a vertical position. These pumps are made small enough in diameter so they can be lowered into the well casing (figure 14). Deep well turbine pumps can be used for wells of any depth. They give long, efficient, and dependable service but are more costly than centrifugal pumps.

Every pump is designed and made to perform under specific conditions. For this reason, used pumps are not generally recommended. Unless the performance curve which shows the operating characteristics of a used pump is available, the purchaser has no way of knowing whether the pump is suitable to his conditions. Also, most old pumps are uneconomical to operate because of their low efficiency.

HOW MUCH POWER IS NEEDED?

The amount of power needed for irrigation depends on how much water is pumped and the conditions under which the pump is operated. Determining the power requirement accurately requires the attention of a trained technician. Figure 15 can be used to determine the approximate power requirement, however, provided reasonable estimates can be made of the following:

1. Maximum length of main line (in feet), usually obtained by pacing off the distance in the field.
2. Static lift (in feet) which is the vertical distance the water is raised from the source to the highest sprinkler. This distance can usually be estimated close enough by eye.
3. Pumping rate (in gallons per minute). This can be estimated as suggested on page 15.
4. Operating sprinkler pressure (in pounds per square inch). Perforated-pipe systems can be figured at 20 pounds per square inch and oscillating-pipe systems at 30 pounds. The operating

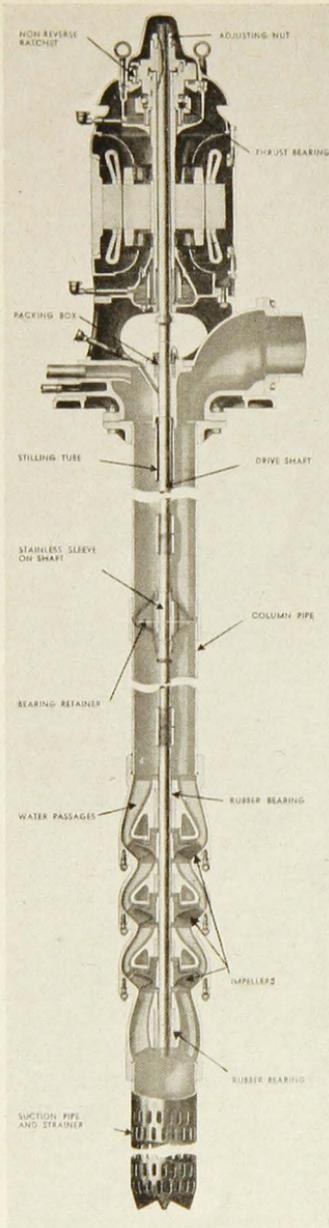


Fig. 14. Turbine pump used to irrigate from deep wells.

pressure of rotating sprinkler systems varies from 40 to 100 pounds per square

inch, depending on the sprinkler used. Pressures of 40 to 60 pounds per square inch are most common for rotating sprinklers.

To illustrate the use of figure 15, suppose an estimate of the power required to operate a system having a 450-foot main line and operating at an average sprinkler pressure of 50 pounds per square inch is desired. Assume the water is to be pumped at a rate of 600 gallons per minute and lifted 30 feet (vertically) from its source to the highest sprinkler.

With this information, figure 15 is entered at the lower left part of the chart, opposite a 450-foot length of main, and a horizontal line is extended to point A, on the 50 p.s.i. curve. Proceed vertically upward to point B (on the 30-inch static lift curve), then horizontally to a point C, which corresponds to a discharge of 600 gallons per minute. After point C has been located, proceed vertically downward and read the brake horsepower requirement from the indicated scale. Brake horsepower is the power required to drive the pumping unit. In the above example about 40 brake horsepower is needed.

CHOOSING A SUITABLE TYPE OF POWER

Power for irrigation is usually limited to electric motors or internal combustion engines, such as gasoline, Diesel, natural gas, LP gas, or propane. In choosing a particular type of power unit, consider such factors as:

1. Availability and cost of electricity or fuel.
2. Amount of horsepower required.
3. Total hours of operation per year.
4. Initial cost.
5. Degree of portability desired.
6. Amount of maintenance required.
7. Life expectancy of unit.
8. Performance under continuous load conditions.
9. Normal operating speed.

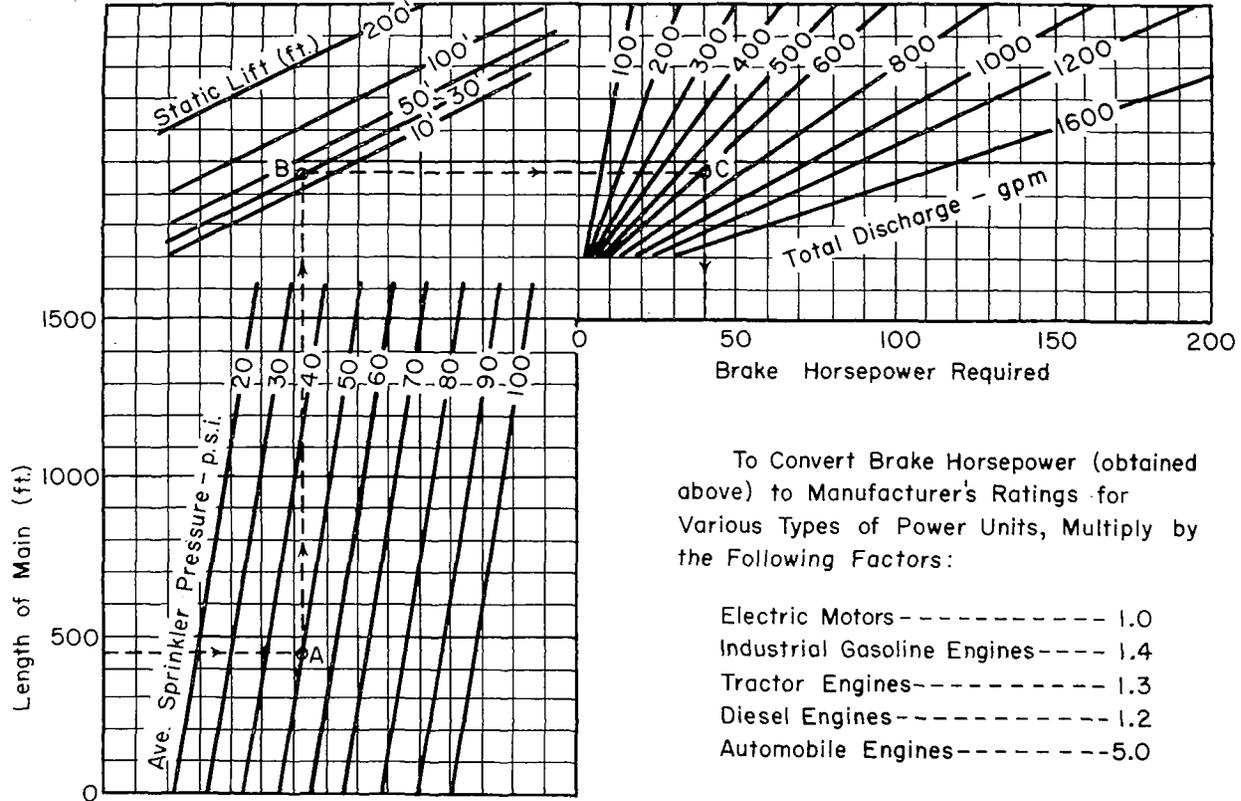


Fig. 15. Chart for estimating the brake horsepower requirement for irrigation systems (based on 70 percent pump efficiency).

Electric Motors

Electric motors are classified as "single-phase" or "3-phase," depending on their construction. Neither type is interchangeable with the other since they require a different type of electrical current. Single-phase motors cannot be used if the power requirement exceeds $7\frac{1}{2}$ horsepower. Thus single-phase motors can be used only on small irrigation systems.

Three-phase motors are available in a complete range of sizes, but few rural areas have access to this type of current. In some instances, 3-phase lines are extended so that a large electric motor can be used. However, such an extension may be rather costly. Inquire at your local power company to determine if 3-phase current is available. Or, if not, how much it would cost to extend such current to your pumping site.

When they can be used, electric motors have several advantages over other types of power for irrigation. They require little attention during operation, perform at high efficiency, have low cost for maintenance, and take up little space. Figure 16 shows a centrifugal

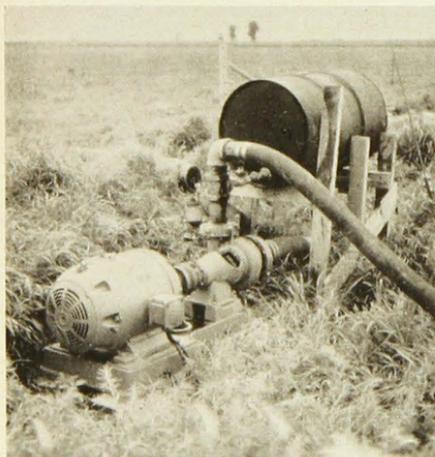


Fig. 16. Irrigation pump driven by electric motor.

pump with a direct connection to an electric motor. Electricity is not as convenient as other types of power if the pumping unit is to be moved from one location to another.

Gasoline Engines

Gasoline engines are widely used for irrigation pumping in Minnesota because they are highly portable, have a relatively low first cost, are available in a wide range of sizes, and can be readily serviced. The cost of operating and maintaining a gasoline engine is comparatively high. As a result, if an engine is to be operated over 1,000 hours each year it may be more economical to consider other types of fuel.

Safety controls should be provided on all types of gasoline engines to prevent damage in case of trouble. These controls are connected into the electrical system of the engine. If a loss of pressure occurs at the pump, if the oil pressure drops, or if the engine overheats, the engine stops automatically.

The industrial type of gasoline engine (figure 17) is best suited for irrigation, because its operating speed is about the same as normal pump speeds. Also, it can be obtained in almost any size and is usually the most economical to operate.

A farm tractor can be used to operate an irrigation pump, provided it isn't required elsewhere when needed for irrigation. Some farmers buy a new tractor and plan to use the old tractor for irrigation pumping. But unless the old tractor is in good condition, the total cost and upkeep may exceed the cost of having a new power unit for the irrigation pump.

Small centrifugal pumps mounted on wheels or skids for easy movability, and especially adapted for tractor take-off power, are available and becoming increasingly popular (figure 18).

Used automobile engines are sometimes used as a source of power for irrigation. Since much of their useful

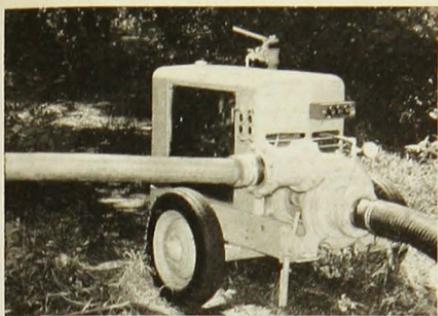


Fig. 17. Irrigation pumping with gasoline engine.

life has been expended and their mechanical condition often unknown, such engines are not generally recommended. The major difficulty with automobile engines, whether new or used, is that some means must be provided for reducing the speed at the pump. Automobile engines operate at much higher speeds than is advisable for most pumps.

Selecting an Engine of Proper Size

The power unit selected to operate an irrigation pump should perform economically, have a maximum life expectancy, deliver a sufficient and continuous amount of power to the pump shaft, and maintain the recommended pump speed. Factory-mounted pump and power units are available if desired. With such units the manufacturer selects the proper engine for the pump and the risk of having an improperly sized engine is greatly reduced.

If the engine and pump are purchased separately, be sure the engine you select will operate economically and not be overloaded. Overloading an engine invites serious trouble.

Engines and motors are rated in a wide variety of ways. The internal combustion engine used must have a higher rating than the brake horsepower requirement to allow for losses within the

Other Types of Engines

The initial cost of a Diesel engine is considerably higher than for a gasoline engine of similar horsepower output. Operating costs for a Diesel-powered plant, however, are less than for a gasoline-operated plant, since a less costly fuel is used. The saving in Diesel fuel must be great enough to justify the increased cost of the engine. Usually a seasonal pumping period of 1,000 hours, or more, is required to justify the greater initial cost of a Diesel engine. Seasonal pumping periods in Minnesota are normally less than that.

Where propane, LP gas, and natural gas can be obtained at reasonable cost, these fuels are frequently used. Engines using such fuels overcome many of the disadvantages of both gasoline and Diesel engines. Their initial cost is but slightly higher than for gasoline engines of similar size. The maintenance cost of engines using these fuels is generally low. Their use is determined largely by the availability of the fuel supply.

engine. The allowance to make for various types of power units is shown at the lower right of figure 15 on page 19.



Fig. 18. Pumping for irrigation from power take-off of tractor.

For example, if an industrial gasoline engine is to be used where the brake horsepower requirement is 40, an engine with a manufacturer's rating of at least 40×1.4 or 56 HP should be

used. The same installation would require a Diesel engine rated at about 48 HP, or a tractor engine rated at about 52 HP. For electric motors, rated and brake horsepower can be the same.

Estimating Irrigation Costs

The amount of investment depends on the size of the farm, type and size of equipment purchased, availability of the water supply, source and type of power, and numerous other factors. Because of so much variation, each farm must be considered on the basis of its own conditions. Before buying irrigation equipment, however, be sure to determine whether such an investment will prove economically feasible.

You can determine irrigation profits only by comparing the annual costs with the expected annual benefits. Annual costs are made up of **fixed costs** and **operating costs**.

Annual benefits are usually more difficult to predict in advance, since they largely depend upon the increase in yield and future price levels. Unless the expected annual benefits exceed the annual cost by a comfortable margin, the investment is not worthwhile.

ANNUAL FIXED COSTS

You must know the initial cost of an irrigation system to compute such yearly fixed costs as depreciation, interest, taxes, and insurance. Fixed costs must be met each year whether the system is used or not. In Minnesota, initial costs usually vary from \$50 to \$150 per acre. However, the initial cost per acre may be greater for small systems covering less than 10 acres, or if the equipment is not used to its fullest extent. As the irrigated acreage is increased the cost per acre is usually reduced.

If possible, obtain an estimate of the cost of the irrigation equipment from a reputable local dealer. To make such an estimate the dealer should visit your farm to familiarize himself with the soil

characteristics, cropping patterns, water supply, and other conditions affecting the design and operation of the system. He should also discuss any possible choices or alternate layout designs with you so that the most suitable arrangement can be selected.

For comparison purposes, it is usually desirable to obtain cost estimates from more than one dealer. When this is done, however, use a little caution if you find any one of the estimates substantially lower than all the others. In such cases, check the lower estimate thoroughly to be certain it is of suitable quality and adequate in design.

Yearly depreciation costs are found by dividing the total initial cost by the expected life of the equipment. Sprinkler irrigation equipment is usually assumed to have a life expectancy of 15 years. On this basis, a system costing \$3,000 will depreciate 1/15 of its initial value, or \$200 each year.

Interest charges must also be included in computing your annual irrigation costs since money must either be borrowed, or withdrawn from an account earning a given rate, to meet your initial investment cost. The amount of capital investment against which interest must be charged is reduced each year because the equipment is depreciating in value as it becomes older. For preliminary cost estimates the annual interest is usually figured to be 6 percent of the average value of the equipment. Thus, for a system costing \$3,000 new the average value is \$1,500 and the interest cost is $\$1,500 \times .06$ or \$90.00 per year.

Annual taxes and insurance costs vary from one area to another, but are

usually assumed to be about 1 per cent of the initial cost of the equipment.

OPERATING COSTS

The annual cost of operating an irrigation system will depend on such items as cost of fuel or electricity, lubrication, maintenance, and labor.

Fuel consumption can be determined if the manufacturer's fuel consumption curve for the engine used is available. Otherwise, use table 3. The values shown in table 3 are only approximate, however, as they are based on average mechanical and operating conditions. Engines with higher compression ratios consume less fuel. Also, engines in poor repair may exceed the rates given.

For example, suppose a water-cooled gasoline engine is used to operate an irrigation pump which requires 30 brake horsepower. The rate of fuel consumption for this engine is shown by table 3 to be about 1/10 gallon per hour for each brake horsepower, or 3 gallons per hour.

The rate of fuel consumption for natural gas engines is found to vary with the b.t.u. content of the gas. About 10 cubic feet of gas are required for each horsepower-hour of operation. The cost of electrical energy depends on the size of the motor, power consumed, and the rate schedule. Such costs in Minnesota will usually vary from 1½ to 3 cents per kilowatt-hour.

Lubricating costs are negligible for electrically driven plants. The cost of lubricating oil for internal combustion engines is usually estimated to be about 2 cents per hour of operation.

Table 3

Type of engine	Fuel consumed per brake horsepower-hour	Annual repair cost in percent of fuel cost
Gasoline (air-cooled) ...	1/8 gal.	10 %
Gasoline (water-cooled)	1/10	10
Propane	1/7	7
High Speed Diesel	1/12	25

Repair costs are confined largely to the power unit and are difficult to estimate since they tend to increase with the age of the equipment and will also depend on the type of power used. Repair costs are higher for engines than for electric motors. Since the need for repairs is related to the total hours of operation, such costs are generally figured as a percentage of the total fuel cost. Approximate repair and maintenance costs for gasoline, Diesel, and propane engines are given in the last column of table 3. Repair costs for electric motors are often estimated at 5 percent of the annual cost of electricity.

Labor costs vary widely with the number of irrigations, crops irrigated, type of soil, and size and type of system. An average handmove sprinkler irrigation system is estimated to have a total labor requirement of about 1 man-hour per irrigation per acre. Mechanically moved systems have smaller labor requirements.

TOTAL ANNUAL IRRIGATION COST

The total annual cost of irrigation is found by adding all the fixed and operating costs for the year. To illustrate how the cost analysis of an irrigation system should be made, assume the following conditions exist on a given 30-acre farm:

Initial cost of equipment (dealer's estimate)	\$3,200
Expected life of equipment	15 yrs.
Irrigations required per year	3
Brake horsepower requirement (water-cooled gasoline engine) ..	18 HP
Total hours of operation per year ..	300
Gasoline cost, per gallon	\$0.20
Labor cost, per man-hour	\$1.50

Cost analysis:

Fixed Costs	
Depreciation (\$3,200 ÷ 15)	\$213.33
Interest (\$1,600 × 6%)	96.00
Taxes and Insurance (\$3,200 × 1%)	32.00
Total Annual Fixed Cost	\$341.33

Operating Costs

Fuel (18 h.p. x 1/10 gal. x 300 hrs. x \$.20)	\$108.00
Lubrication (300 hrs. x \$.02).....	6.00
Repair and maintenance (\$108.00 x 10%).....	10.80
Labor (30 acres x 1 man-hour x 3 irrigations x \$1.50)	135.00

Total Operating Cost	\$259.80
Total Annual Cost	\$601.13
Total Cost per Acre (\$601.13 ÷ 30 acres).....	\$20.04

It is evident in the above example that the annual fixed costs depend en-

tirely upon the amount of your initial investment. In attempting to reduce these costs, it is not always a sound policy to purchase smaller equipment or equipment of lower quality. To pump a given volume of water, a small pumping plant must operate over a longer period of time than would be required for a larger plant. While your fixed costs are being reduced by the use of the smaller plant, your operating costs may be increasing in greater proportion. The combination of fixed and operating costs resulting in the lower overall annual cost should be the one you select.