USDA-SOIL CONSERVATION SERVICE IRRIGATION WATER MANAGEMENT PROGRAM IN MISSISSIPPI

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INTRODUCTION

Mississippi receives approximately 52 inches of rainfall annually. However, much of this rainfall occurs during local summer thunderstorms which produce intense rainfall. Beneficial rainfall is often lacking during critical crop growth stages. To fill this void, irrigation provides the much needed water.

The Mississippi alluvial aquifer provides groundwater for irrigation in the Mississippi delta. Although this aquifer is not a principal source for potable water, questions of quality and quantity of groundwater remain a concern to all the people of the delta. This concern is primarily due to the enormous economic impact of irrigated agriculture. Recent studies indicate that localized shortages may occur in the central delta region[1]. Just over 1 billion gallons of water per day is pumped from the ground for rice, catfish, cotton, and soybean production[1]. This is two times the daily consumption of the cities of Jackson, Tupelo, and Vicksburg combined[2].

To help Mississippi farmers use their water resources most efficiently, the USDA-Soil Conservation Service initiated an Irrigation Water Management program in the summer of 1985. An Irrigation Water Management (IWM) team consisting of an agronomist, soil scientist, and agricultural engineer has been charged with providing technical assistance to farmers in managing their irrigation water supplies.

The initial thrust of the irrigation team has been directed toward evaluating the performance of existing center pivot irrigation systems for water and energy use efficiency and the intake characteristics of the soil under these systems. There are approximately 1000 center pivot systems in the delta. One center pivot system pumping 1200 gpm will pump 1-3/4 million gallons per day which is the equivalent to the water use of the town of Indianola[2]. The irrigation team is also responsible for updating the Mississippi irrigation guide with information on the intake capability of different soils under different cropping patterns.

This report will briefly explain the 1986 test methods, accomplishments, and goals of the IWM team.

PUMPING PLANT TEST METHODS

A pumping plant test involves determining the energy efficiency of the entire pumping plant (motor and pump). If a pumping plant is found to have a low efficiency the Soil Conservation Service has the equipment to determine the separate pump efficiency and motor efficiency (for non-electric power plants).

For a pumping plant test several variables must be measured. These include: pumping depth, flowrate, operating pressure, and energy consumed (gallons of fuel per hour, kilowatt hours). The Soil Conservation Service has purchased specialized equipment to determine these variables. A M-Scope water level indicator is used to obtain pumping depth. Several size impeller flow meters are available to determine well flow rate. For a closed system, a Cox velocity gauge can be inserted to determine water velocity in a pipe, which allows flowrate to be determined. Pressure gauges are available to insert into the system if there are none present or if those in the system are inoperative. For diesel power plants a one gallon reservoir is attached to the motor so that fuel consumption can be measured. For electric motors the electric meter is read. The pump RPM is also measured using a hand-held tachometer, in case the operating speed needs to be adjusted to change the system flow and operating pressure.

The pumping plant efficiency is determined by comparing the energy out of the system (water horsepower) to the energy consumed by the system (diesel fuel, electricity).

The pumping plant efficiency is then rated according to a standard for pumping plat efficiencies (either a national standard or the Nebraska Standard). If a pumping plant is found to have a low efficiency, it is then necessary to determine if the pump and/or motor have a deficiency. Therefore the separate motor efficiency and pump efficiency must be determined. To accomplish this the Soil Conservation Service has purchased a strain gage shaft torque sensor. The torque sensor is installed in the driveline between the motor and pump (normally can only be used with internal combustion engines connected to the pump by a drive shaft). The torque sensor has a RPM sensor installed on it to determine the shaft rpm. The torque sensor measures the torque in the drive shaft. From these two values the shaft horsepower (which is the motor horsepower output and the pump horsepower input) can be computed. With this additional information the separate motor efficiency and pump efficiency can be calculated to determine which pumping plant component requires maintenance or repairs.

CENTER PIVOT SYSTEM TEST METHODS

The center pivot system test evaluates how efficiently and uniformly the system is capable of delivering water to the field. Equipment needed includes cups to catch irrigation water, stakes on which to place cups, graduated cylinder to measure the amount of water caught in each cup, a stopwatch, and a 100′ tape.

The catch cups are placed at 30′ intervals on a radial line from the pivot point to beyond the end gun range. The line of catch cups is placed out in front of the system a sufficient distance to ensure that when the system is started the catch cups are outside the spray pattern. To facilitate the evaluation, the catch cups under the first two spans are omitted since the watering cycle is so long within this area. The system length and the distance to the end tower are recorded at this time.

Beneath the last span, 5 catch cups are placed in a straight line perpendicular to the main cup catch line. These catch cups are placed 10′ apart with the center cup located on the main catch cup line. When the system is over the second cup, all five cups are emptied and replaced and the stopwatch is started. When the system is over the fourth cup, the stopwatch is stopped and the five cups retrieved. The water in each cup is measured. The highest catch is used with the recorded catch time to determine the maximum application rate (inches per hour) of the system. The maximum application rate can be compared to the maximum infiltration capacity of the soil to determine if a runoff hazard exists.

The system is allowed to pass over the line of catch cups. Once all the cups are outside the wetted pattern (including the end gun), the system is stopped and the water in each catch cup is measured. This information is used together with the pumping plant data to determine the gross application, pattern efficiency, application efficiency, and system efficiency of the existing sprinkler package.

1986 CENTER PIVOT EVALUATION RESULTS

Twenty-two center pivots were evaluated over the past year. The results of the evaluations are shown in Table I. Of 22 systems evaluated, 19 were diesel powered, two were electric, and one was propane. The majority of the diesel systems evaluated were shown to have a pumping plant efficiency greater than the national average of 20%. This result is not surprising due to the fact that most of the motors and pumps in the Mississippi delta are relatively new (less than 5 years old) and have not been in operation a sufficient length of time to experience wear and degradation that would result in a decrease in performance. Additionally, pumping depths in the delta are shallow (approximately 30 feet) decreasing the loading on the pump.

Pattern efficiencies were generally rated as satisfactory to good. Pattern efficiency is a measure of the uniformity of application along the system length. The national criteria is for a 77% or higher pattern efficiency. Application efficiency is a measure of the water applied to the field compared to the water pumped. Water losses can occur due to evaporation and system leaks. In humid regions, such as the delta, evaporation losses are generally low resulting in high application efficiencies in the range of 90 to 95% if there are no major system leaks. This range adequately describes the results shown in Table I.

Maximum application rates ideally should not exceed the infiltration capacity of the soil. Measured maximum application rates varied from 5.5 to 1.5 inches per hour. Results of the infiltration studies have shown that the maximum short term infiltration (the type that occurs under a center pivot system) for a Dundee soil should be kept below 3.5 inches per hour. Field observations indicate that many of the center pivots have excessive runoff under the last several segments.

To prevent excessive runoff it is suggested that for systems over one-quarter mile (1320 ft.) medium pressure impact nozzles be a minimum requirement and that low pressure spray nozzles be avoided for longer systems. For systems less than 1320 ft. (excluding towable systems) low pressure spray nozzles would provide a sufficiently low application rate to prevent excessive runoff. Any system using medium to high pressures (30-60 psi) with spray nozzles should consider medium or high pressure impact nozzles if the system is ever re-nozzled. Using medium to high pressures with low pressure spray nozzles is a waste of energy that could be put to good use with impact nozzles to give a larger wetted area per nozzle.

It has been found that a system that has a good pattern efficiency may still be wasting water. Most irrigators apply approximately 1 inch of water per irrigation with a center pivot system. This is normally sufficient in order to meet 3 to 4 days of the crop water requirement during peak demand periods. Part of the irrigation evaluation involves calculating a new speed calibration chart for the system. On average by using the manufacturer's speed chart the irrigator is applying 25% less water than intended and is therefore failing to meet his crop water requirement. If the crop enters stress because of the inaccuracy of the speed chart, then the entire amount of irrigation water and the associated irrigation system costs can be considered wasted. It would appear imperative that every system be evaluated for the accuracy of its speed selection chart. A farmer can check this himself with a couple of rain gages, a watch, a tape measure, and two survey flags.

A management aspect of center pivots that appears to be lacking is that operators tend to operate their systems within a range of operating RPM's rather than at one specific operating RPM. An example of this is report #8. This report was given to the farmer. Later

TABLE I

CENTER PIVOT EVALUATION SUMMARY

REPORT NO.	PROP ANE	PATTERN EFFICIENCY	APPLICATION EFFICIENCY	PUMPING PLANT EFFICIENCY	GALLONS FUEL PER AC-IN	WETTED LENGTH	GPM	PRESSURE	NOZZLE TYPE	MAX. APPLICA-TION RATE	HOURS	1" APPLI. DAYS
1	DIESEL	78.0	91.5	21.0	1.64	1860	1100	40	SPRAY			4.7
2	DIESEL	83.3	100.0	22.0	2.02	1148	895	72	IMPACT	2.40		2.0
3	DIESEL	77.7	100.0	20.8	1.87	1830	1231	51	IMPACT	2.58		3.7
4	DIESEL	76.9	89.2	21.5	2.17	2100	1520	66	SPRAY		4.4	
5	PROPANE	81.1	99.0	8.5		1437	1439	39	SPRAY	2.44	1068	2.0
6	DIESEL	80.0	100.0	20.7	1.27	1870	1600	39	SPRAY	4.11	1625	2.9
7a	DIESEL	79.0	92.0	22.8	1.11	1685	990	40	SPRAY	5.61	235	4.3
8	DIESEL	75.6	100.0	27.5	1.50	1874	1650	66	SPRAY	5.33	2893	2.8
9T	DIESEL	78.5	84.4	15.9	1.52	1358	1000	32	SPRAY	5.69		2.9
10	DIESEL	73.3	90.0	14.0	1.44	1871	940	28	SPRAY	3.95		5.6
11	DIESEL	75.0	93.0	18.3	1.23	1404	700	29	SPRAY	2.41	99	4.2
12	ELECTRIC	82.0	100.0	78.9		2604	1414	62	IMPACT	2.63	566	3.3
13	DIESEL	70.6	91.0	19.7	1.49	1445	870	43	SPRAY	2.37	689	3.4
14	DIESEL	83.4	93.0	25.4	1.91	2920	3000	73	IMPACT	3.72	73	4.2
15	DIESEL	81.4	98.9	19.0	1.83	2240	1415	53	SPRAY	4.68	2100	4.9
16T	DIESEL	89.6	96.7	18.5	1.57	1320	1300	40	IMPACT	4.40	1258	1.8
17	DIESEL	79.6	90.8	21.1	1.92	1990	1000	66	SPRAY	3.52	371	2.7
18a	DIESEL	81.2	100.0	24.0	1.75	1776	1580	68	SPRAY	3.52	371	2.7
19	DIESEL	79.7	95.2	17.3	2.40	1900	1175	70	IMPACT	1.38	2179	4.3
20T	ELECTRIC	73.0	85.0			975	560	23	SPRAY	3.43	2803	2.7
21	DIESEL	75.0	95.0			1405	625	27	SPRAY	3.43	1720	4.5
22	DIESEL	87.8				210	170	10	SPRAY	3.47	10	0.5
23	DIESEL	85.0				210	170	20	SPRAY	4.91	10	0.5

a - designates same system that was evaluated twice

T - towable system

in the summer another of his systems was evaluated. At this time the farmer stated that he believed the first report given to him was in error with regards to the operating pressure of the system. At the time of the evaluation, the pressure gauge on the system was broken so that a SCS gauge was installed, with this problem noted in the report. When the farmer replaced the gauge, he found a lower operating pressure than in the evaluation.

A return trip was made to the system cited in the example to determine the reason for the discrepancy. A change in operating RPM was the most likely cause. Table II shows the differences in operating conditions between the initial evaluation and the follow-up. The farm manager knew of the lower operating RPM, but said that the system still seemed to be putting out enough water.

Table II

RPM	PRESSURE	FLOWRATE
RPM	psi	gpm
1830a	66a	1650a
1575b	49bc	1420c

a-original evaluation b-measured c-affinity laws

This problem arises in that for electric drive systems, the operators set the voltage (and therefore the operating RPM) between 500 and 550 volts without necessarily referencing a particular RPM. This points out the need for a functioning RPM meter and a fixed operating point (RPM, voltage, pressure, flow).

Another observation made was that no system evaluated had a flow meter. Coupled with other system discrepancies, without a flow meter an operator has no knowledge of the performance of his system, and cannot detect fluctuations or changes in performance. All systems should have a flow meter, RPM meter, and pressure gauge, all in good operating condition.

SOILS INFILTRATION

During 1986 infiltration tests were run on 23 sites. In most cases an infiltration test was done at the same time and site as a center pivot evaluation. Of the 23 tests the majority were run on Dubbs (10), Dundee (3), and Forestdale (3) soils. The Soil Conservation Service plans to use this data to develop typical infiltration curves to be used as a guide to assist landowners plan the most efficient way to use their irrigation water. Some average curves have been developed, but more information is needed to assure that the most accurate data possible is provided to farmers.

Plans have been made to concentrate on individual soils during 1987. Soils typically used for cotton production have been selected for further study, since a major portion of the irrigated land is used for cotton production. Dubbs soils have been targeted as the first soils to be intensively studied. As soon as enough data is collected to develop accurate infiltration curves for the Dubbs series, another soil will be selected. This method will assure accurate information for the greatest amount of the acreage needing study. More farmers will benefit from the information in the long run than would have benefited from studies on randomly selected sites.

Attached are some preliminary curves developed from the data that has been gathered, infiltration examples, and a list of the sites. Figure 1 shows a curve for cumulative infiltration. Cumulative infiltration curves can be used to determine infiltration over long periods of time. Figure 2 shows a curve for the infiltration rate. Infiltration rate curves can be used to determine infiltration amounts for short periods of time.

COMPACTION STUDY

On July 18, 1986, during a field trip to a farm to observe an underground irrigation pipeline it was observed that a pattern of two short rows and four tall rows of cotton repeated through the field. After discussion with the farmer, it was decided that compaction was the probable cause. An investigation by the Irrigation Water Management team was begun to determine if compaction was indeed the problem, and if so, where was the compaction and what effect did it have on yield.

The farmer was contacted about his farming operations. He has 370 acres of 2x1 skip row cotton southwest of Greenwood, MS. The farm consists mostly of Dundee soils with small areas of Forestdale and Dowling soils. The tillage practices for this year were as follows: the stalks were cut, the field disked and subsoiled twice at 45 degrees to the row in both directions in the fall. In February the field was rehipped and subsoiled in the row middle. In April the field was rehipped, the row tops dradded off and planted. The field was cultivated four times during the season using John Deere 4630 and 4430 tractors with single tires which were 18.4 to 20.8" wide on the rear and 10 to 12" wide on the front. In addition to the tractor were 8 row cultivators and 400 gallons of water and chemicals per tractor.

Ideally in skip row cotton the tractor tires should run in the middle of the skip, but since the farmer also used the tractors for soybean cultivation the tires were set narrow. The farmer indicated where the tractor tires ran in the row. The tractor tires ran close to the outside of the two rows of short cotton.

For the initial field investigation it was decided to use a recording soil penetrometer to detect any compaction. A traverse was run across eight rows at one foot increments. The penetrometer can penetrate to a depth of two feet. A plot of the recorded data showed a compacted zone just on the outside of the short rows (Figure 3). This compaction was located just where the farmer had narrowed his wheel track. Once the location of the compaction had been pinpointed, a return trip was made to the field to obtain soil samples to quantify the amount of compaction. Samples were taken at 2.2", 6.5", and 10.8" below the soil surface. Two replicate samples were taken at each of two sites. The first site was located between the two rows of short cotton where no compaction had occurred. The second site was one foot on the outside of the short row where the penetrometer had indicated a compaction problem. The results are shown in Table III.

Table III

	DENSITY	
Depth	Non-compacted	Compacted
2.2"	1.26g/cc	1.39g/cc
6.5"	1.40g/cc	1.47g/cc
10.8"	1.32g/cc	1.43g/cc

The soil samples indicate that compaction is occurring down to 10.8" in depth. This compaction causes a barrier to moisture movement and root growth. In addition, infiltration of water into the soil is slowed by the compacted layer. As the attached infiltration graph shows, infiltration decreases as the bulk density increases. Therefore the two short rows have a limited soil volume in which to extract water and nutrients combined with a decrease in the amount of water that enters the soil. This effect was magnified due to the fact that the farmer has his tractor wheels adjusted to a narrow width, running just off the short row beds, rather than in the middle of his skip row.

The farmer picked 20 rows 700 feet long on both the short and tall cotton rows. This cotton was put in separate trailers to obtain a yield for each set of rows. The seed cotton was also weighed to get an estimate of the seed cotton yield for each set of rows.

Figure 1
Dubbs Cumulative Infiltration

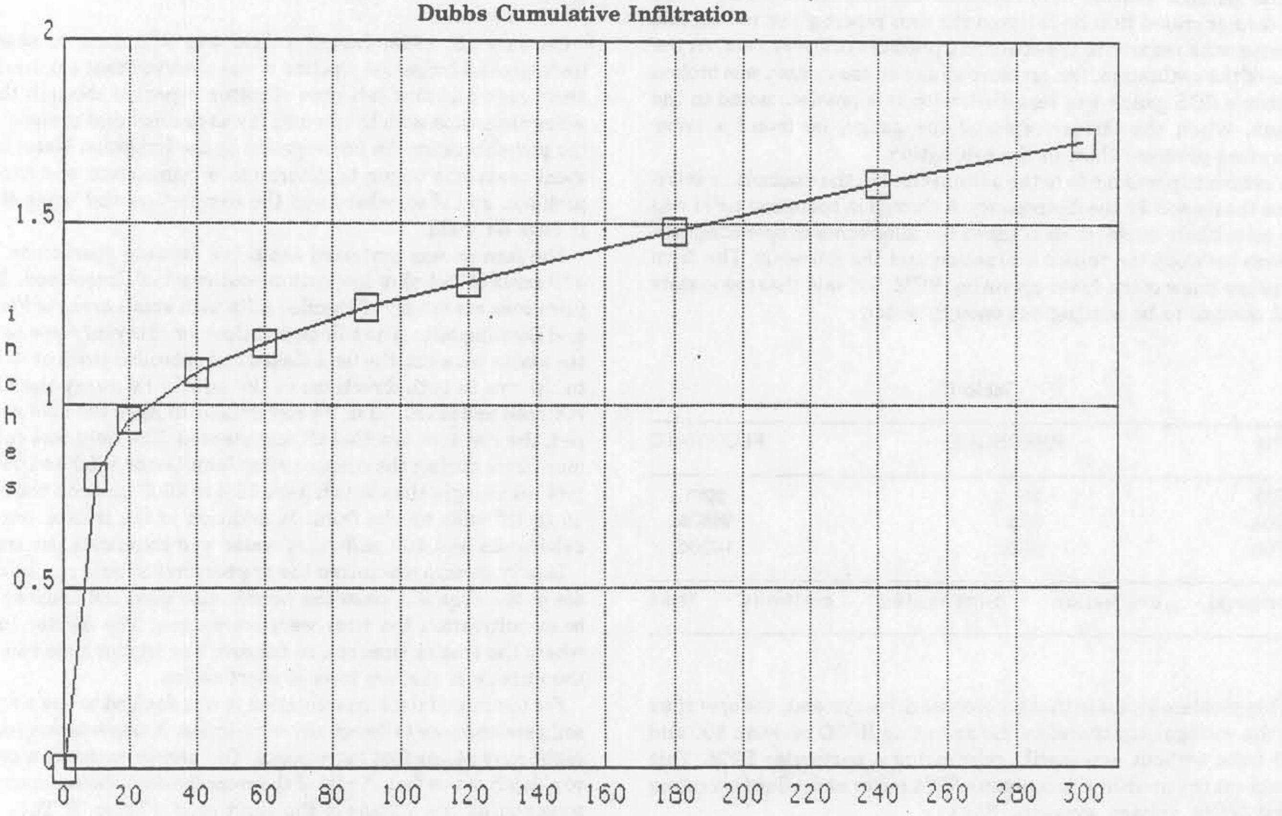
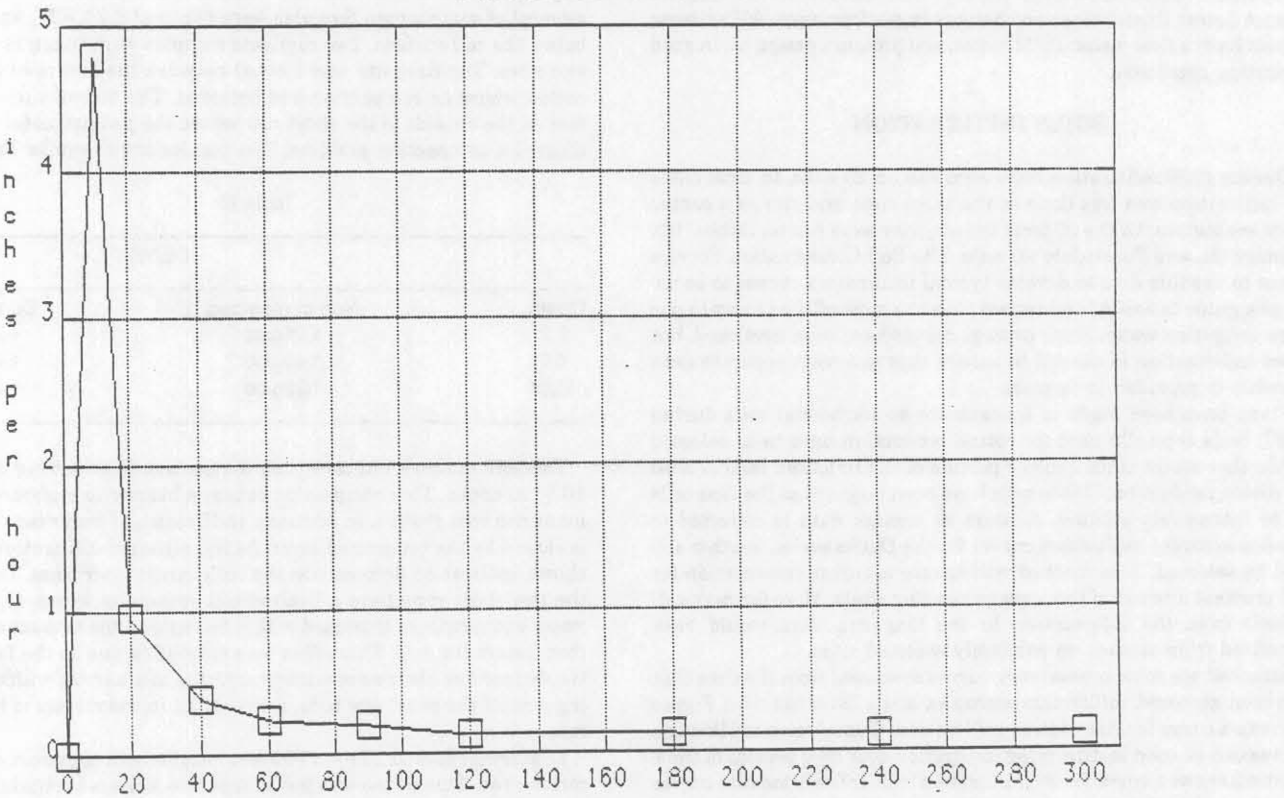


Figure 2
Dubbs Infiltration Rate



Results of the harvest showed that the tall rows yielded 1338 lbs. of lint and 2220 lbs. of seed per planted acre while the short rows of cotton yielded 1233 lbs. of lint and 2180 lbs. of seed per planted acre. The yield difference was 105 lbs. of lint per planted acre. Since there were four rows of tall cotton for each two rows of short cotton and three skip rows, the average yield was 869 lbs. per acre, which was a 23 lb. reduction from the 892 lbs. per acre yield on the compaction-free cotton. With cotton priced at \$0.81/lb. this compaction problem relates to a loss of \$18.61 per acre due to compaction. Compaction on this farm resulted in a loss of \$6,893.10.

This compaction problem is a major yield inhibitor. The yield difference was held to a minimum because of irrigation and a good job of management as evidenced by the farmer's yield in a less than desirable crop season. If either of these factors were omitted the compaction problem would have had a greater effect.

The compaction problem was probably created by the number of cultivation trips across the field and intensified by narrow tractor tire spacing. Subsoiling three times did not prevent this problem from occurring. What can be done to prevent this problem? Some suggestions are:

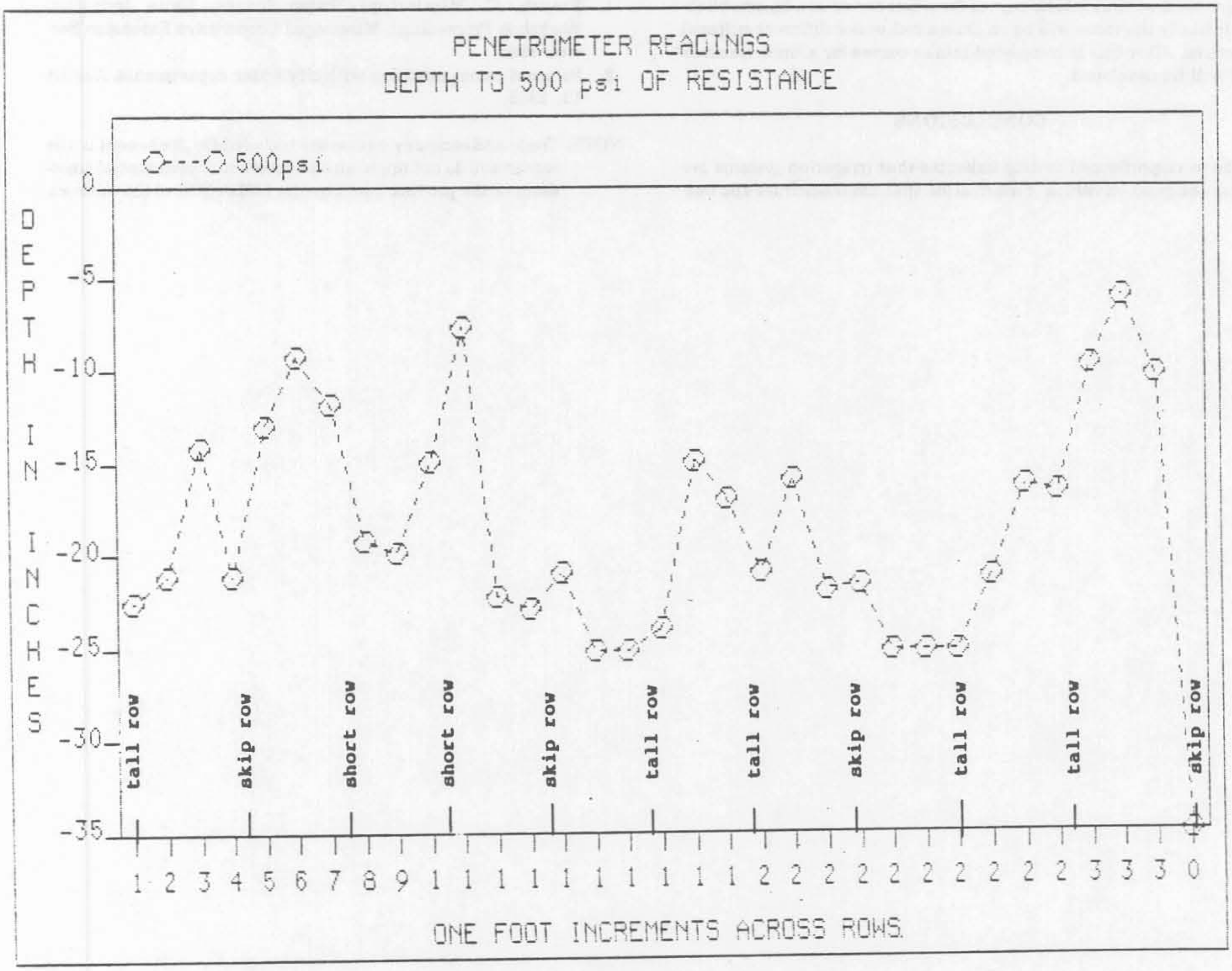
1. Eliminate unnecessary cultivation trips or limiting cultivation to times when the soil is not too wet.
2. Widen tractor tire spacing to eliminate compaction near the row.
3. Increase organic matter through the use of cover crops, crop residue use and conservation tillage to decrease compaction.

As today's farmer continues to till the soil with heavy equipment, allowing organic matter in the soil to be exposed to the air and oxidize, compaction of the soil will occur. As this study shows, these compaction problems will have to be considered for farmers to continue to achieve maximum production.

IRRIGATION TEAM THREE YEAR PLAN OF OPERATION

As shown by the 1986 list of accomplishments, center pivot systems in the Mississippi Delta have high efficiency compared to national standards. For this reason the irrigation team is planning to evaluate other methods to conserve irrigation water. The irrigation team will conduct five center pivot evaluations during 1987. These evaluations

Figure 3



will be used as training sessions for field office personnel and allow the IWM team to pursue other goals. After a field office receives training they will be required to conduct 3 evaluations in the remainder of 1987. There are two fully equipped irrigation mini-labs which will be available to the field offices on a need basis. This will allow a total of at least 32 systems to be evaluated in 1987.

In the summer of 1987 an evaluation on irrigation of rice will begin. Total water pumped, rainfall, evapotranspiration, deep percolation, and runoff will be monitored. Methods to reduce water use and runoff will be studied. This work will continue through 1988.

An irrigation scheduling program will be started in 1987. Weather data and soil moisture data will be used along with several different irrigation scheduling methods (checkbook, evaporation pan, atometer) to determine irrigation timing and amounts. 1987 work will concentrate on cotton on a Dubbs soil. In 1988 a different crop will be selected on Dubbs soil. The intent of this work is to provide the beginnings of an irrigation scheduling service in the delta.

Surface irrigation will be studied in 1988-1989 along with such technologies as surge irrigation and cablegation. If a cooperator is trying to put such practices to use during 1987, the irrigation team would provide whatever technical assistance is needed. 1989 will also see the study of catfish pond water use, and reuse of such water for irrigation.

The infiltration trailer will work separately from the irrigation evaluations so that intake curves for a soil series can be established. Initially the focus will be on Dubbs soil under different cultural practices. After this is completed intake curves for a finer textured soil will be developed.

CONCLUSIONS

The work performed to date indicates that irrigation systems are being designed on values of infiltration that are inaccurate and outdated. The information being collected at present should help to rectify this situation. Farmers are often working blind in regards to their center pivot system performance, especially with regards to depth of application. This results in water waste and lower crop yields. A center pivot evaluation increases a farmer's ability to manage his crops. Compaction is undoubtedly a widespread problem. Compaction can limit the amount of rainfall stored by the soil, thereby increasing the demand on groundwater supplies.

A point of general observation is the lack of flowmeter usage on irrigation systems. This indicates a poor manager who is operating in the dark. Without a flowmeter it is impossible to tell how much water is being applied, and therefore the depth of application is unknown.

ACKNOWLEDGMENTS

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REFERENCES

1. Branch, C. **Mississippi Water Issues,** Delta Irrigation Workshop Proceedings, Mississippi Cooperative Extension Service, 1985.
2. Personal communication with city water departments, August 13, 1986.

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