Saving Energy in Irrigation

Saving Energy in Irrigation was developed and produced for the New Mexico Energy, Minerals and Natural Resources Department (EMNRD) by the Water Resources Research Institute (WRRI) at New Mexico State University. This booklet was published for the Energy Conservation and Management Division of EMNRD by WRRI under EMNRD Joint Powers Agreement No. 76-521.34-124.

Garrey Carruthers, Governor
Anita Lockwood, Secretary
Robert Evetts, Deputy Secretary
Walter Smith, Division Director
Dianne Caron, Bureau Chief

Saving Energy in Irrigation was compiled by Leslie Blair of WRRI. Production by Jim Wood and Richard W. Cole, Director, New Mexico Research and Development Institute Communications Office at the University of New Mexico (UNM). Printed by UNM Printing Services. Cover art by Peter Hurd was provided courtesy of the Roswell Museum and Art Center, Roswell, New Mexico.

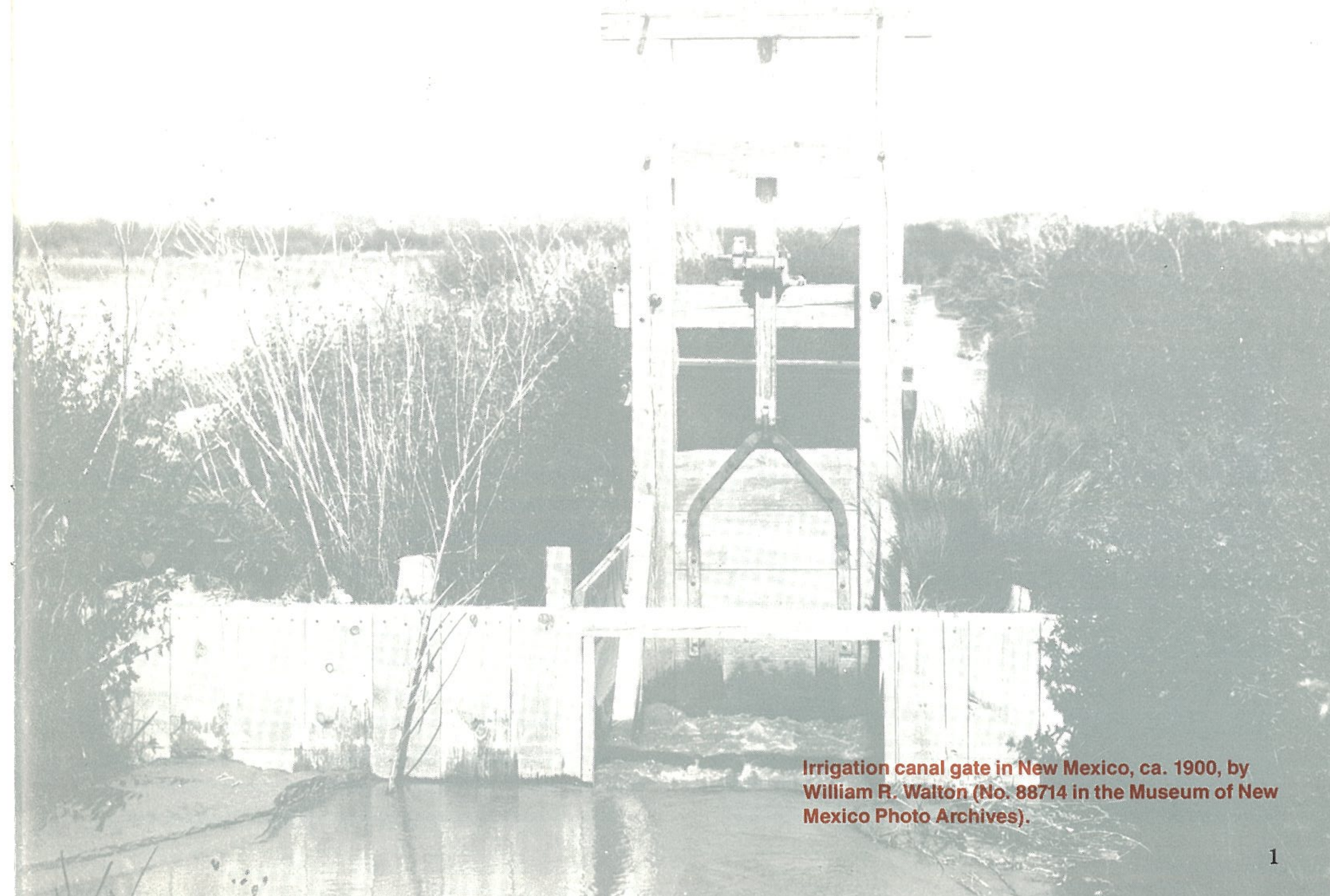
Cover:

Peter Hurd, "Dust Haze"
Watercolor, 1953, 21-1/4" x 27 1/4"

Gift of Mr. and Mrs. Donald Winston and Mr. and Mrs. Frederick Winston, Collection of the Roswell Museum and Art Center, Roswell, New Mexico.

Contents

Saving energy with your irrigation system can slash your operating costs. And you don't have to sacrifice productivity. This booklet suggests ways to achieve worthwhile economies in energy use without handicapping your farm in any way.



Irrigation canal gate in New Mexico, ca. 1900, by William R. Walton (No. 88714 in the Museum of New Mexico Photo Archives).

Irrigation and Energy Use

Improving the efficiency of your irrigation system can reduce your operating costs by saving two valuable resources: energy and water. Irrigated agriculture is one of New Mexico's largest industries. It represents over 90 percent of the water used in New Mexico. The industry is a major energy consumer as well. New Mexico State University agricultural economists estimate irrigation costs amount to 30 percent or more of an average agricultural producer's production costs.

Energy costs are a critical problem for producers who must pump ground water to meet their irrigation needs. In southwestern New Mexico, for example, over 50,000 acres of irrigated cropland have been retired since 1974 as a result of higher energy costs. As the region's ground water has been depleted, energy consumption also has risen because it takes more energy to pump the water to the surface from deeper depths.

USING TOO MUCH WATER

☐ Don't over irrigate.

☐ Apply irrigation water uniformly.

☐ Match water applications to your crop and soil. Approximate annual water requirements for common New Mexico crops are shown in Table 1. Requirements will vary according to location and climate. For more precise information, consult your local farm advisor or irrigation consultant.

☐ Crops in sandy soil do not need more water per application than those in heavier soils. They need the same sized applications applied more often.

DON'T WASTE IRRIGATION WATER

☐ Use gated pipe instead of header ditches.

☐ Prevent weed growth and seepage on long irrigation ditches. Try lining canal with plastic.

☐ Fix leaks in valves, water pipes, standpipes and the like.

☐ Control rodent activity in surface-irrigated fields.

☐ If timing of the irrigation cycle permits, irrigate at night.

☐ If you have runoff from a sprinkled field, something is wrong with the sprinkler system. Investigate and correct.

ENGINEERED IRRIGATION SYSTEMS

☐ To keep irrigation costs as low as possible, the entire irrigation system needs to be engineered for maximum efficiency: drilling the well, selecting the pump, designing the pipeline, designing final delivery services and operating the system.

☐ An irrigation well is an important basic resource. Expert drilling, perforating, selecting gravel pack material and developing can make the difference between an inexpensive source of water and an expensive one.

☐ The proper pump will match the water needs of the irrigation system to the capability of the well and the capacity of the delivery system.

☐ Take care in selecting the water distribution system Excessive friction in a pipeline that is too small for the flow it is carrying can cost more in extra energy than is saved by installing smaller pipe.

☐ Be sure to consider energy requirements as well as labor, capital and maintenance costs when choosing the final delivery system. No single system is ideal for all crops or locations.

☐ Consider updating your irrigation system if it is obsolete. You may find that savings in energy costs will more than pay for the improvements.

TABLE 1

Annual Water Requirements of Crops

CROP	ACRE-FEET
Alfalfa	3 to 4¼
Barley	drylands to 1
Beans	1¼to 1¾
Beets	2 to 3
Chile Peppers	1½ to 2
Corn	1 to 2
Cotton	3 to 3½
Grapes	2½ to 3½
Grain, Sorghums	1½ to 2
Lettuce	1
Onions	1½
Orchard, Fruit	2 to 3½
Peanuts	1
Pecans	3 to 4
Permanent Pasture	3 to 4½
Potatoes	2¾ to 3 ½
Tomatoes	2 to 3
Wheat	drylands to 2

MECHANICAL AIDS TO BETTER IRRIGATION

Use soil augers, evaporation pans, tensiometers and gypsum blocks or other moisture meters. These can be of great help in determining when and how much water to apply.

A hole bored with a soil auger can tell you how far down the moisture goes. Evaporation pans show how many inches of water a day are being lost by evaporation. You can use a tensiometer with any method of irrigation to trigger automatic controls. Inexpensive gypsum blocks work best with less water sensitive crops such as cotton, grain sorghum and other small grains. All of these devices must be properly located and maintained, and are not applicable to all situations.

LOW PRESSURE VS. HIGH PRESSURE SPRINKLERS

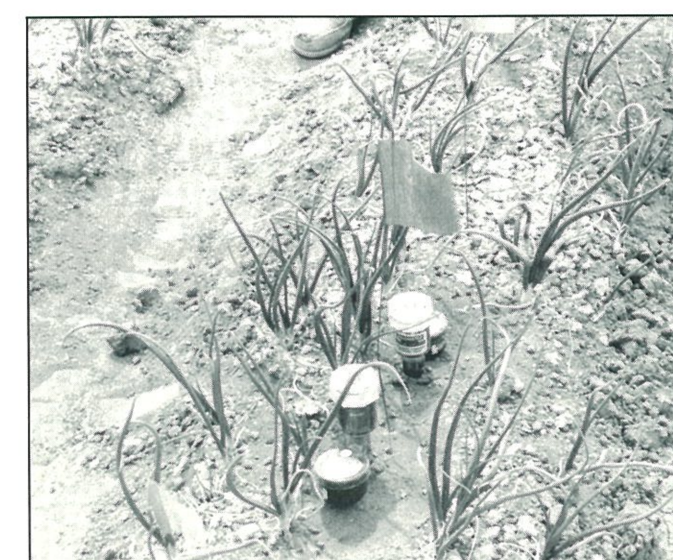
See whether you can use low-pressure rather than high-pressure sprinklers. Several new systems of the "continuous move" type have been developed. In comparison with conventional high pressure systems, low-pressure nozzles can cut energy consumption by 30 percent or more.

SOFTWARE AVAILABLE FOR IRRIGATION SYSTEM ANALYSIS

Producers can get help making decisions about irrigation systems using computer programs. One program is designed for pumping plant and irrigation system economics; the other for surface irrigation design and evaluation.

The programs can tell producers such things as how long it takes to pay back an investment based on energy and water savings. The software was developed for the New Mexico Energy, Minerals and Natural Resources Department by the Civil, Agricultural and Geological Engineering Department at New Mexico State University.

Tensiometers measure how much moisture is in the soil on this New Mexico farm. The instruments can be installed at six to 72 inch depths. (Photo by New Mexico Energy, Minerals and Natural Resources Department)



Those wanting more information on the software may contact Dr. Al Blair, Civil, Agricultural and Geological Engineering Department, New Mexico State University, P.O. Box 30001, Dept. 3CE, Las Cruces, NM 88003, (505) 646-6103.

RECYCLE IRRIGATION WATER

Re- use water. If you have runoff or ponding that you cannot correct any other way, install a re-use pump and reservoir to return water to the irrigation system.

SURFACE IRRIGATION VS. SPRINKLERS

Consider using surface irrigation rather than sprinklers on flat lands. Surface irrigation eliminates the power consumption of the booster pump, and a properly engineered and managed system can be as efficient as sprinkler irrigation.

SURGE IRRIGATION

Use a new furrow watering technique—surge irrigation—if your soil takes in too much water at the top end of the field and loses it to deep percolation while the water advances toward the end of the field. The equipment investment is relatively small, about $1,400. Recent field tests in New Mexico indicate this system can pay for itself in energy savings and increased crop yields in one growing season.

Surge irrigation is a relatively new concept in furrow watering. It involves turning the irrigation flow on and off for set lengths of time rather than allowing it to continuously flood from one end of the field to the other. The system is automated and already is commercially available.

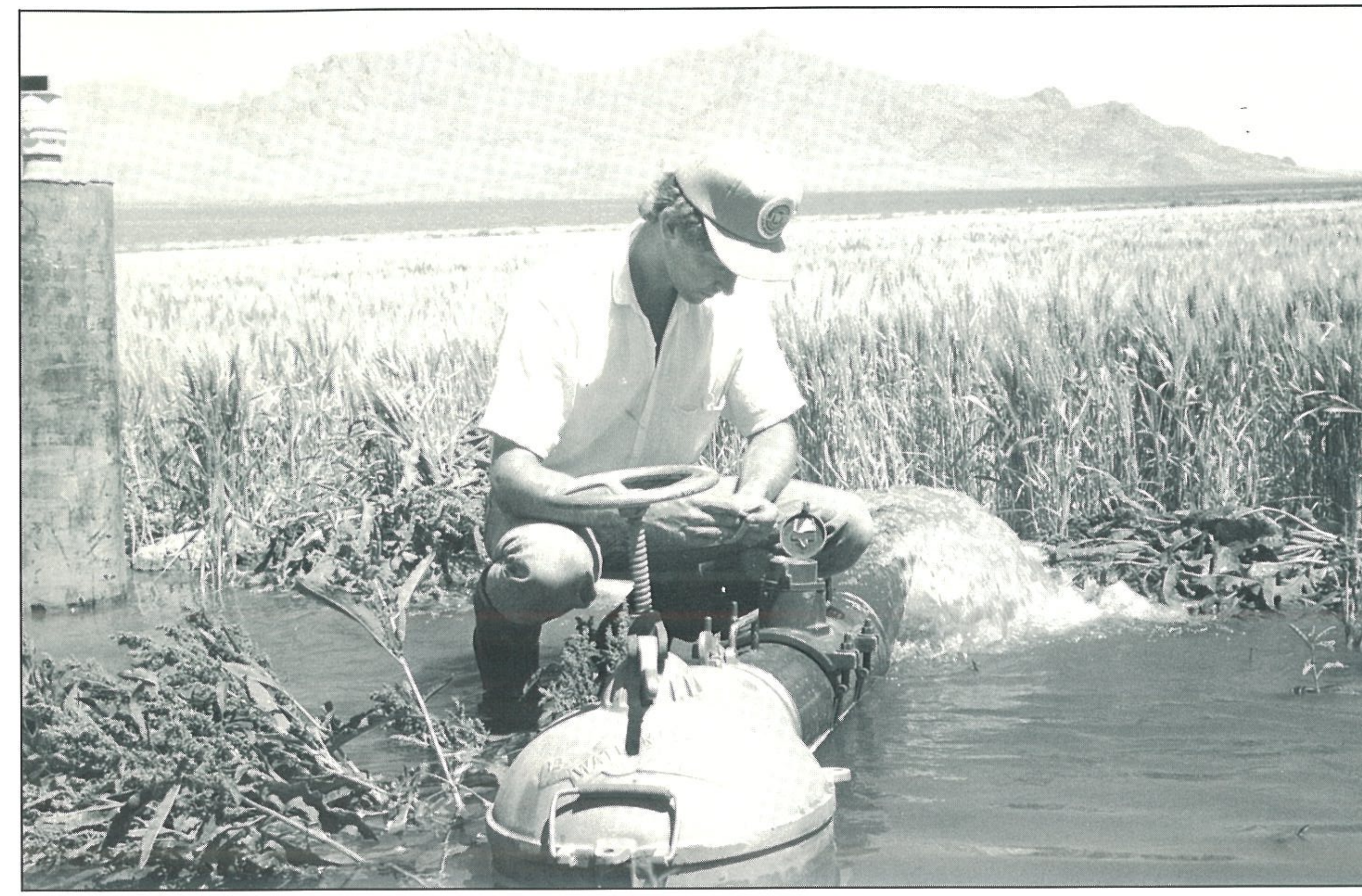
If properly used, surge irrigation uses less water to furrow irrigate the same number and length of rows. Field tests in southern New Mexico and West Texas indicate that it can reduce water use by as much as 50 percent. It reduces tailwater runoff and deep percolation losses.

EDUCATIONAL VIDEOS AVAILABLE

Two irrigation efficiency educational programs are available on 1/2-inch videocassette. The two videos are titled *Water and Energy: When Conservation is the Only Choice* and *Working Toward Irrigation Efficiency.*

The programs were filmed on New Mexico farms to promote irrigation efficiency techniques. The videos were prepared for the New Mexico Energy, Minerals and Natural Resources Department by the Water Resources Research Institute at New Mexico State University.

The videos are available free- of-charge for a 10-day loan by writing the Water Resources Research Institute, Box 30001 Department 3167, Las Cruces, NM 88003, (505) 646- 4337.



An irrigation pump is audited by James Head, an engineer with New Mexico State University, at a well on the James Koenig farm near Deming in southwestern New Mexico. (Photo by New Mexico Water Resources Research Institute)

Types of Irrigation Systems

SURFACE IRRIGATION SYSTEMS

Surface irrigation systems comprise approximately 74 percent of the irrigation systems in New Mexico, and include furrow, flood and border irrigation systems. Although these systems have sometimes come under attack for being inefficient, tests have indicated that well-managed and well- designed surface systems can be as efficient as sprinkler and approaches drip irrigation efficiency.

Surface irrigation systems have many advantages. They:

- ☐ Can be tailored to accommodate a wide range of stream sizes and still maintain a high water application efficiency
- ☐ Are flexible enough to meet emergencies in case of extreme climatic conditions that cause prolonged periods of high water use by crops
- ☐ Are usually less expensive to install and operate when compared to other irrigation methods
- ☐ Eliminate the power consumption of a booster pump

During flood or furrow irrigation, the irrigation continues until the amount of water has soaked into the soil. This usually means that soil at the upper end of the field becomes more saturated and there is generally runoff or tailwater at the lower end of the field while the center of the field is unevenly watered. When using unlined ditches and siphon tubes for conventional surface irrigation, evaporation and percolation can be as high as 40 percent. Easy ways to conserve water include lining the ditches with concrete or, if that is cost prohibitive, with plastic.

By lining ditches, you can

- ☐ Decrease conveyance and seepage losses
- ☐ Prevent weed growth
- ☐ Reduce drainage problems
- ☐ Increase capacity to convey water

☐ Prevent damage by gophers which contributes to seepage losses

Excess ditch seepage can waterlog fields and increase the soil's salt and alkali content. Weeds growing along the banks of ditches are not only a source of weed infestation to cropland, but contribute to water losses through evaporation and consumption.

Also using gated pipe instead of header ditches can greatly improve efficiency. Gated pipe is aluminum or plastic pipe that has individual openings or "gates" on its side for each furrow.

Recycling tailwater can help prevent water loss, thereby helping producers attain relatively high application efficiency. However, installation of the water recovery system and pumping costs to recirculate the water add to the cost of the irrigation.

Furrow Irrigation

In furrow irrigation, the pumping cost per unit of water is lower than for sprinkler or drip methods since the pump must produce only enough head to transport water to the high point of the field.

There are seven factors affecting the amount of water absorbed in the soil, the uniformity of water absorption along the furrow, and water losses through runoff and percolation beyond the crop root zone. Producers should consider all of these when designing a furrow irrigation system:

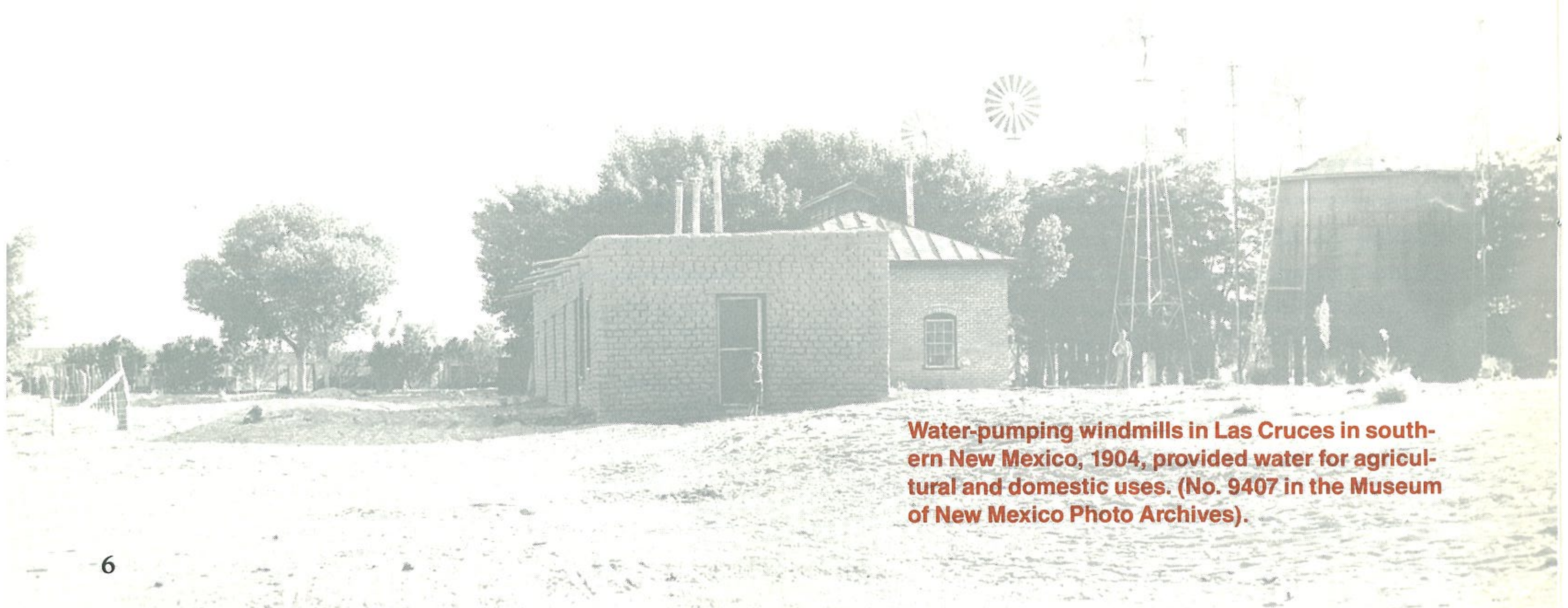
☐ Length of run
☐ Slope of furrow
☐ Soil's water intake rate
☐ Furrow shape
☐ Furrow roughness
☐ Furrow stream size
☐ Total application time

With conventional furrow irrigation, water losses from evaporation or deep percolation can be as high as 40 percent. With open ditches and siphon tubes, there is greater likelihood that the upper and lower portions of the field will be over-irrigated while the center is unevenly watered. Use of surface or underground pipe to transport water to the field and the use of a surge flow system can cut water losses at least 50 percent.

Surge Flow Irrigation

Surge flow irrigation, which is the intermittent application of irrigation water to furrows, was developed to overcome some of the problems associated with furrow irrigation, such as tailwater and deep percolation below the root zone. With proper management, a surge flow system can reduce labor needs too. It also permits light irrigation application of as little as two to three inches of water, giving producers some of the flexibility of sprinkler systems. Surge flow does not reduce the amount of water needed by a crop, but it may improve irrigation efficiency and allow a field to be covered more quickly.

During surge flow irrigation, water is delivered to a field in controlled pulses from a main water supply by surge valves. The valves permit irrigation of one set of furrows, then irrigation of a second set of furrows. The surges are patterned so the first surge of water to the first set of furrows soaks into the soil closest to the valve. Similarly, the second set of furrows is



Water-pumping windmills in Las Cruces in southern New Mexico, 1904, provided water for agricultural and domestic uses. (No. 9407 in the Museum of New Mexico Photo Archives).

irrigated. The next surge carries water over the wetted soil of the first set of furrows to a dry section. The surges continue until water reaches the end of the field for both sets of furrows.

During subsequent surges, the water moves more quickly over previously watered ground because the soil's water intake rate has been reduced. The cycling time and furrow stream size depends on the length of the field, furrow size and shape, soil infiltration characteristics and surface debris. For coarse soils with long and wide furrows and abundant crop residues, the stream size should be large and the cycle time great, compared to fine-textured soils with short, small, clean furrows.

Surge valves have been in widespread use in eastern New Mexico since 1981. In 1988 approximately 900 valves were in use in Curry, Quay and Roosevelt counties. Recent demonstrations in Luna and Hidalgo counties in southwestern New Mexico by the U. S. Soil Conservation Service indicate the potential savings with surge valves is $20 to $40 per acre per season, depending on soil conditions, crop, and system management. The valves have the potential to pay for themselves in one season in energy savings and improved crop quality.

Flood Irrigation

Flood irrigation can be uncontrolled from farm ditches or controlled as in border strip or level basin flooding.

For border strip flooding, the field to be irrigated is divided into wide, shallow channels, or strips, by constructing border dikes. Water flows from the head ditch down the strips. When the land is graded properly, this method of irrigation can be very efficient. Crops can be planted on the dikes if they are low and rounded on the fields with low gradients. In this way, no land is taken out of production.

When using the level basin method of flood irrigation, a field area is completely surrounded by a dike. The entire amount of water needed for the irrigation is applied quickly and ponded in the basin until absorbed. If graded properly and built to the right dimensions for soil conditions and stream size available, level basin flooding results in high water application efficiencies and uniform distribution of water.

SPRINKLER SYSTEMS

Sprinkler systems account for approximately 26 percent of the irrigation systems in New Mexico. They are more costly to install than surface irrigation systems, but higher water application efficiency can normally be obtained by using sprinkler systems. Other reasons why the systems may be desired over surface irrigation include:

☐ The soil may be too porous for good distribution by surface irrigation

Bill Speir prepares a laser leveling system for use on a field in southern New Mexico. A laser-leveled field can reduce water consumption by as much as 20 percent by insuring uniform distribution of water. (Photo by New Mexico Water Resources Research Institute)

☐ The topography of shallow top soils may prevent proper leveling for surface irrigation methods
☐ The land has steep slopes and soil that erodes easily
☐ The irrigation stream may be too small to distribute water efficiently by surface irrigation
☐ The land needs to be brought into top production quickly, and sprinkler systems can be designed and installed quickly.

Other advantages of sprinkler irrigation include easier measurement of water applied with sprinkler than surface methods and frequent and small applications of water can be applied when using sprinkler systems.

There are drawbacks to sprinkler systems, however.

- ☐ Wind can cause uneven distribution of water
- ☐ Water must be clean, with no sand, debris, or large amounts of dissolved salts
- ☐ Energy requirements can be high for pressurizing
- ☐ Fine-textured soils with slow intake rates are hard to irrigate with sprinkler systems because of high evaporation during the low rate of application

Center Pivot Systems

Center pivot irrigation systems are self- propelled machines which have decreased the labor associated with sprinkler irrigation. The system moves in a circular path around a pivot point, driven by an electric or hydraulic motor. It has a high initial cost, but is the most efficient of sprinkler systems, especially when it is a Low Energy Precision Application (LEPA) system.

Field tests on the High Plains area of Texas indicated center pivots improve irrigation efficiency to irrigate 20-25 percent more acreage than can be irrigated using a furrow irrigation system with the same amount of water. These tests also indicated a reduced annual irrigation time per acre with the center pivot units, from 16-17 hours per acre with furrow irrigation to 12-13 hours with a center pivot system.

One of the major problems with the center pivot system is runoff, especially for clay soils. By using furrow diking and farming in a circular pattern, runoff can be decreased. Furrow dikes are made using special equipment which mounds soil in the furrow to create a small basin. Water collects in the basin until there is time for it to soak in the basin, eliminating runoff.

The Low Energy Precision Application System

Released in 1983, the LEPA center pivot system places water at low pressure only 8- 15 inches above the soil surface and incorporates furrow diking and circular farming as integral to the system. Because the system applies water over a smaller soil surface than spray nozzles, it lessens evaporation. Circular farming helps hold water in the furrow. Some producers have resisted using furrow dikes, however, because they must be made using special equipment and then later removed. In cases where furrow diking isn't used with LEPA systems, then ripping and chiseling can be used to control runoff. LEPA systems may have only a 2-3 percent application loss, compared to 20-25 percent loss from impact sprinklers and low pressure spray nozzles. Some producers in the High Plains area of New Mexico and Texas, where LEPA systems are more popular, estimate their LEPA systems are 98 percent efficient. Recent studies by the University of California at Davis indicate LEPA efficiencies on the order of 80-90 percent.

DRIP IRRIGATION SYSTEMS

Drip irrigation systems account for less than one percent of the systems used by New Mexico producers. One reason for this is the high cost involved in installing a drip system and the extensive management necessary for the system, although such systems can be highly efficient. Because of the high installation costs, drip systems are found mostly in large orchards and vineyards where the tubes and emitters can be left in place. They can also be economically feasible for high-value vegetable crops.

Installing a drip system doesn't guarantee water savings. Like other systems, drip requires good management to achieve water use efficiency. There will be some savings due to a reduction in evaporation and certain situations do provide opportunities to save water significantly. These include the following situations where the drip system:

- ☐ Takes the place of an outdated or poorly managed sprinkler or surface system
- ☐ Is installed in problem soils or steep areas where excess runoff and percolation is not recovered and reused
- ☐ Is used in fields with immature plants where the drip system takes the place of other systems that wet the entire soil surface (the drip system places water only near the plants instead of between the rows of young plants where evaporation and deep percolation will cause excessive water loss)

Because a natural water supply generally contains suspended material, filter systems ensure clean water will be sent through the drip irrigation system. Your water supply should be tested for suspended solids before the filter system is designed. Additionally, filters must be kept clean to function properly. A dirty filter can result in more hours of operation to deliver a given volume of water, meaning higher energy costs and lower irrigation efficiency.

The low flow rates and small-diameter emitters which give producers more control over the water and distribution also permit the accumulation of materials that clog the system. One way to cut down on the clogging is to use foggers, misters and spitters which will apply water to a much larger area.

When using a drip system, water and nutrient supply must be monitored because the wetted soil volume is much smaller than with other irrigation systems. This restricts the plant root systems horizontally and vertically. When drip irrigation is properly managed, the salt content of the wetted zone is low and the soil's moisture content stays high.

Irrigation canal in New Mexico by Ward Anderson (No. 58874 in the Museum of New Mexico of Photo Archives).

The laser-leveling technique uses a rotating laser beam mounted on a command post that transmits signals to a receiver mounted on the tractor's scraper, directly above the cutting blade. The laser beam controls the scraper's action and can be set to any desired grade. (Photo by New Mexico Water Resources Research Institute)

Laser-leveling improves the efficiency of an irrigation system by perfectly leveling a field which insures uniform distribution of water. This prevents overwatering and runoff. (Photo by New Mexico Resources Research Institute)

Aids for Better Irrigation Efficiency

Crops must have water for transpiration. Producers apply more water than needed for the process to allow for uneven distribution of water in a field and to leach salts from the soil. Irrigation is considered very efficient if 85-95 percent of the applied water is used by the crop.

To achieve maximum efficiency, irrigation scheduling is necessary to determine the timing and amount of irrigation water for a certain crop. An adequate water supply makes irrigation scheduling much easier since the irrigation can be scheduled so that the soil water content in the crop's root zone can be maintained at levels which promote optimal yields. However, if water supply is limited, scheduling becomes complex. Irrigation decisions will then depend on the crop's sensitivity to water deficits during different growth stages. The producer will be faced with evaluating alternative schedules and finding one which maximizes yields for his water supply. The following provides an overview of some of the aids which may help in irrigation scheduling and in achieving irrigation efficiency.

MAINTAINING AND IMPROVING SOIL STRUCTURE

Maintaining and improving the structure of irrigated soils can help crops to achieve better water use efficiency. Although there are times when hard pan or compacted soil is desirable to help control infiltration rates, generally hard pan greatly reduces the water infiltration rate and contributes to runoff and erosion. It can prevent irrigation water from reaching the lower part of the root zone and stunt plant growth since the plant's roots may not be able to penetrate the hard pan.

Annually plowing below compacted layers at different soil depths and allowing as much time as practical for soil and air to react before applying pre-plant irrigation can help maintain and improve soil structure. Producers also can reduce evaporation by minimum tillage, keeping crop residues on the soil surface. This practice often necessitates increased chemical use, however, which may have an adverse effect on water quality.

SOIL MOISTURE MONITORING

No matter what kind of irrigation system is used, producers must make the same decisions over and over: when to irrigate and how much water to apply. Soil moisture monitoring can play an important role in irrigation scheduling. It can help producers answer such questions as:

- ☐ How much water should be applied during pre-plant irrigation? Pre- plant irrigations ensure a full soil profile which helps prevent early plant moisture stress and improves a producer's chances to have high-yielding crops
- ☐ When should a crop be watered—now or next week?
- ☐ To save money, can the last watering be skipped, or will it cost more in reduced yields?

By knowing how much water is in the soil profile before you irrigate, you can calculate how much water to apply without over-irrigating or plan an irrigation before a crop is stressed. Not only can over-irrigation result in excessive water and energy use, but it can contribute to the leaching of nutrients and chemicals and accelerate erosion.

Each type of soil holds moisture differently due to its texture and structure. Table 2 illustrates the amount of water, per foot of depth, different soil types can store. There are a number of ways to monitor the moisture in soil: by feel or using devices such as soil augers, evaporation pans, gypsum blocks, tensiometers, or neutron moisture meters. It is important for producers to take regular moisture measurements and record the data to help plan for the next irrigation no matter how the moisture is measured.

TABLE 2

Available Water Storage for Different Types of Soil

Soil Type	Available Water Storage (inches per foot of depth)
Sandy (coarse)	0.5 to 1
Sandy loam	1 to 1.5
Silts and clay loams	1.5 to 2
Clays (heavy)	2 to 2.5

Source: Hohn, Charles M. "The 'Feel' Test Tells When to Irrigate." New Mexico State University Cooperative Extension Service, Guide A-11, 1986.

Chile in a surge-irrigated field in southern New Mexico is examined by Stan Bulsterbaum of the U.S. Soil Conservation Service. Studies show that a surge irrigation system can pay for itself in one growing season in energy savings and increased crop yield. (Photo by New Mexico Energy, Minerals and Natural Resources Department)

The "Feel" Method

The feel method is the simplest and cheapest way to measure moisture in soil. By squeezing a soil sample, you can estimate the amount of useful moisture in the soil by comparing the results with Table 3. With only a soil auger, you can test a crop's total root zone. By taking a sample every six inches, then averaging the percentages obtained from Table 3, you can get a fairly good idea of moisture remaining in soil.

Evaporation Pans

The evaporation pan or washtub method for scheduling irrigation is relatively inexpensive and easy to use. This method relates the amount of water evaporating from a tub in the field to the amount of water being taken from the soil by the plant. Your local Cooperative Extension Service agent can provide you with publications on using evaporation tubs to schedule irrigations.

Gypsum Blocks

The inexpensive gypsum blocks work best when used with less water sensitive crops such as cotton, grain sorghum, and other small grains. They may give inaccurate readings when soils are near field capacity, and are not suitable for use in saline soils. More accurate readings are given when soils are less wet.

The blocks are buried in the soil to a total depth of four feet, spaced about a foot apart. They have lead wires which extend above the ground surface that can be attached to stakes for easy visibility in the field. The blocks work with a resistance meter which measures resistance to an electric current. Its reading translates into soil moisture.

New blocks should be installed each growing season because the gypsum deteriorates, and the lead wires are often destroyed during farming operations.

Tensiometers

Tensiometers are probably the most commonly used device for measuring soil moisture. They are fairly inexpensive, costing around $35-$40 each and come in lengths ranging from six to seventy-two inches. They are best used when soil moisture is kept above 50 percent of field capacity, with high moisture demand crops such as corn or vegetables.

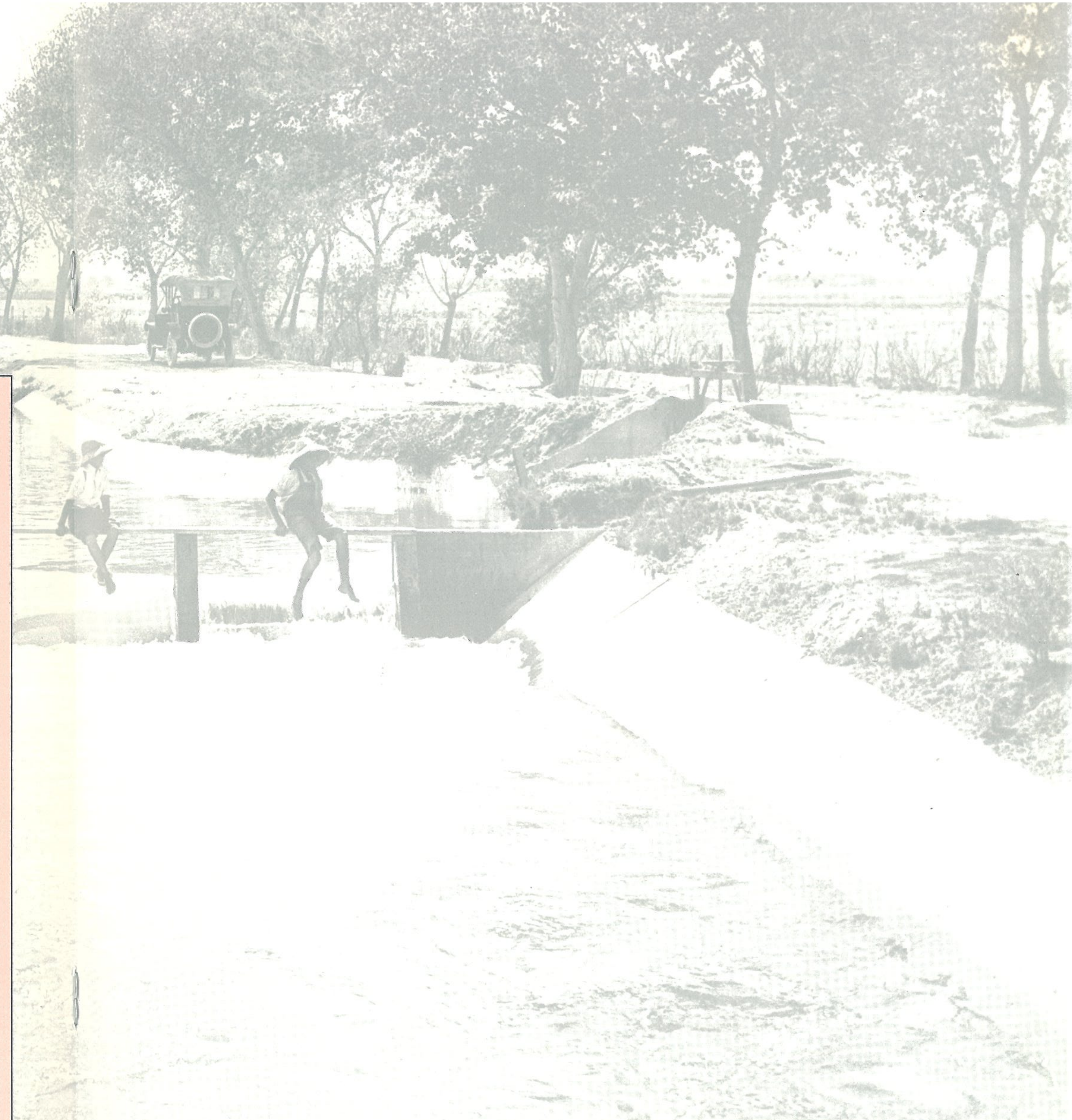
Tensiometers consist of a water-filled tube with a ceramic, porous tip and a vacuum gauge. They measure the amount of

TABLE 3

Soil Moisture Indication—The Feel Test

Degree of Moisture	Percent Useful Soil Moisture Remaining	Soil Type: Coarse	Light	Medium	Heavy-Very Heavy
Dry	0	Dry, loose, single-grained, flows through fingers	Dry, loose, flows through fingers	Powdery, dry, sometimes slightly crusted but easily breaks down into powdery conditions	Hard, baked, cracked; sometimes has loose crumbs on surface
Low	50 or less	Still appears to be dry; will not form a ball with pressure	Still appears to be dry; will not form a ball	Somewhat crumbly, but will hold together from pressure	Somewhat pliable, will ball under pressure
Fair	50 to 75	Same as coarse texture under 50 or less	Tends to ball under pressure but seldom will hold together	Forms a ball and is very pliable; sticks readily if relatively high in clay	Easily ribbons out between fingers, has a slick feeling
Excellent	75 to field capacity	Tends to stick together slightly; sometimes forms a very weak ball under pressure	Forms weak ball; breaks easily, will not stick	Forms a ball and is very pliable, sticks readily if relatively high in clay	Easily ribbons out between fingers, has a slick feeling
Ideal	At field capacity	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand	Same as coarse	Same as coarse	Same as coarse
Too wet	Above field capacity	Free water appears when soil is bounced in hand	Free water will be released with kneading	Can squeeze out free water	Puddles and free water forms on surface

Source: Hohn, Charles M. "The 'Feel' Test Tells When to Irrigate." New Mexico State University Cooperative Extension Service, Guide A 111, 1986.



Main Irrigation Canal in Carlsbad in southeastern New Mexico, ca. 1920. Built in the 1890s, the canal opened up vast areas of southeastern New Mexico for irrigated farming (No. 58889 in the Museum of New Mexico Photo Archives).

Surface irrigation system in northern New Mexico, ca., 1940. Established by the Spaniards when they settled in New Mexico in the 17th century, community-operated acequia irrigation systems continue to provide the economic backbone for northern New Mexico farming today (No. 58868 in the Museum of New Mexico Photo Archives).

soil moisture suction the plant requires to get water from the soil, working in much the same way a plant root does to get water from the soil. The tube is inserted into the soil with the ceramic tip at the depth where you want a moisture reading. The tensiometer can indicate only the average moisture of the soil it touches. As the soil dries, it sucks water out of the tensiometer through the porous tip, creating a partial vacuum inside the tensiometer that can be read on the vacuum gauge. As the soil becomes drier, its ability to withdraw water from the tensiometer increases, as does the vacuum gauge reading. After irrigation, soil suction is reduced and the vacuum force draws water back into the tensiometer.

The tensiometers' usefulness is dependent on the soil's texture. For example, in clay soils, tensiometers lose their effectiveness when soil moisture reaches 75 percent of capacity, which is before the soil is dry enough to irrigate. The clay holds more water under tension than the tensiometer can measure. But tensiometers can measure a wider range of available moisture in sandy soil.

Tensiometers should be removed from the ground before harvesting annual crops. For perennial crops, the tensiometers should be moved every two to three years because they can influence the root pattern. Also, the roots may grow enough that a new location would give a more accurate moisture reading. Tensiometers require some maintenance. They occasionally need to be refilled with water and should be tested periodically with a test pump. Each time a tensiometer is moved, the life of the ceramic tip is reduced, especially if the soil contains a lot of calcium or lime or is saline. There are now portable tensiometers which let producers spot check soil moisture at different locations. These are very sensitive, however, and require more maintenance and careful handling than permanently installed tensiometers.

Neutron Moisture Meters

Neutron moisture meters (or neutron probes as they are sometimes called) are another type of device used to monitor soil moisture. However, with their radioactive source, the meters are not deemed practical for a normal farming operation. Costing close to $4,000, they are not only expensive, but require special handling, storage and transportation procedures.

The neutron moisture meter consists of a probe which contains a source of fast neutrons, and a gauge which monitors the flux of slow neutrons scattered in the soil. The probe is set into the soil down an access tube. Fast neutrons are emitted from the probe and the soil causes the neutrons to slow and scatter. The probe becomes surrounded by a cloud of slow neutrons. If the soil is dry, the cloud of neutrons will be less dense and extend further from the probe. If wet, the cloud will be more dense, extending a shorter distance. The detector measures the density of the cloud and displays a number on the gauge which is an index of soil moisture. Readings from the meter are correlated to soil types and it measures the total water content in the soil.

Low Energy Precision Application (LEPA) systems apply water at low pressure only 8-15 inches above the soil surface. Because the system applies water over a smaller soil surface than conventional spray nozzle, it lessens evaporation. (Photo by New Mexico Water Resources Research Institute)

Low Energy Precision Application (LEPA) systems can have only a 23 percent application loss, compared to 20-25 percent loss from impact sprinklers and low pressure spray nozzles. Some farmers on High Plains area of eastern New Mexico estimate their LEPA systems are 98 percent efficient. (Photo by New Mexico Water Resources Research Institute)

INFRARED LASER GUN

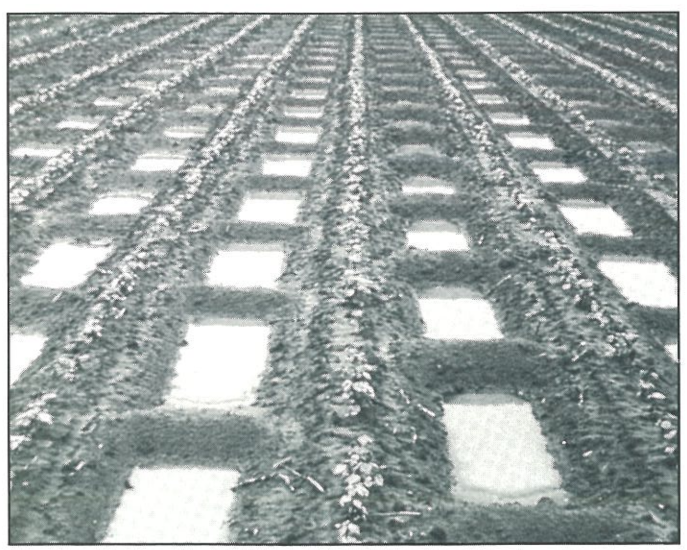
Another state-of- the-art device to help producers schedule irrigations is the infrared laser gun, used to determine a plant's stress by measuring its temperature. The laser gun enables a producer to find areas in a field that have problems such as those which dry out first, have diseases in the plants, or insect infestations. Because it often costs over $4,000, the laser gun is not cost-efficient for every producer. Whether it is cost-efficient is dependent in part on what type of crop is being raised and how many acres of the crop are under production.

LASER-LEVELING

A laser- leveled field can pay back the producer as much as 20 percent in water savings. Laser-leveling improves the efficiency of an irrigation system by perfectly leveling a field which insures uniform distribution of water. This not only prevents overwatering in some areas, but also prevents runoff.

The technique uses a rotating laser beam mounted on a command post that transmits signals to a receiver mounted on the tractor's scraper, directly above the cutting blade. The laser beam controls the scraper's action and can be set to any desired grade. The laser system takes into account outside disturbances such as temperature changes, wind, and ground vibrations from passing machines.

Other advantages of using laser-leveling is that it can move soil from cut areas to fill areas accurately and it can be used to survey a field in a short time. In the survey mode, as the scraper follows the field's contours, the ground elevations are registered on the control box inside the tractor's cab. The finished grade is calculated from the readings.



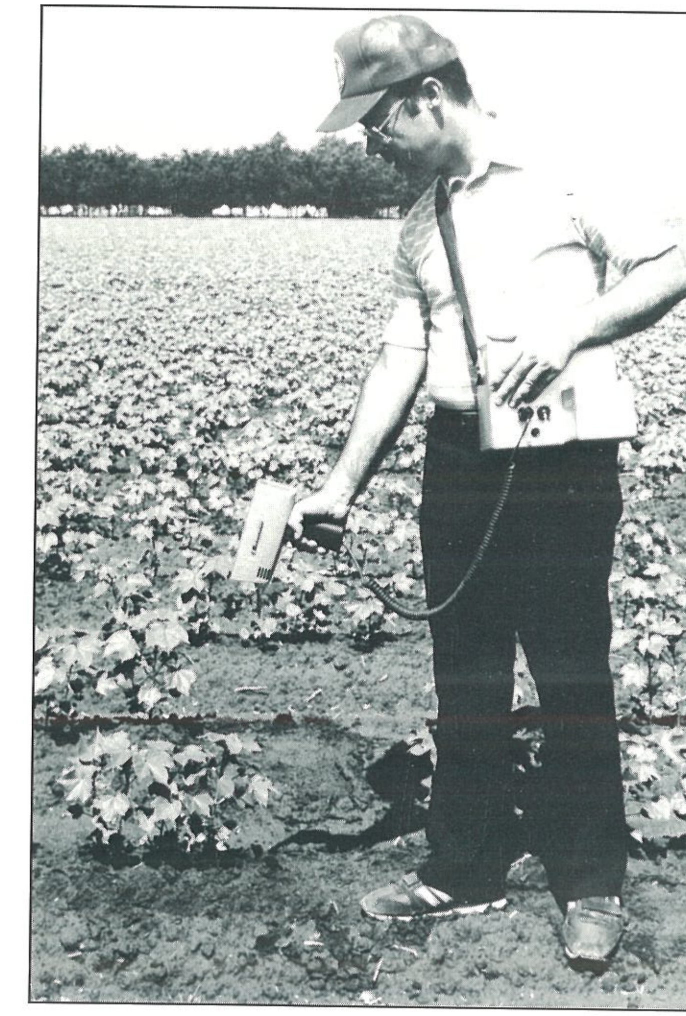
Furrow diking increases crop yields and eliminates water runoff. Furrow dikes are made using special equipment which mounds soil in the furrow to create a small basin. (Photo by New Mexico Water Resources Research Institute)

FURROW DIKES

Maximum use of rainfall can reduce the amount of ground water which a producer must pump. Although not in widespread practice, furrow dikes can be used to gather rainfall when it exceeds the soil's infiltration rate.

Two studies done in the High Plains region of Texas indicated using dike furrows could increase crop yields. These studies were done using dryland crops, but they illustrate the potential of furrow diking as a water conservation practice. During a five-year study at the Bushland Experiment Station, yields on furrow-diked acreage averaged almost 600 pounds per acre more than undiked acreage. The fields studied were cropped in a wheat-sorghum-fallow rotation. At the Texas Agricultural Experiment Station in Lubbock, dryland cotton yields on diked acreage were 25 percent over that of the undiked acreage.

As was mentioned earlier when discussing the LEPA system, furrow dikes have been met with some resistance on the part of producers because of additional work to install and remove the dikes. However, furrow diking equipment has become more compact, simple and faster operating. Additionally some producers install and remove the dikes while performing other farming operations.



The infrared gun, when aimed at a plant, measures leaf and air temperatures, humidity and sunlight. From that, it determines if it is time to irrigate. Infrared guns can be cost-effective on very large farms. (Photo by New Mexico Water Resources Research Institute)

Pumping Plant Efficiency

An electric pumping plant should have an energy use efficiency of 70 percent or more if the pump and motor are in good repair and designed to produce the quantity of water being pumped from the depth it is being lifted. By keeping tabs on fuel costs and amount pumped each month, producers can determine when a pumping plant efficiency test is necessary. Higher than normal fuel costs for the amount of water being pumped can indicate poor pump efficiency. A significant drop in the water table since the pump was installed, pumping sand, and surging or pumping air can reduce plant efficiency as will failure to select equipment to match the specific pumping conditions.

Factors which affect the fuel required to pump a given quantity of water (a gallon, an acre- inch or an acre-foot) include:

- ☐ Pumping lift or vertical distance from the water surface to the point of discharge
- ☐ Pressure required at the pump discharge to operate the irrigation system
- ☐ Efficiency of each pump component

Fuel requirements are lower when pumping lift and discharge pressures are lower. Determining overall pumping plant efficiency requires measuring pumping rate, pumping lift, fuel use and discharge pressure. Table 4 can help producers predict irrigation power cost based on the unit fuel cost for the irrigation pumping plant.

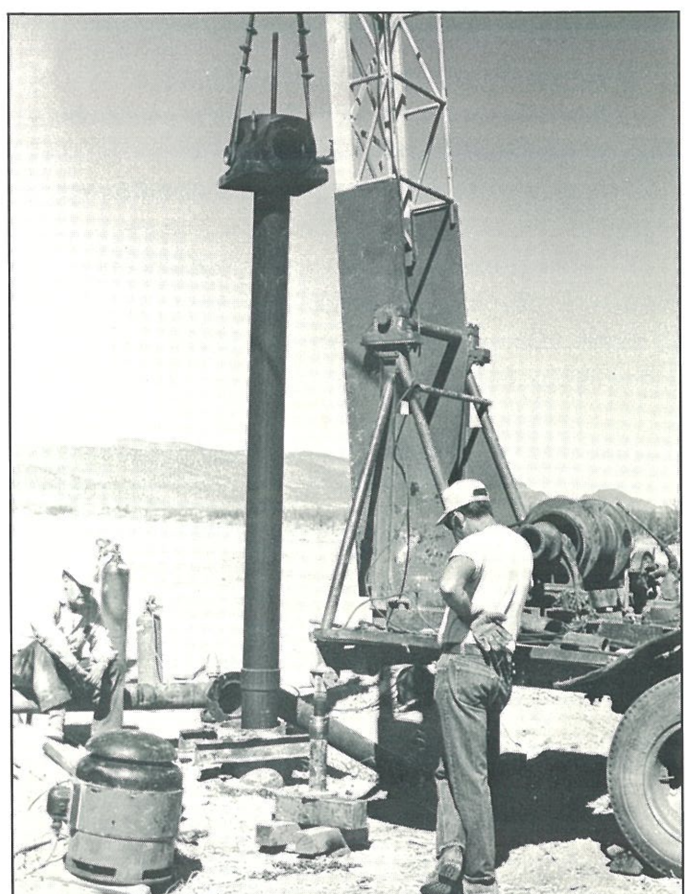
Sometimes a pump's bowls may need to be rebuilt or replaced or new impellers installed. Depending on the number of stages, bowls, and impeller size, it could cost a producer $3,000-$7,000 to bring a pump to maximum efficiency. However, he may realize a payback in one to three years. A pump that is repaired will show increases in pumping efficiency and flowrate. Not only will energy costs decrease, but there is the potential for increased crop yields.

In a recent pump repair program in Luna County, one producer reduced the energy used for his irrigation system by 26 percent after having his pump repaired. The pump's efficiency was raised from 47 percent to 82 percent and there was an increase in flow rate from 235 gallons per minute to 450 gallons per minute.

Pumping plant efficiency tests are being conducted around the state through a program funded by the New Mexico Energy, Minerals and Natural Resources Department. To find out more information, contact EMNRD at (505) 827-5900. Some of the U.S. Soil Conservation Service field offices also will conduct pumping tests.

Tables 4- 7 can help producers estimate irrigation power cost, based on the unit cost of fuel for pumping plants. Using the table for your type of pumping plant—whether electric, natural gas, diesel or propane—select the fuel type and condition of your power plant. Read down the corresponding column until your find the unit cost you pay for fuel. Read your fuel cost per horsepower-hour (HP-HR) of operation on the same line in the far right-hand column. Total hourly fuel cost can be estimated by multiplying energy cost per HP- HR by actual loaded engine horsepower.

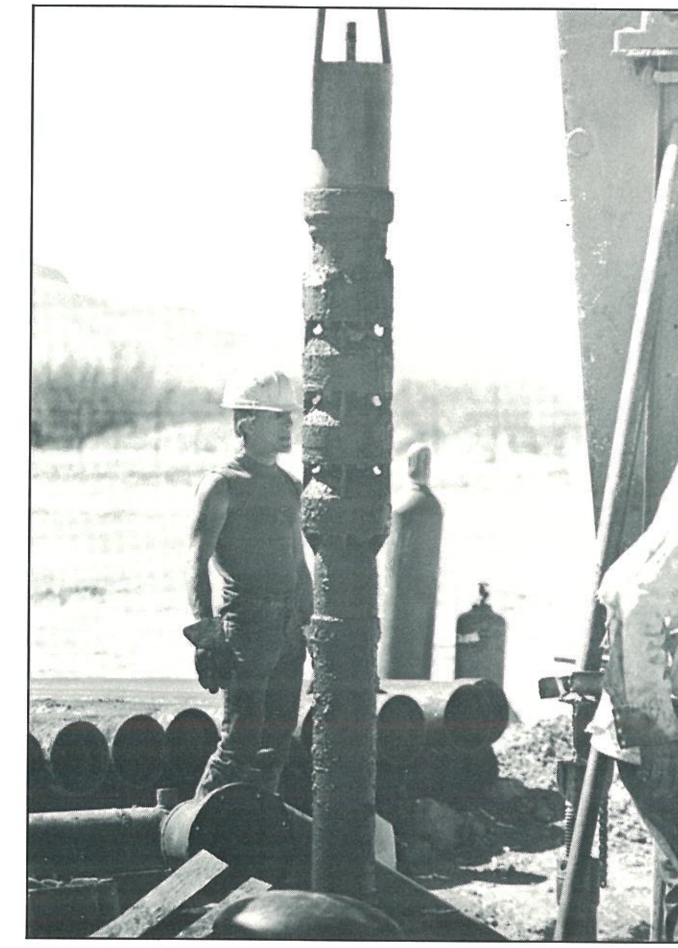
An irrigation pump is pulled for repair on a farm in southwestern New Mexico. Tests showed this repair reduced the energy used for this irrigation system by 26 percent. (Photo by New Mexico Water Resources Research Institute)



For example, if you are using a 120-horsepower electric motor, and your total electricity cost is $0.11 per Kwh, look down the column marked "Over 50 HP" on Table 4 until you find $0.11. Read across to find an energy cost of $0.091 per HP-HR in the right-hand column. Hourly electricity cost is 120 HP x $0.091/HP-HR or $10.92 per hour under full load.

The charts can be used to determine potential fuel cost savings obtainable by overhauling or replacing a worn engine. For example, if you are using a 150-horsepower natural gas engine in poor condition and if natural gas costs you $3.99 per MCF, read down the column marked "Poor" on Table 5, until you find $3.99/MCF. Read your energy cost in the right- hand column which is $0.058 per HP-HR. Compare this to a natural gas engine in good condition, by finding $3.99/MCF under the "Good" column. Reading across to the far right-hand column, you see the fuel cost is $0.041 per HP-HR for this condition. By overhauling your engine, you can estimate that you will reduce fuel costs by (.058 - .041) x 150 HP, or $2.55 per hour.

As a decision-making tool, the New Mexico State University Cooperative Extension Service offers a Pumping Cost Generator software package to estimate costs on per acre-inch, per-hour and annual bases. The program was designed to be used on an IBM-PC, PC/XT or compatible computer capable of running Lotus 1-2- 3.



A pumping plant should have an energy use efficiency of 70 percent or more if the pump and motor are in good repair. The repair on this irrigation system increased the pump's efficiency from 47 percent to 82 percent. The repair is expected to pay for itself in energy savings in less than three years. (Photo by New Mexico Water Resources Research Institute)

Where to Get Additional Information

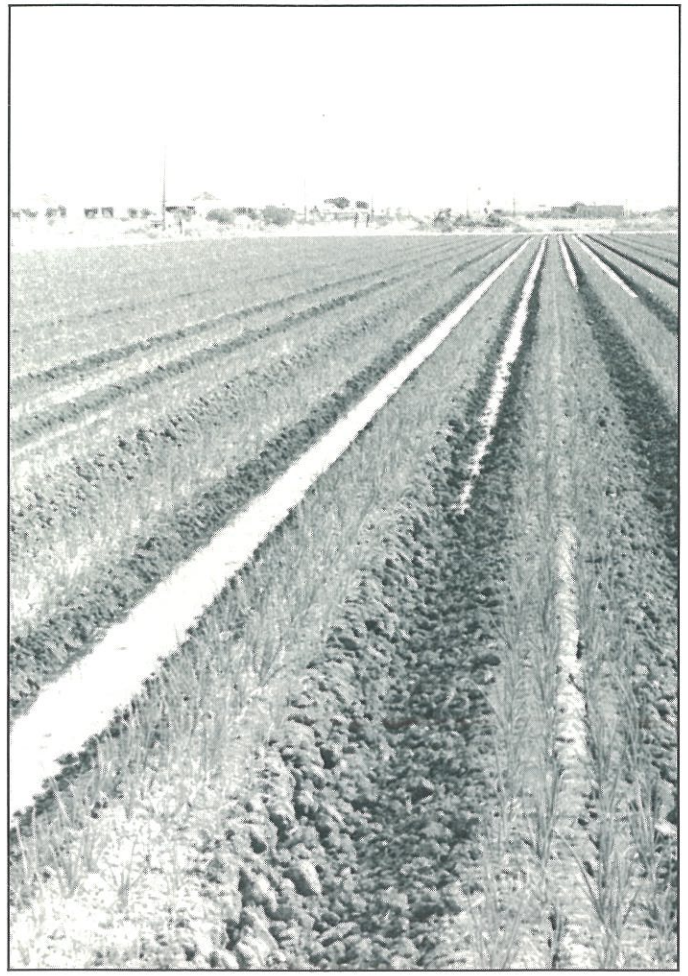
For additional information and/or technical assistance, producers may contact the following:

The New Mexico Energy, Minerals and Natural Resources Department, Energy Conservation and Management Division, 525 Camino de los Marquez, Santa Fe, NM 87503, (505) 827-5900.

Cooperative Extension Service of New Mexico State University at Box 30003, Department 3AE, Las Cruces, NM 88003, (505) 646-3547. There is also a local office in each county, offering a wide range of information and technical assistance.

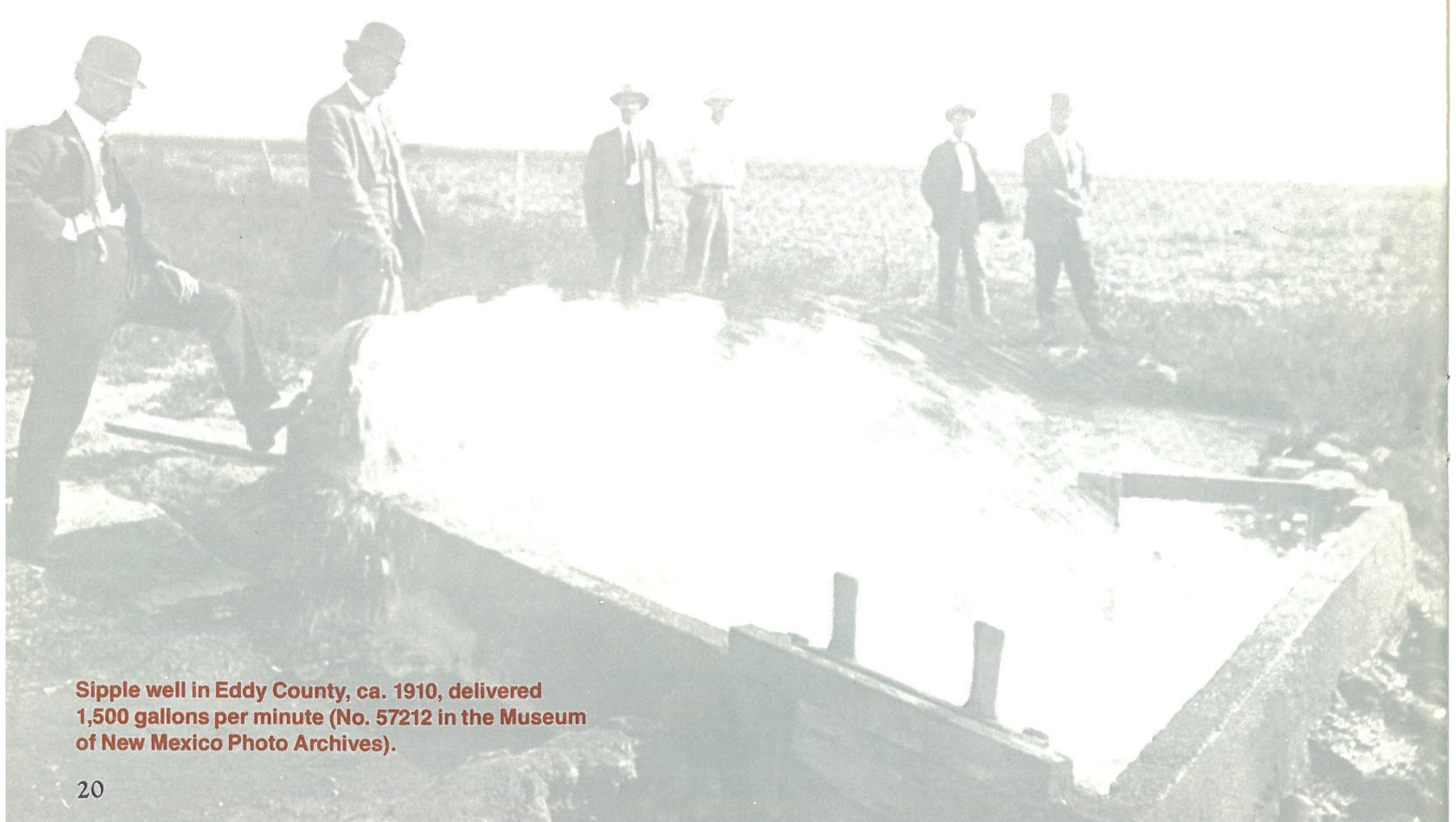
The U. S. Soil Conservation Service. The SCS has a technical field office for each major irrigated area of the state.

The agricultural engineering program of the Civil, Agricultural and Geological Engineering Department, New Mexico State University, Box 30001-Department 3CE, Las Cruces, NM 88003.



Farmers inspect a solar-powered surge irrigation valve during a field day on a farm near Deming. Surge valve irrigation helps smooth out the uneven distribution of water in furrows. (Photo by New Mexico Energy, Minerals and Natural Resources Department)

The surge valve works by sending water down the furrow in stages. As water soaks into the upper end of the furrow, that area becomes saturated and the soil partially seals. The next surge of water passes quickly over the part of the furrow to soak into the next section of furrow. (Photo by New Mexico Water Resources Research Institute)



Sipple well in Eddy County, ca. 1910, delivered 1,500 gallons per minute (No. 57212 in the Museum of New Mexico Photo Archives).

TABLE 4

Electric Motors

OVER 50 HP	UNDER 50 HP $/KW-HR	SUBMERSIBLE	$/HP-HR
0.200	0.191	0.174	0.165
0.195	0.186	0.170	0.161
0.190	0.181	0.165	0.157
0.185	0.177	0.161	0.153
0.807	0.172	0.157	0.149
0.175	0.167	0.152	0.144
0.170	0.162	0.148	0.140
0.165	0.158	0.144	0.136
0.160	0.153	0.139	0.132
0.155	0.148	0.135	0.128
0.150	0.143	0.131	0.124
0.145	0.138	0.126	0.120
0.140	0.134	0.122	0.116
0.135	0.129	0.117	0.111
0.130	0.124	0.113	0.107
0.125	0.119	0.109	0.103
0.120	0.115	0.104	0.099
0.115	0.110	0.100	0.095
0.110	0.105	0.096	0.091
0.105	0.100	0.091	0.087
0.100	0.096	0.087	0.083
0.095	0.091	0.083	0.078
0.090	0.086	0.078	0.074
0.085	0.081	0.074	0.070
0.080	0.076	0.070	0.066
0.075	0.072	0.065	0.062
0.070	0.067	0.061	0.058
0.065	0.062	0.057	0.054
0.060	0.057	0.052	0.050
0.055	0.053	0.048	0.045
0.050	0.048	0.044	0.041
0.045	0.043	0.039	0.037
0.040	0.038	0.035	0.033
0.035	0.033	0.030	0.029
0.030	0.029	0.026	0.025
0.025	0.024	0.022	0.021
0.020	0.019	0.017	0.017
0.015	0.014	0.013	0.012
0.010	0.010	0.009	0.008
0.005	0.005	0.004	0.004

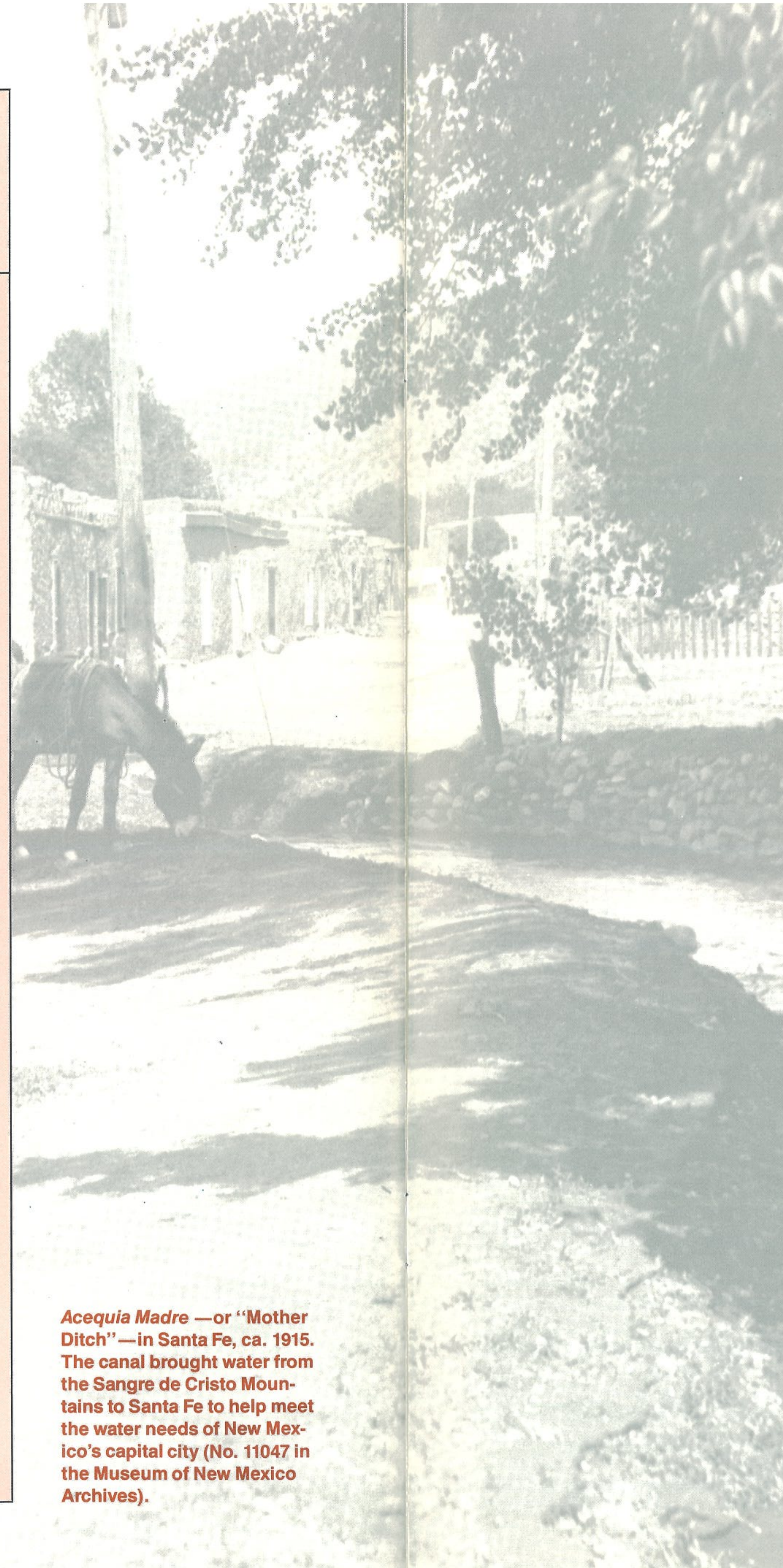
Source: Grubaugh, Elston and George Abernathy. "Power Costs for Irrigation Pumping." New Mexico State University Cooperative Extension Service, Guide M-201, 1986.

TABLE 5

Natural Gas Engines

GOOD	FAIR $/MCF	POOR	$/HP-HR
15.960	13.680	11.400	0.165
15.151	13.338	11.115	0.161
15.162	12.996	10.830	0.157
14.763	12.654	10.545	0.153
14.364	12.312	10.260	0.149
13.965	11.970	9.750	0.144
13.566	11.628	9.690	0.140
13.167	11.286	9.405	0.136
12.768	10.944	9.120	0.132
12.369	10.602	8.835	0.128
11.970	10.260	8.550	0.124
11.571	9.918	8.265	0.120
11.172	9.576	7.980	0.116
10.773	9.234	7.695	0.111
10.374	8.892	7.410	0.107
9.975	8.550	7.125	0.103
9.576	8.208	6.840	0.099
9.177	7.866	6.555	0.095
8.778	7.524	6.270	0.091
8.379	7.182	5.985	0.087
7.980	6.840	5.700	0.083
7.581	6.498	5.415	0.078
7.182	6.156	5.130	0.074
6.783	5.814	4.845	0.070
6.384	5.472	4.560	0.066
5.985	5.130	4.275	0.062
5.586	4.788	3.990	0.058
5.187	4.446	3.705	0.054
4.788	4.104	3.420	0.050
4.389	3.762	3.135	0.045
3.990	3.420	2.850	0.041
3.591	3.078	2.565	0.037
3.192	2.736	2.280	0.033
2.793	2.394	1.995	0.029
2.394	2.052	1.710	0.025
1.995	1.710	1.425	0.021
1.596	1.368	1.140	0.017
1.197	1.026	0.855	0.012
0.798	0.684	0.570	0.008
0.399	0.342	0.285	0.004

Source: Grubaugh, Elston and George Abernathy. "Power Costs for Irrigation Pumping." New Mexico State University Cooperative Extension Service, Guide M-201, 1986.



Acequia Madre —or "Mother Ditch"—in Santa Fe, ca. 1915. The canal brought water from the Sangre de Cristo Mountains to Santa Fe to help meet the water needs of New Mexico's capital city (No. 11047 in the Museum of New Mexico Archives).

TABLE 6

Diesel Engines

SUPER CHARGED	GOOD $/GAL	FAIR	$/HP-HR
2.690	2.610	2.270	0.165
2.623	2.545	2.213	0.161
2.556	2.479	2.156	0.157
2.488	2.414	2.100	0.153
2.421	2.349	2.043	0.149
2.354	2.284	1.986	0.144
2.287	2.219	1.930	0.140
2.219	2.153	1.873	0.136
2.152	2.088	1.816	0.132
2.085	2.023	1.759	0.128
2.017	1.958	1.703	0.124
1.950	1.892	1.646	0.120
1.883	1.827	1.589	0.116
1.816	1.762	1.532	0.111
1.749	1.696	1.475	0.107
1.681	1.631	1.419	0.103
1.614	1.566	1.362	0.099
1.547	1.501	1.305	0.095
1.480	1.435	1.249	0.091
1.412	1.370	1.192	0.087
1.345	1.305	1.135	0.083
1.278	1.240	1.078	0.078
1.211	1.174	1.022	0.074
1.143	1.109	0.965	0.070
1.076	1.044	0.908	0.066
1.009	0.979	0.851	0.062
0.942	0.913	0.795	0.058
0.874	0.848	0.738	0.054
0.807	0.783	0.681	0.050
0.740	0.718	0.624	0.045
0.673	0.653	0.568	0.041
0.605	0.587	0.511	0.037
0.538	0.522	0.454	0.033
0.471	0.457	0.397	0.029
0.404	0.392	0.341	0.025
0.336	0.326	0.284	0.021
0.269	0.261	0.227	0.017
0.202	0.196	0.170	0.012
0.135	0.130	0.114	0.008
0.067	0.065	0.057	0.004

Source: Grubaugh, Elston and George Abernathy. "Power Costs for Irrigation Pumping." New Mexico State University Cooperative Extension Service, Guide M-201, 1986.

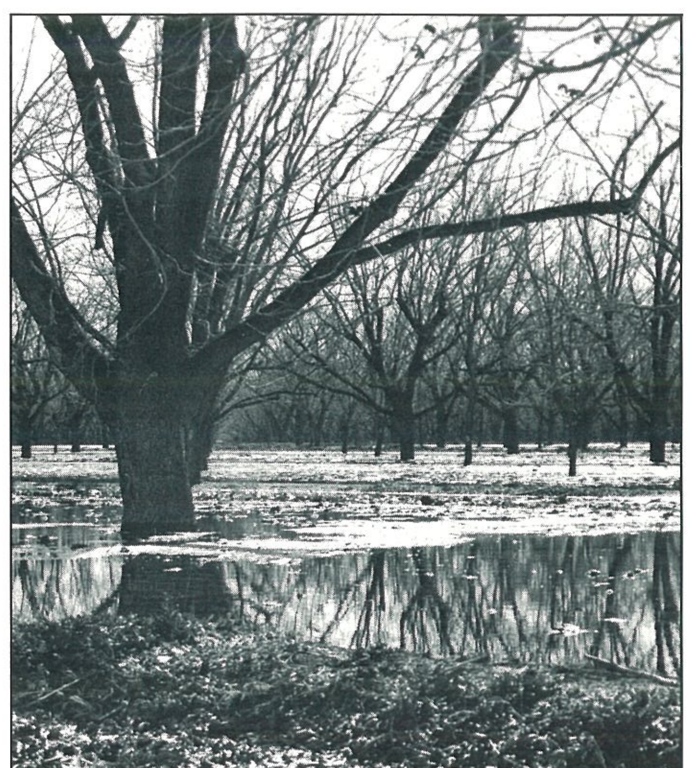
TABLE 7

Propane Engines

GOOD	POOR	
$/GAL		$/HP-HR
1.405	1.170	0.165
1.370	1.141	0.161
1.335	1.111	0.157
1.300	1.082	0.153
1.265	1.053	0.149
1.229	1.024	0.144
1.194	0.995	0.140
1.159	0.965	0.136
1.124	0.936	0.132
1.089	0.907	0.128
1.054	0.877	0.124
1.019	0.848	0.012
0.984	0.819	0.116
0.948	0.790	0.111
0.913	0.760	0.107
0.878	0.731	0.103
0.843	0.702	0.099
0.808	0.673	0.095
0.773	0.644	0.091
0.738	0.614	0.087
0.703	0.585	0.083
0.667	0.556	0.078
0.632	0.527	0.074
0.597	0.497	0.070
0.562	0.468	0.066
0.527	0.439	0.062
0.492	0.409	0.058
0.457	0.380	0.054
0.422	0.351	0.050
0.386	0.322	0.045
0.351	0.293	0.041
0.316	0.263	0.037
0.281	0.234	0.033
0.246	0.205	0.029
0.211	0.176	0.025
0.176	0.146	0.021
0.141	0.117	0.017
0.105	0.088	0.012
0.070	0.059	0.008
0.035	0.029	0.004

Source: Grubaugh, Elston and George Abernathy. "Power Costs for Irrigation Pumping." New Mexico State University Cooperative Extension Service, Guide M-201, 1986.

Flood irrigation is used to water a pecan orchard in the Mesilla Valley near Las Cruces in southern New Mexico (Photo by New Mexico Water Resources Research Institute)



Bibliography

Carver, Ken, A. Wayne Wyatt and Mike Risinger. 1985. *Furrow Dikes: Small Reservoirs of Yield Potential*. Lubbock: High Plains Underground Water Conservation District.

"Center pivot development reviewed." 1988. *The Cross Section* 34:5.

Fereres, ed. 1981. *Drip Irrigation Management*. University of California Division of Agricultural Sciences, Leaflet 21259. Berkeley: University of California.

Fereres, Elias. et al. 1981. *Basic Irrigation Scheduling*. University of California Division of Agricultural Sciences, Leaflet 21199. Berkeley: University of California.

Fereres, Elias et al.*Irrigation Costs*. University of California Division of Agricultural Sciences, Leaflet 2875. Berkeley: University of California.

Grubaugh, Elston and George Abernathy. 1986. *Power Costs for Irrigation Pumping*. Cooperative Extension Service Guide M-201. Las Cruces: New Mexico State University.

Henggeler, Joseph C., John M. Sweeten and C. Wayne Keese. 1986. *Surge Flow Irrigation*. Texas Agricultural Extension Service, L-2220. College Station: Texas A&M University.

Hohn, C. M. 1983. *Design Considerations for Drip Irrigation*. Cooperative Extension Service, Guide A-119. Las Cruces: New Mexico State University.

Hohn, C. M. 1986. *The "Feel" Test Tells When to Irrigate*. Cooperative Extension Service, Guide A-111. Las Cruces: New Mexico State University.

Hohn, C. M. and G. H. Abernathy. 1980. *Pumping Plant Efficiency Check for Natural Gas Engines*. Cooperative Extension Service, Guide A-121. Las Cruces: New Mexico State University.

Hulsman, Robert and Charles M. Hohn. 1984. *A Computer Model for Irrigation*. Cooperative Extension Service, Guide A-411. Las Cruces: New Mexico State University.

"Lubbock County Producers Praise Surge Irrigation Benefits." 1989. *The Cross Section*. 35:5.

Marsh, Albert. 1981. *Questions and Answers About Tensiometers*. University of California Division of Agricultural Sciences, Leaflet 2264. Berkeley: University of California.

"New Improves Irrigation Spray Nozzles." 1988. *The Cross Section*. 34:6.

New, L. Leon. 1986. *Pumping Plant Efficiency and Irrigation Costs*. Texas Agricultural Extension Service, L-2218. College Station: Texas A¿M University.

Pacific Gas and Electric Company 1988. *Saving Energy on the Farm*.

"Poor Pump Performance Raises Fuel Costs." 1988. *The Cross Section*. 38:7.

Risinger, Mike and Ken Carver. n.d. *Neutron Moisture Meters: The Scientific Approach to Monitoring Soil Moisture*. Lubbock: High Plains Underground WaterConservation District No. 1.

__________. n.d. *Soil Moisture Monitoring: An Overview of Monitoring Methods and Devices*. Lubbock: High Plains Underground Water Conservation District No. 1.

________. n.d. *Tensiometers: A Gauge for Measuring Soil Moisture*. Lubbock: High Plains Underground Water Conservation District No. 1.

Snyder, Richard L., Blaine R. Hanson, and Raymond Coppock. 1986. *How Farmers Irrigate in California*. University of California Division of Agricultural Sciences. Berkeley: University of California.

Walker, Lloyd R. 1988. *Energy Management*. Longmont, Colorado: Energy Conservation for Colorado Agriculture.

This publication was prepared in cooperation with:

New Mexico Energy, Minerals & Natural Resources Department
New Mexico Water Resources Research Institute
U.S. Department of Energy Western Area Power Administration
NMRDI Communications Office
New Mexico Rural Electrification Cooperative Association, Inc.
New Mexico State University Civil, Agricultural & Geological Engineering Department
New Mexico Cooperative Extension Service
Plains Electric Generation & Transmission Cooperative, Inc.
Black Range Resource Conservation and Development Area, Inc.

9/89