Graphic Solution of Furrow Irrigation Problems

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Irrigation water management includes knowing how much water is being applied to a specific area. Fact Sheet 1501 contains a discussion of water measurement units, factors for converting from one measurement unit to another, and formulas for calculating the average depth of water applied. Fact Sheet 1502 discusses some of the more common water measurement methods and equipment. The purpose of this fact sheet is to provide a means of solving water application problems graphically rather than using the conversion formulas contained in Fact Sheet 1501.

Required Information

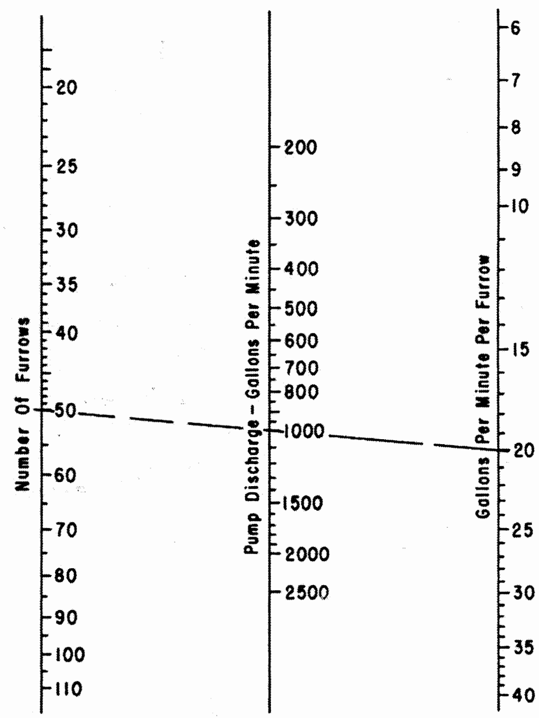
The graphic solution of water application problems calls for knowing the same information as solving problems mathematically. Information which must either be known or determined includes length of row, row spacing, gallons per minute per furrow, and hours that water is applied. Of these, three are relatively easy to determine: row length, row spacing, and hours that water is applied. Either of two methods can be used to determine size of furrow stream in gallons per minute. Individual furrow streams can be measured using a container of known size and a stop watch. An alternate method is to divide the pump discharge in gallons per minute by the number of rows irrigated per setting. Ditch flows measured in terms of cubic feet per second (cts) can be converted to gallons per minute (gpm) by multiplying cubic feet per second times 450. One cfs equals 448.83 gpm ordinarily rounded to 450. For example: 2 cfs = 900 gpm.

Graphic Solution Procedure

Nomograph A can be used to read the gallons per minute per furrow whenever the number of furrows and pump discharge are known. Fol example, 1,000 gpm equally divided among 50 furrows results in 20 gpm per furrow.

Nomograph B can be used to determine the number of hours required to apply a given depth of water when the length of row, water furrow spacing, and gallons per minute per furrow are all known.

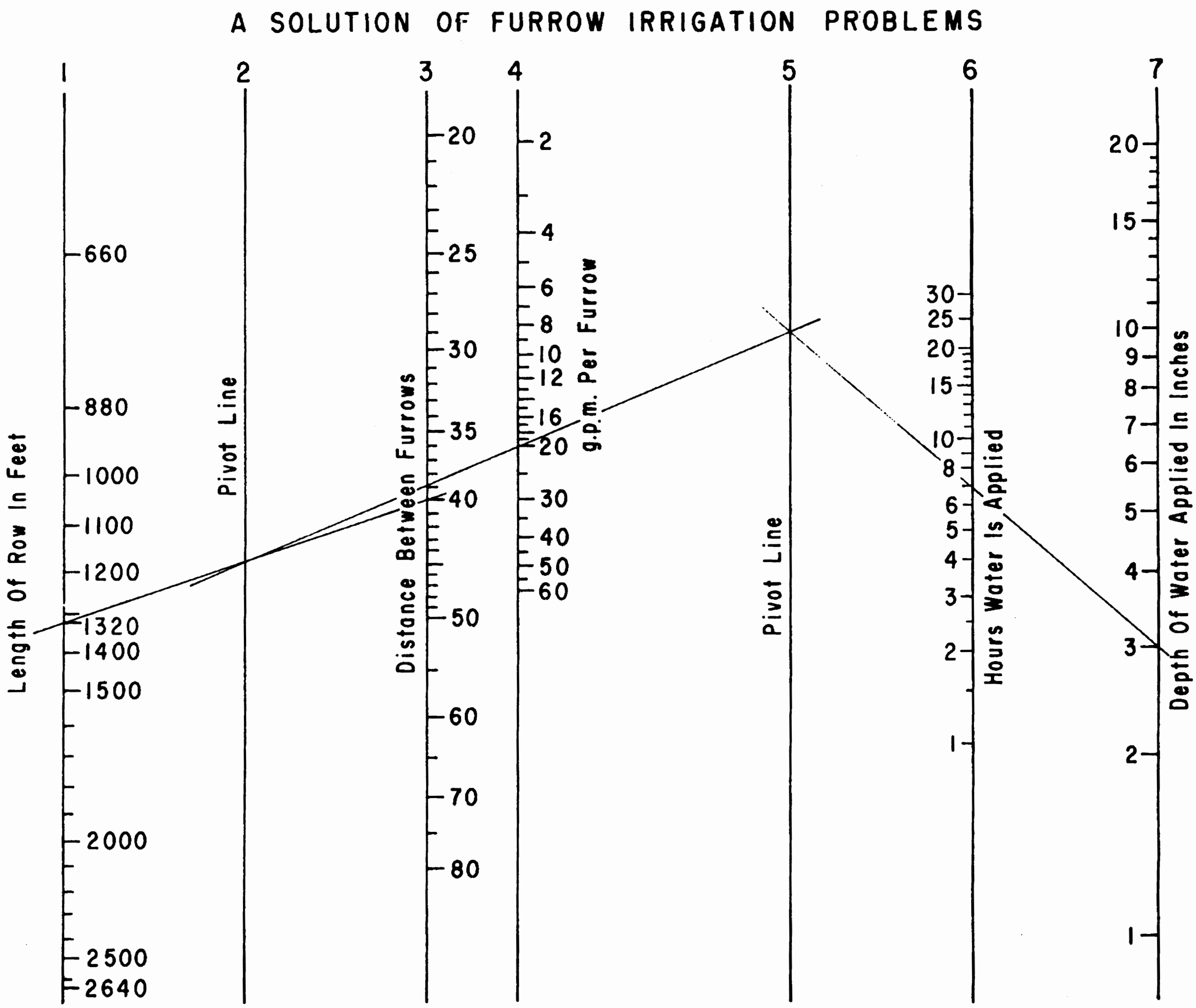
For example, suppose 20 gpm per furrow is applied to quarter-mile (1,320 feet) rows spaced 40 inches on centers. How many hours are required to make a 3-inch average application?



Nomograph A for reading gallons per furrow per minute when number of furrows and pump discharge are known.

Using a ruler or other straight edge, draw a straight line connecting the point 1,320 on scale 1 (length of row in feet) and the point 40 on scale 3 (distance between furrows in inches). Note the point in intersection of this line just drawn on scale 2 (pivot line). Enter scale 4 (gpm per furrow) and locate point 20. Using a straight edge, connect the point of intersection on scale 2 with point 20 on scale 4. Note the point of intersection on scale 5 (pivot line). Using this point of intersection of scale 5 (pivot line), align the straight edge through the point labeled 3 on scale 7 (depth of water applied in inches) and read on scale 6 that about 6.9 hours are required.

Nomograph B can also be used to determine how many inches are applied in a specified period of time. For example, how many inches are applied in 12 hours using a 900 gpm water supply to water 55 rows 1,320 feet long and 38 inches



Nomograph B determines depth of water applied when length of row, water furrow spacing, gallons per minute per furrow, and hours water is applied are known.

on center? (The solution to this example is not shown on the nomographs.)

The solution is virtually the same as the preceding example. Using nomograph A and connecting points for 55 rows and 900 gpm, we find the gallons per minute per furrow to be 16.3. On nomograph B, we locate the intersection on scale 2 using 1,320 on scale 1 and 38 on scale 3. Using this point of intersection on scale 2 and the value 16.3 on scale 4, locate the point of intersection on scale 5. Using this point of intersection on scale 5 and the value of 12 on scale 6, we read on scale 7 that an average depth of 4.5 inches would be applied during the 12 hour period.

It is possible to use nomograph B to estimate the number of rows which can be irrigated from a water supply that will result in some desired depth of water being applied in a given time. For example, using a water supply of 1,055 gpm, approximately how many furrows spaced 56 inches on centers and 1,000 feet long should an irrigator water at one time so as to apply 6 inches of water in 12 hours? (The solution to this example is not drawn on the nomograph. For practice draw the lines indicated.)

The solution is virtually the reverse of our earlier examples. Using a straight edge, align the value of 6 on scale 7 and the value of 12 on scale 6. Note the point of intersection on scale 5. Using the values of 1,000 on scale I and 56 on scale 3, locate the intersection point on scale 2. Using points of intersection on scales 2 and 5, read about 24 gpm per furrow on scale 4. Divide 1,055 by 24 or can use nomograph A to determine that about 44 rows should be watered at one time.

Size of Furrow Stream

The irrigator should use a size of furrow stream that does not cause serious erosion. Slope, soil type, soil condition, and size of water furrows limit the allowable size of furrow stream. Furrow slope should be uniform for the full length of the furrow. In general, the greater the slope along the furrow, the smaller the size of maximum non erosive furrow stream. On nearly flat slopes, furrow size, not slope, may determine the maximum allowable size of furrow stream.

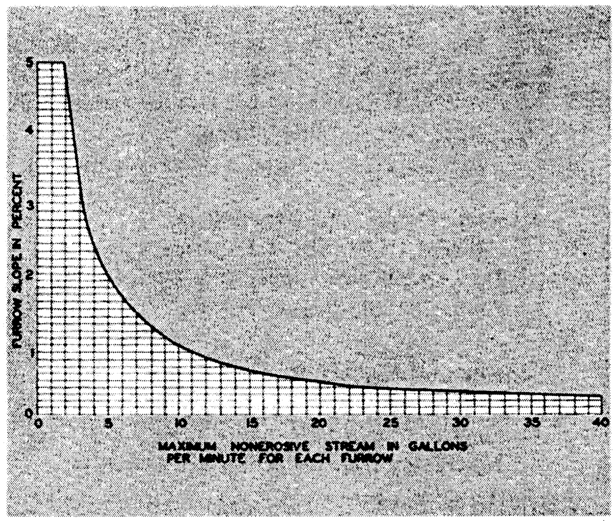
The adjacent graph shows a typical relationship between furrow slope and maximum non erosive stream for a loam soil with an average organic matter content. Freshly cultivated soils are more subject to erosion than are undisturbed soils. Soils covered with vegetative material are less subject to erosion than are barren soils. The furrow stream finally selected will probably be less than the maximum non-erosive stream, but still large enough to obtain a uniform water application along the length of the furrow without excessive deep percolation losses.

Maximum Furrow Spacing

Irrigation furrow spacing is usually fitted to the type of crop and/or equipment required for crop production. Generally speaking, furrows for rowed crops are closer spaced than are furrows for drilled crops such as small grains. In a homogenous, medium textured soil, the depth and width of the "wetted bulb" beneath an irrigation furrow are frequently nearly equal. However, soils are seldom homogenous throughout the root zone, as "plow pans" or some other restrictive layer may cause more horizontal movement of the water. On the other hand, a highly permeable subsoil will allow more rapid downward movement resulting in less horizontal movement of the water. Maximum furrow spacing should not exceed the width of the "wetted bulb" beneath the furrow when the depth of the "wetted bulb" equals the root zone depth of the crop at maturity.

Length of Irrigation Run

The maximum length of irrigation run should be the longest distance in which the maximum allowable furrow stream can effect nearly uniform distribution of water in the soil. The major factors affecting the length of irrigation run are soil type, furrow slope, and size of furrow stream. Heavier textured soils, i.e. silts and clays, and flatter slopes permit longer irrigation runs. A larger furrow stream also requires less time to reach the end of the furrow. Irrigation runs which are too long result in water being lost by deep percolation at the head of the furrow by the time the water reaches the far end of the run. On the other hand, too short a run results in run off f rom the field unless the size of the furrow stream is cut back after wetting the entire furrow length. As a rule of thumb, for nearly uniform irrigation of a field, the furrow stream "fronts" should reach the lower ends of the furrows in one-fourth the time required to replenish the soil moisture in the crop root zone and then be cut back to "hold water the length of the furrow." This practice will allow about 25 percent more time for water to be absorbed at the upper end of the furrow as compared to the lower end. However, the water intake rate decreases with time, so the extra amount of water actually absorbed will be less than 25percent of the total, probally more nearly a 12 percent difference.



Relationship of furrow slope and maximum nonerosive stream on an average soil.

Surface Water Runoff Re-use

As commonly practiced, it is just not practical to attempt to furrow irrigate without run off occurring at the far end of the furrow. The amount of run off which occurs is dependent upon the degree of control exercised by the irrigator. Actual field measurements made in Oklahoma indicate the run off from furrows averages about 20 percent of the water turned in at the head of the furrow. This is a significant amount of water, and over the past several years many irrigators have constructed re-use pits to capture this runoff.

Basically, one of three concepts can be followed relative to the utilization of the captured runoff. First, the water can be periodically recirculated back over the same area from which it originated. Second, the water can be collected and stored until there is sufficient to irrigate another area. A third concept is to collect runoff water from one irrigation set and then, by adding it to the regular water supply, provide a furrow stream capable of more rapid initial wetting of the furrows of the next irrigation set. By balancing runoff, pit size, and re-use pump capacity, the cycling of the re-use pump thus provides a degree of automated cutback of furrow streams. The choice of concept to follow will be dictated by the cropping system, available irrigable land, and amount of runoff water involved. Each concept has its advocates and its advantages and disadvantages.

Some general rules of thumb regarding run off reuse systems are:

1. Re-use pit capacity should be adequate to store the runoffoccurring from one irrigation set. Keep in mind that the percentage of runoff is greater for later season irrigation.
2. Design capacity of the re-use pump must be greater than the average anticipated runoffrates into the pit.
3. The re-use pit should be emptied at the end of the last set of the irrigation cycle. This will provide limited storage in the event rainfall produces significant runoff between irrigation cycles.

Summary

Water application problems can be solved either mathematically or graphically. Graphic solutions can speed up the process and eliminate chances of errors in arithmetic.

The Role of Agricultural Engineers

The primary role of agricultural engineers is the application of engineering principles to agricultural problems. Oklahoma State University employs a staff of extension agricultural engineers to provide highly qualified and specialized support to county and area extension personnel in solving problems of urban, suburban, and rural Oklahoma.

Extension agricultural engineering programs currently include:

Electric Power and Processing
Efficient Utilization of Electrical Power
Domestic Water Supply Improvement
Sanitation and Waste Disposal

Power and Machinery
Calibration and Utilization of Spray Equipment
Farm Machinery Management
Machinery Systems for Crop Production

Soil and Water
Irrigation
Erosion Control
Drainage

Structures and Environment
Crops Handling and Processing Systems
Livestock Handling System
Environment and Pollution Control

4-H Engineering Projects
Automotive
Electric
Tractor
Woodworking, Crafts and Handicrafts

Safety
A part of all Extension Agricultural Engineering Programs

Energy
Efficient Use of Energy in Housing
Energy Use in Production Agriculture
Alternative Energy Sources

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