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PB1721-Irrigation Cost Analysis Handbook

The University of Tennessee Agricultural Extension Service

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Introduction

Irrigation is a risk management tool. The risk of yield reduction due to drought is minimized with irrigation, because moisture can be added to the soil to match the water requirements of the crop. Irrigation is also a major capital investment. The yield produced under irrigation must be sufficient to produce a positive return on the investment.

This handbook is intended to assist users in determining the economics of investing in irrigation at their location. All irrigation systems are unique. Many factors are used to estimate the cost of irrigation, and each of these factors will vary with location. Issues such as the selection of pumps, pipes and power are dependent upon the characteristics of the site and cannot be generalized. This guide allows the user to approximate pump power requirements and pipe diameters so that realistic prices can be obtained from irrigation suppliers.

Scope and Purpose of Handbook

The anticipated user of this handbook is someone who is considering the purchase of an irrigation system. This document is a tool that can be used to assist in understanding how irrigation will affect the overall profitability of the farming operation. This document is not an irrigation design manual – the actual system design must be completed by a qualified irrigation engineer.

The primary focus of this handbook is the economics of sprinkler irrigation over agronomic crops grown in Tennessee. Economic analysis of high-value crops (such as tobacco and sod) with sprinkler irrigation can also be studied using the methodology prescribed by this handbook. While other styles of irrigation, such as surface irrigation or drip irrigation, can be evaluated through the use of this handbook, the user needs to be very familiar with the unique aspects of these irrigation methods to do a complete economic analysis.

This handbook includes assumptions that aid in simplifying the economic analysis. The inclusion of all design variables used for irrigation would require that the system be designed before economic analyses could be completed. These simplifying assumptions should not significantly affect the results of the economics.

The secondary purpose of this handbook is to serve as a communications tool between the agricultural producer and an irrigation engineer. This handbook demands that information be collected concerning the layout and operation of the farm. Having this information collected and organized will speed the design process and increase the likelihood that the producer will receive the best design for his/her location.

Using This Handbook

This handbook contains a methodical series of questions to be answered by the user. The answers to these questions are to be written on a set of forms that are included in this handbook. An electronic spreadsheet version of these forms is available for rapid assessment of the economics. The text provides assistance and guidance for answering each of the questions. Your local county Agricultural Extension agent or a farm management area specialist can provide assistance with interpreting the results of this analysis.

The first set of questions (lines 1-18) are related to the unique aspects of the field and crop to be irrigated. Lines 19-21 provide a process to estimate the flow rate, pipe diameter and pump power requirement. The initial expense of purchasing equipment is approximated by lines 22-38. Annual operating costs are computed by lines 39-46. Lines 47-52 provide information about estimating the return on the irrigation investment and lines 53-60 analyze the cash flow of using irrigation.

Steps for Completing the General Information Sheet

The general information sheet provides for the input of information about the farm and field to be irrigated. Answers are required for each question to complete the economic analysis.

1. **Crop to Be Irrigated.**
   Most fields are put through a rotation of crops, so an irrigation system must be able to supply different crop needs. For the purpose of doing the preliminary design work, select the crop with the highest water demand. As different crops are analyzed for economic return, adjust labor costs, number of irrigation applications and energy consumption for each crop, while holding constant the size of the equipment, pressure and flowrate.

2. **Expected Average Increase in Yield Per Acre from Irrigation.**
   Remember that irrigation does not increase yields – it provides the ideal soil moisture for the crop to grow to its full potential. There must also be enough nutrients in the soil to support the full crop potential. Having said that, some commonly used values for increased yield in fields with irrigation include:

Cotton	180 to 400 additional pounds per acre of lint
Corn	40 to 50 additional bushels per acre
Soybeans	15 to 25 additional bushels per acre

3. **Value of Crop Per Unit.**
   Obtain this value from current market prices and try to anticipate the future price.

4. **Maximum Soil Water-Intake-Rate.**
   This question is really asking for the infiltration capacity of the soil. Surface ponding and runoff will occur when water is applied at a rate greater than the ability of the soil to pull the moisture through the surface. The soil survey manual for your county has information about the permeability of each soil type. This value is related to the infiltration capacity; however, this value does not consider surface effects such as crusting and crop litter. Infiltration rate can be measured; however, most irrigation-designers will use approximated infiltration rates based on soil texture.

Light, sandy soils	0.5 to 0.75 inch per hour
Medium-textured soils	0.25 to 0.5 inch per hour
Heavy-textured soils	0.1 to 0.25 inch per hour

5. **Seasonal Water Consumption by the Crop (inches).**
   Consumptive-use is the total volume of water that leaves the soil during the growing season. Remember that 1 inch of water over one acre of land is 27,156 gallons. Some commonly used values for consumptive use include:

Cotton	25 to 35 inches
Corn	25 to 30 inches
Soybeans	20 to 25 inches

6. **Peak-use Demand Rate of Crop.**
This number represents the maximum rate that water will leave the soil. It is at this period of time that the most water is being consumed by the crop. This value is the primary parameter for designing an irrigation system. Water must be put back into the soil at the same rate at which it was withdrawn to maintain the soil-moisture supply. Typical values for Tennessee row crops include:

Cotton	0.30 to 0.36 inch per day
Corn	0.30 to 0.35 inch per day
Soybeans	0.20 to 0.30 inch per day

7. **Provide a Map with the Dimensions of the Field.**
With the explosion of GPS/GIS technologies, producing excellent maps of fields to be irrigated is getting much less expensive. The acreage and shape of the field are needed to design the layout of the hydraulic network and to decide which type of system is most efficient. Documenting the elevation changes across a field is very important if surface irrigation is to be used. If a sprinkler system is chosen, then elevation information does not have to be as exact; however, it is still needed so the designer can develop a system that will provide a uniform application of water.

At minimum, a scaled aerial photograph is needed. These maps can be copied from the local Farm Service Agency office. It is important that these maps be photocopied at the same scale as the original aerial photograph. Several sheets may need to be taped together when photocopying larger fields. Please note the scale on the aerial photographs. Typical scales are "1000 feet per inch" and "660 feet per inch."

8. **Number of Acres in the Field.**
This value should be determined from information collected in question 7.

9. **Number of Acres to Be Irrigated.**
Often, the irrigation system does not cover the whole field. The economics of irrigation must be based on the acreage that is actually irrigated.

Traveling guns, solid-set, hand-move and subsurface drip systems are capable of irrigating irregularly shaped fields. Center pivots irrigate a large circle within a field. Cornering systems are available on center pivots and they can fill in the corners of a square field. The extent to which a surface system can cover a field is dependent on the topography.

10. **Number of Irrigations Expected per Season.**
This number depends on the rainfall pattern during the growing season. Some typical values based on fairly normal years include:

Cotton	7 irrigation events
Corn	6 irrigation events
Soybeans	5 irrigation events

11. **Type of System.**
This will be answered by evaluating the sketch of the field and determining which type of system will best fit this land.

12. **Source of Water.**
Will the water come from surface water or groundwater? Is there an existing well? Does the area have a good history of producing good wells? Is there access to a nearby river, lake or canal?

13. **Length of Mainline.**
What is the length of pipe that will be required to transfer water between the source and the distribution system? In other words, what is the furthest distance that water will have to be pumped before it reaches the irrigation system?

14. **Total Height That Water Is to Be Lifted (Feet).**
This is the total elevation difference from the water level of the source to the tallest sprinkler in the highest part of the field. If pulling water from a surface source, the elevation of water surface should be taken when the water body is at the lowest stage. If groundwater is the source, then the elevation needs to be calculated from the elevation of the drawdown curve. Local drilling contractors may be able to provide assistance in obtaining this elevation.

The total elevation difference that water is pumped is called the static head. The pump must produce at least this much pressure before any water is produced at the upper end of the pipeline.

15. **Energy Source of Power Unit.**
This decision is based on the availability of the fuel or power, and the total annual cost of using that fuel or power.

16. **Current Interest Rate.**

17. **Stand-by Charges for Electricity or Demand Charge for Electricity.**
This only applies for producers who will be drawing electricity from the utility lines. Often, utilities will charge irrigators extra fees to maintain the high-capacity transmission lines to rural areas. Many areas will give a discount on this fee if the utility can "cut-off" the power to the irrigation system if the demand on the rest of the system becomes too high.

18. **Hours of Labor per Acre of Irrigation per Event.**
For the purpose of estimating cost, Table 1 offers some guidance on the labor required to operate various types of irrigation equipment.

Estimation of Power Requirement

The cost of moving water is the most significant component of the annual operating cost. A reasonable estimate of the power requirement is necessary in order to approximate the cost of energy. The Estimation of

Table 1. Labor Requirements by Type of Irrigation System[1]

Type of System	Estimates of Labor Required (hrs per acre per event)	Type of System	Estimates of Labor Required (hrs per acre per event)
Sprinkler Irrigation System		Surface Irrigation System	
Permanent solid set	0.1 to 1	Border	0.5 to 1
Hand-move portable set	1 to 2	Flood	0.5 to 0.1
Side wheel roll	1 to 3	Furrow	0.5 to 1.5
Center pivot	0.1 to 0.5		
Lateral move	0.1 to 0.5	Subsurface Drip System	
Hand-move big gun	1 to 2	Dripperline	0.06 to 0.08
Traveling gun (soft or hard hose system)	0.5 to 1.5		

[1]Turner, J. H., C. L. Anderson. (1980). "Planning for an Irrigation System." Am Assoc. for Vocational Instructional Materials, Athens, GA.

Power Requirement Form is a stand-alone document that guides the user through a series of simple calculations estimating the horsepower needed to move water from the source through the irrigation distribution system. Lines 19 - 21 assist with the determination of the pump flow rate, pipe diameter, system pressure and the required power (see pages 13 - 15).

Steps for Completing the Initial Investment and Depreciation Form

Lines 22 - 30 provide an opportunity for the user to customize and determine the total investment by entering the price of the various components needed in an irrigation system. Additionally, by using straight line depreciation, the user can estimate the annual cost of wear and tear to the equipment. Lines 31 - 38 provide for the computation of annual cash and non-cash expenses.

22. Well

In West Tennessee, drilling a high-production well is expensive and uncertain. The common dollar amount for drilling is $30,000 for a 12-inch diameter, 200-feet deep, 1000-gallon per-minute well. This includes the casing but does not include the pump. Contact a local driller and they will be able to give you an estimate based on location and flowrate required. Most areas in Middle and East Tennessee do not have high-production aquifers, thus the use of wells is rare.

23. Reservoir Pump

This is the cost of the pump – either from a groundwater or surface water source. In general, you can assume that if the pump head is submerged, the pump is a turbine. If the pump is setting next to the water source, it is a centrifugal. The flowrate and pressure was calculated in the General Information Sheet. With these two pieces of information, estimates of pump prices can be obtained from dealers.

24. Power Unit

This represents the cost of providing power to the pump. Pumps are generally powered in one of three different ways: 1) a stationary engine with the pump mounted directly on the engine, 2) tractor or station engine with the pump being driven through a drive-shaft, or 3) an electric motor coupled to the pump. Well pumps are connected to engines via a right-angle drive, while electric motors are mounted vertically over the well. For the purpose of this analysis, the cost of the right-angle drive needs to be included with the cost of the power unit.

Brake-hp was calculated in the Estimate for Power Requirement Form and this value can be used to obtain a cost estimate for a motor or engine with this capability. If the power unit is also going to be used to generate electricity for the drive-towers of a center pivot, then contact a pivot supplier to get an estimate for the extra horsepower required. Even if the pump is pto-driven by an existing tractor, there is a real cost in the accelerated depreciation of the tractor.

25. Miscellaneous

If an electric motor is selected, there are costs associated with conducting power from the main transmission line to the location of the pump. The electric utility will charge the cost of installing the poles, wires and disconnects to the property owner. Consult with the local electric utility to get an estimate for these costs. The utility will need the horsepower requirement of the pump and how far the pump is located from existing power lines.

Fuel tanks and fuel lines may be needed. The prices of these can be found at a local dealer.

If using surface irrigation, equipment such as land planes, ditchers, middle-busters, etc. may be needed to work the soil surface.

26. Water Pipe
An approximate pipe diameter and pressure requirement have been calculated in the Estimation of Power Requirement form. Generally speaking, if the mainline is above ground, it will be coupled aluminum; if it is buried, it will be slip-joint PVC. Aluminum has the advantage of having resell value. Once PVC is buried, it would be cost-prohibitive to recover and resell. PVC has the advantage of being out-of-harm's-way and has less friction loss to overcome. A per-foot cost from either material can be obtained from a pipe dealer. Include an additional $2 per foot as an estimation for installation cost.

27. Pipe Trailer
If coupled-aluminum is purchased, then a pipe trailer is needed for moving and storing pipe. Pipe trailers can purchased new, used or can be shop-made.

28. Sprinkler Systems
If a sprinkler system is going to be employed, select the type of system and enter a cost. A dealer can provide an estimate of the cost based on the type of system and the acreage to be covered.

29. Surface System
A surface-irrigated field must be very flat to permit the uniform distribution of water and to allow for drainage to prevent flooding. The only way to get a good approximation of the cost of land grading is to have a good topographic survey of the field and let a grading contractor estimate the land leveling required.
A district conservationist from the Natural Resources Conservation Service (NRCS) may be able to provide some cost estimates for land shaping.
If the land is already leveled, surface irrigation generally has the least expensive initial cost. Surface irrigation pumps are usually "high-flow, low-head." These pumps are capable of rapidly moving a tremendous volume of water, but not against any pressure. Depending on where the water source is located relative to the field, an inexpensive distribution pipe (polypipe) can be used to spread the water across the field. Vinyl "polypipe" cannot be used to move water uphill, so must be placed on level ground.

Flood gates and water controls are used to maintain a certain depth of water in a field, and/or control the outfall to reduce erosion. Often these devices are made locally out of pressure-treated timbers.

30. Subsurface Drip Irrigation (SDI)
This technology is not common in Tennessee. It is a proven and beneficial method of applying supplemental water to a row crop. However, with SDI, many of the traditional methods of cultivating a crop will need to be modified. Dripperline is placed 8 to 12 inches below the surface and is spaced about every other row. Obviously, deep tillage is no longer an option for that field. There are reports of dripperlines that have been in place for more than 20 years that are still being used.

The major initial costs for SDI include the dripperline, filters, mainline and pump. SDI is a low-pressure technology, so the cost of energy is greatly reduced. High-quality filtration is needed to prevent the emitters from being plugged by sediment and algae. If groundwater is used, the iron in the water can form precipitants that can block emitters. The iron can be removed by oxidation.

The cost of a SDI system can be estimated by a dealer. However, it is important to remember that this method may require different tillage equipment and that adds to the cost of installing the system.

31. Total Investment (initial cost)
Sum all the figures in the initial cost column. This is an estimate of the

up-front money required to install an irrigation system.

32. **Total Annual Depreciation Cost**
Sum all the figures in the annual cost column. This will be an estimate of the loss of value due to wear and tear on the equipment.

33. **Interest**
This is the total investment multiplied by the decimal form of the interest rate. Even if money is not borrowed, this represents the opportunity costs of converting liquid assets into equipment.

34. **Total Annual Noncash Fixed Cost**
This is the sum of Line 32 and Line 33.

35. **Taxes and Insurance**
Taxes and insurance are estimated by multiplying the total investment by 0.02 (2 percent of total investment).

36. **Stand-by or Demand Charges for Electricity**
Stand-by or demand charges only apply if electricity is going to be used. These values will have to be obtained from the electrical utility.

37. **Loss of Income Due to Acreage Out of Production**
An irrigation system may force some land to be taken out of production (access roads, drainage areas, equipment storage areas). This is computed by multiplying the dryland yield (typical yield without irrigation) by the unit value of the yield (Line 3) and multiplying this product by the number of acres lost.

38. **Total Annual Cash Fixed Cost**
The total annual cash fixed cost is the sum of Line 35 through Line 37.

Steps for Completing the Annual Operating Cost Form

The previous section computed the annual fixed costs of the irrigation system. These expenses occur whether the system is operating or left idle in the field. This section estimates the costs of operating the system. The purchase of energy is the most significant annual component of irrigating. Other annual costs for operating the system include maintenance and labor.

39. **Fuel**
Fuel or electricity power consumption is a function of horsepower and length of operation. It is common to use an index value for each energy source. Table 2 is a collection of these index values. These values include the efficiency by which the fuel is converted to useful work. Multiply the brake-hp by the number of hours of operation and by the cost per unit of fuel. Take this product and divide it by the index value for the selected fuel type.

Table 2. Annual Fuel Consumption[2]

Fuel or Power	Efficiency of Motor or Engine	Bhp-hours per Unit of Fuel
Electric	80	1.07 per Kw-Hour
Gasoline	20	9.74 per gallon
Diesel	26	14.3 per gallon
Propane/Butane	21	7.77 per gallon
Natural Gas	21	8.2 per 100 cubic feet

[2]Longenbaugh, R. A. and H. R. Duke. (1981). "Farm pumps." In *Design and Operation of Farm Irrigation Systems*, M. E. Jenson, Editor. ASAE, St. Joseph, MI.

40. Engine Oil
The standard method of estimating the cost of engine lubrication is to multiply the fuel cost by 0.15 (15 percent of fuel cost).

41. Repair and Maintenance (power unit)
Estimation of the cost for repair and maintenance is based on a percentage of the initial cost of the energy source.

42. Repair and Maintenance (irrigation equipment)
The annual cost of repair and maintenance of the irrigation system is approximated as 5 percent of the total initial system cost.

43. Reservoir and Field Maintenance
The annual cost of maintenance of the water reservoir and field is approximated as one-half percent of the total initial cost of the developing the reservoir and/or shaping the field for the irrigation system. Such cost might include permit fees to withdraw water from a surface source, removing trash from the pump intake and re-forming drainage ditches after a heavy rain event.

44. Additional Seed, Fertilizer, Chemicals and Harvesting Costs
Irrigation allows the crop to grow without being limited by soil moisture. To get the maximum productivity, sufficient nutrients, additional pesticides and increased harvesting capacity may be needed.

45. Labor
Line 18 on the General Information Sheet allows for the estimation of the number of hours of labor required per acre. Take this number and multiply it by the number of irrigation events per season (Line 10), the number of irrigated acres (Line 9) and the dollar-per-hour cost of labor.

46. Total Annual Operating Cost
This is the sum total of lines 39 through 45. This value represents the annual cash-flow expense of operating the irrigation system.

Steps for Completing the Return on Investment Form

This section computes the payback period and the return on investment. Most of the lines on this form have already been calculated. Guidance is given as to the location of these values. To simplify the calculation, the user is asked to transfer the previously calculated values and use them in the given equation.

47. Expected Average Increase in Revenue from Irrigation
Multiply the per unit increase in yield from Line 2 and by the dollar value per unit (Line 3) and the irrigated acres (Line 9). This is the annual increase in revenue due to increased crop yield.

48. Total Annual Operating Cost for Irrigation
This value is from Line 46 on the Annual Operating Cost Form.

49. Total Annual Fixed Cost
Sum Lines 34 and 38 on the Initial Investment and Depreciation Cost Form.

50. Total Investment
Transfer this value from Line 31 on the Initial Investment and Depreciation Cost Form.

51. Payback Period
This is a simplified calculation procedure. This calculation ignores interest expense and is a before-tax analysis. With the depreciation, there should be additional tax benefits.

The total investment (Line 50) is divided by the sum of the increase in revenue (Line 47), minus the annual cash fixed cost (Line 49), minus annual operating expense (Line 48).

52. **Return on Investment**
The sum of the total annual cash fixed cost (Line 49) and the total annual operating cost (Line 48) is subtracted from the increase in revenue (Line 47). This value is divided by the total investment (Line 50).

Steps for Completing the Annual Cash Flow Analysis

53. **Percent of Total Investment Financed**
If money is borrowed to purchase irrigation equipment, this is the percent of the total investment that will be financed.

54. **Loan Term, Years**
Number of years to pay back loan.

55. **Annual Principal and Interest Payment**
Based on the number of compounding periods (12 per year) and the interest rate, the formula for the annual payment is given on the form.

56. **Expected Average Increase in Revenue**
From Line 47 on the Return on Investment Form.

57. **Total Annual Operation Cost**
From Line 46 on the Annual Operating Cost Form.

58. **Principal and Interest Payment**
From Line 55 on the Annual Cash Flow Analysis Form.

59. **Total Annual Cash Fixed Cost**
From Line 38 from the Initial Investment and Depreciation Cost.

60. **Annual Net Cash Flow**
Annual increase in revenue minus the annual cash costs (Line 56 minus Line 57 minus Line 58 minus Line 59).

Irrigation Cost Analysis Forms

General Information Sheet

Name: ______________________________ Farm or Field Name: ____________________

County: ____________________________

1. Crop to be irrigated. _______________
2. Expected average increase in yield per acre from irrigation. _______________
3. Value of crop per unit ($/bu or $/lb). _______________
4. Maximum soil water intake rate. _______________
5. Seasonal water consumption by the crop (inches). _______________
6. Peak-use demand rate of the crop. _______________
7. Provide a map with the dimensions of the field. _______________
8. Number of acres in the field. _______________
9. Number of acres to be irrigated. _______________
10. Number of irrigations expected per season. _______________
11. Type of system. _______________
12. Source of water. _______________
13. Length of mainline. _______________
14. Total height that water is to be lifted (feet). _______________
15. Energy source of power unit. _______________
16. Current interest rate. _______________
17. Stand-by charges for electricity or demand-charge for electricity. _______________
18. Hours of labor per acre per irrigation event. _______________

Estimation of Power Requirement Form

19. Flow rate of pump.

For the purpose of this analysis, a ballpark estimate of flow rate is needed. The procedure listed below provides a rough estimate. Flow rate is computed by the following formula, which includes the number of acres irrigated, the hours per day allowed for irrigation, the number of days required to cover the field, the depth of water to be applied and the efficiency of the water application.

19-a) Number of hours of operation per irrigation event ____________________

Table 3 can be used to approximate the number of hours required per irrigation. This table is only a guide. Actual times will vary with soil moisture conditions and infiltration rates.

Table 3. Estimates of hours of operation per irrigation event.[1]

Irrigation method	Typical number of hours	Notes
Center pivots	60 hours	assumes that a full circle is being irrigated
Traveling guns	96 hours	assumes 16 hours per day and six days
Surface irrigation	48 hours	
Subsurface drip irrigation	48 hours	
Hand-moved	100 hours	
Permanent solid set	48 hours	

[1]Center pivots can operate with a minimal amount of supervision, while traveling guns need almost constant attention. Other considerations include whether disease problems will occur if the crop is irrigated at night. The maximum number of hours per day should be limited to 23 to allow for maintenance of the system.

19-b) Depth of water applied (inch) ____________________

Unless better information is available, assume 1 inch is going to be applied during each irrigation event.

19-c) Acres irrigated (Line 9) ____________________

19-d) Application efficiency ____________________

Common application efficiencies include:

- 0.95 for subsurface drip
- 0.85 for center pivots, linear moves, wheel-roll and solid set
- 0.70 for traveling guns
- 0.40 for surface-flood
- 0.30 for furrow irrigation

19e Determination of flow Rate Chart

Insert the above numbers into the flow rate equation.

$$\text{flowrate} = \frac{\text{volume}}{\text{time}} = \frac{\text{depth applied (in)} \times \text{acres irrigated} \times 453}{\text{(hours per irrigation)} \times \text{decimal efficiency}} = \text{gpm}$$

$$\text{gpm} = \frac{(\qquad\qquad)\text{ in} \times (\qquad\qquad)\text{ acres} \times 453}{(\qquad\qquad)\text{ hrs} \times (\qquad\qquad)\text{ efficiency}} = \underline{\qquad\qquad}$$

For example: If 1 inch is to be applied, the system runs for 16 hours per day, it takes 3 days to cover the 60-acre field, and the application efficiency is 80 percent (0.80), then the minimum pumping rate is 708 gallons per minute (gpm). The "453" is a unit conversion constant.

20. Determine the pressure required by the pump

20-a) Determine the pipe diameter ____________________

An estimate of the diameter of the mainline is required. The goal is to size the pipe to keep the velocity of water inside the pipe at approximately 5 feet per second (fps). Pipe tables are included in this handbook. Use the tables to find the pipe diameter that will have a velocity at 5 fps at the flow rate determined in 19e. Tables for coupled-aluminum, Class 125 PVC and Schedule 40 PVC are also included in this handbook. The selection of Class 125, Class 200 and Schedule 40 PVC depends on the pressure requirements of the pipe. For the purpose of this economic analysis, assume Class 200 PVC for buried pipe and coupled-aluminum for above-ground pipe.

For example: If the flowrate is 708 gpm, from the Class 200 PVC table, a 8-inch nominal diameter pipe is required.

20-b) How many feet of mainline will be required? ____________________

From Line 13

20-c) What is the pressure drop across the mainline? ____________________

From the pipe tables, determine the psi loss per 100 feet. Take this value and multiply it by the number of 100-foot sections in the mainline.

For example: 2,200 feet of 8-inch diameter Class 200 PVC is needed to supply two traveling guns being fed from a creek. Each traveling gun is spraying 350 gpm. In the table for Class 200 PVC and 700 gpm, the psi loss is 0.36 psi per 100 feet. In this case, the friction loss is 22 times 0.36 psi or 8.0 psi.

20-d) Convert the static head to psi. ______________________

Take the height (in feet) that water is being lifted and divide by 2.31 to get psi.

For example: Assume that there is 40 feet of elevation difference from the creek to the top of the gun cart when the traveler is in the highest part of the field.

40 feet divided by 2.31feet/psi equals 17.3 psi

20-e) What is the pressure required at the sprayer system?______________________

Most modern center pivots require 30 to 40 psi at the pivot. Most traveling gun systems (both hard-hose and soft-hose) require 100 to 120 psi at the reel. Wheel rolls, solid set and hand-move generally have impact-sprinklers that require 50 psi.

20-f) From 20 c-d-e, sum the pressure the pump has to work against.

Friction loss (psi)	________________
Static head (psi)	________________
Sprayer pressure (psi)	________________
Total head (psi)	________________

21. Determine the brake-horsepower of the pump motor/engine

21-a) Estimate the water horsepower required to move the water.

Water horsepower is the theoretical power required to move a volume of water per unit time against a given pressure. The flow rate (gpm) is from Line 19e and the total pressure (head) is from Line 20f.

$$\text{Whp} = \frac{\text{gpm} \times \text{total head}}{1{,}714.3} = \frac{(\qquad)\ \text{gpm} \times (\qquad)\ \text{psi}}{1{,}714.3} = \underline{\qquad\qquad}$$

21-b) Compute the brake-horsepower.

Brake-horsepower is the power required to drive the pump. It is calculated by dividing the Whp (Line 21a) by the efficiency of the pump. The pump efficiency is pump-specific and a pump has not be selected. A value of 60 percent has been assumed for the pump efficiency. The goal of the irrigation designer will be to find a higher efficiency pump.

Brake hp = (water hp) ÷ (decimal pump efficiency)

Brake hp = (   ) ÷ (0.60) = ________________

Initial Investment and Depreciation Cost Form

Use straight line depreciation

Line	Estimated Years of Life	Initial Cost	Annual Cost (divide initial cost by years of service)
22. Well			
Casing			
8 and 10 gage	25+	$ ________	$ ________
12 gage	15	$ ________	$ ________
3/16 inch	25+	$ ________	$ ________
concrete	25+	$ ________	$ ________
23. Reservoir Pump			
Line shaft propeller	10	$ ________	$ ________
Turbine	20	$ ________	$ ________
Centrifugal	20	$ ________	$ ________
24. Power Unit			
Electrical	25	$ ________	$ ________
Gasoline	9	$ ________	$ ________
Diesel	14	$ ________	$ ________
Natural gas, LP or propane	14	$ ________	$ ________
25. Miscellaneous			
Electrical disconnect	20	$ ________	$ ________
Gas line			
Iron	20	$ ________	$ ________
Plastic	18	$ ________	$ ________
Fuel tank			
Propane	20	$ ________	$ ________
Diesel or gasoline	18	$ ________	$ ________
Land plane	15	$ ________	$ ________
26. Water Pipe			
Underground pipe: (include trench cost)			
Concrete	40	$ ________	$ ________
Steel (waterworks class)	40	$ ________	$ ________
Asbestos cement	40	$ ________	$ ________
Plastic	40	$ ________	$ ________
Above-ground pipe:			
Aluminum	15	$ ________	$ ________
Galvanized steel	15	$ ________	$ ________
27. Pipe Trailer	10	$ ________	$ ________

Initial Investment and Depreciation Cost Form (cont.)

Line	Estimated Years of Life	Initial Cost	Annual Cost (divide initial cost by years of service)
28. Sprinkler Systems			
Hand-moved (coupled aluminum pipe)	15	$ ________	$ ________
Self-moved (hard-hose reel, wheel roll)	15	$ ________	$ ________
Tractor-moved (cable-tow)	10	$ ________	$ ________
Self-propelled (center pivot, linear move)	20	$ ________	$ ________
Permanent solid set	20	$ ________	$ ________
29. Surface System			
Land grading	20	$ ________	$ ________
Distribution equipment			
Gated aluminum	15	$ ________	$ ________
Polypipe	1	$ ________	$ ________
Flood gates and controls	5	$ ________	$ ________
30. Subsurface Drip Irrigation System			
Stainless steel filters	25+	$ ________	$ ________
Manifold and valves	10	$ ________	$ ________
Dripper lines	20	$ ________	$ ________

31. Total Investment (Initial Cost)	sum of left column	$ ________
32. Total Annual Depreciation Cost	sum of right-column, Lines 22 through 30	$ ________
33. Interest	total investment × decimal interest rate	$ ________
34. Total Annual Noncash Fixed Cost	Line 32 plus Line 33	$ ________
35. Taxes and insurance	total investment x 0.02	$ ________
36. Stand-by or demand charges for electricity		$ ________
37. Loss of income due to acreage removed from production	________ dryland yield per acre × $ ________ per crop unit × ______ number of acres lost	$ ________
38. Total Annual Cash Fixed Cost	sum Lines 35 through 37	$ ________

Annual Operating Cost Form

Line					Total
	Horsepower Required	Number of Hours Operated	Cost per Unit of Fuel	Bhp-Hrs per Unit of Fuel	
39. Fuel or power	________	× ________	× ________	÷ ________	$ ________
40. Lubrication	0.15 × dollars spent on fuel				$ ________
41. Repair and maintenance (power unit)	Initial cost of power unit × ____ 0.020 for electric 0.066 for diesel 0.070 for gasoline 0.055 for propane 0.055 natural gas				$ ________
42. Repair and maintenance (irrigation equipment)	Initial cost of irrigation equipment × 0.005 $ ________ initial cost × 0.005				$ ________
43. Reservoir and field maintenance	Initial cost of developing reservoir × 0.005 $ ________ initial cost × 0.005				$ ________
44. Additional seed, fertilizer, chemicals and harvesting cost	$ ________ anticipated additional expense per acre × the number of acres				$ ________
45. Labor	________ hours per acre per irrigation × the number of irrigations × the number of acres × the $ ________ per hour.				$ ________
46. Total Annual Operating Cost	sum Lines 39 through 45				$ ________

Return on Investment Form

Line	Total
47. Expected average increase in revenue	
_____ increase in yield per acre (Line 2) × $ _______ per unit (Line 3) × _______ acres (Line 9).	$ __________
48. Total Annual Operating Cost	
transfer from Line 46	$ __________
49. Total Annual Fixed Cost	
sum of Line 34 and Line 38	$ __________
50. Total Investment	
transfer from Line 31	$ __________
51. Payback Period (years)	
$\frac{\text{total investment}}{\text{(annual increase in revenue - (annual operating cost) - (annual cash fixed cost)}}$	__________ yrs.
52. Return on Investment	
$\frac{\text{(annual increase in revenue - (annual operating cost) - (annual cash fixed cost)}}{\text{total investment}}$	__________%

Annual Cash Flow Analysis Form

Item		
53. Percent of total investment financed	________ %	
54. Loan term, years	________ years	
55. Annual principal and interest payment		

$$\text{P \& I Payment} = \left[\frac{\text{total investment} \times \text{decimal percent financed}}{\left[\frac{1 - (1 + i)^{-n}}{i} \right]} \right]$$

where: i is the decimal interest rate
n is the number of compounding periods

56. Expected average increase in revenue	from Line 47	$ ________
57. Total annual operating cost	from Line 46	$ ________
58. Principal and interest payment	from Line 47	$ ________
59. Total annual cash fixed cost	from Line 47	$ ________
60. Annual Net Cash Flow	Line 56 minus Line 57 minus Line 58 minus Line 59	$ ________

Friction Loss: Class 160 U. S. PVC Plastic Pipe - pressure loss in psi per 100 feet of pipe.														
Nominal Pipe ID Pipe OD	**2"** 2.193 2.375		**2-1/2"** 2.655 2.875		**3"** 3.230 3.500		**4"** 4.154 4.500		**6"** 6.115 6.625		**8"** 7.961 8.625		**10"** 9.924 10.750	
Flow GPM	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS
10	0.07	0.85	0.03	0.58	-	-	-	-	-	-	-	-	-	-
20	0.24	1.70	0.09	1.16	-	-	-	-	-	-	-	-	-	-
30	0.51	2.55	0.20	1.74	0.08	1.18	-	-	-	-	-	-	-	-
40	0.86	3.40	0.34	2.32	0.13	1.57	-	-	-	-	-	-	-	-
50	1.30	4.25	0.51	2.90	0.20	1.96	-	-	-	-	-	-	-	-
60	1.82	5.10	0.72	3.48	0.28	2.35	-	-	-	-	-	-	-	-
70	2.43	5.95	0.96	4.06	0.37	2.74	0.11	1.66	-	-	-	-	-	-
80	3.11	6.80	1.23	4.64	0.47	3.13	0.14	1.89	-	-	-	-	-	-
90	-	-	1.52	5.22	0.59	3.53	0.17	2.13	-	-	-	-	-	-
100	-	-	1.85	5.80	0.71	3.92	0.21	2.37	-	-	-	-	-	-
120	-	-	2.60	6.96	1.00	4.70	0.29	2.84	0.04	1.31	-	-	-	-
140	-	-	-	-	1.33	5.48	0.39	3.32	0.06	1.53	-	-	-	-
160	-	-	-	-	1.70	6.27	0.50	3.79	0.08	1.75	-	-	-	-
180	-	-	-	-	2.12	7 05	0.62	4.26	0.09	1.97	-	-	-	-
200	-	-	-	-	-	-	0.76	4.74	0.12	2.19	-	-	-	-
220	-	-	-	-	-	-	0.90	5.21	0.14	2.40	-	-	-	-
240	-	-	-	-	-	-	1.06	5.68	0.16	2.62	-	-	-	-
260	-	-	-	-	-	-	1.23	6.16	0.19	2.84	-	-	-	-
280	-	-	-	-	-	-	1.41	6.63	0.22	3.06	-	-	-	-
300	-	-	-	-	-	-	1.61	7.11	0.24	3.28	0.07	1.93	-	-
320	-	-	-	-	-	-	-	-	0.28	3.50	0.08	2.06	-	-
340	-	-	-	-	-	-	-	-	0.31	3.72	0.09	2.19	-	-
360	-	-	-	-	-	-	-	-	0.34	3.93	0.09	2.32	-	-
380	-	-	-	-	-	-	-	-	0.38	4.15	0.10	2.45	-	-
400	-	-	-	-	-	-	-	-	0.42	4.37	0.12	2.58	-	-
450	-	-	-	-	-	-	-	-	0.52	4.92	0.14	2.90	-	-
500	-	-	-	-	-	-	-	-	0.63	5.46	0.17	3.22	0.06	2.07
550	-	-	-	-	-	-	-	-	0.75	6.01	0.21	3.55	0.07	2.28
600	-	-	-	-	-	-	-	-	0.88	6.56	0.24	3.87	0.08	2.49
650	-	-	-	-	-	-	-	-	1.02	7.10	0.28	4.19	0.10	2.70
700	-	-	-	-	-	-	-	-	1.17	7.65	0.33	4.51	0.11	2.90
750	-						-	-	1.33	8.20	0.37	4.84	0.13	3.11
800	-						-	-	-	-	0.42	5.16	0.14	3.32
850	-						-	-	-	-	0.47	5.48	0.16	3.53
900	-						-	-	-	-	0.52	5.80	0.18	3.73
950	-						-	-	-	-	0.57	6.13	0.20	3.94
1000	-						-	-	-	-	0.63	6.45	0.22	4.15
1100	-	-	-	-	-	-	-	-	-	-	0.75	7.09	0.26	4.56
1200	-	-	-	-	-	-	-	-	-	-	0.88	7.74	0.30	4.98
1400	-	-	-	-	-	-	-	-	-	-	-	-	0.40	5.81
1600	-	-	-	-	-	-	-	-	-	-	-	-	0.51	6.64
1800	-	-	-	-	-	-	-	-	-	-	-	-	0.64	7.47
2000	-	-	-	-	-	-	-	-	-	-	-	-	0.78	8.170

Friction losses calculated with the Hazen-Williams Equation with C = 150

Friction Loss: Class 200 U. S. PVC Plastic Pipe - pressure loss in psi per 100 feet of pipe.														
Nominal Pipe ID Pipe OD	2" 2.149 2.375		2-1/2" 2.601 2.875		3" 3.166 3.500		4" 4.072 4.500		6" 5.993 6.625		8" 7.805 8.625		10" 9.728 10.750	
Flow GPM	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS
10	0.07	0.88	0.03	0.60	-	-	-	-	-	-	-	-	-	-
20	0.26	1.77	0.10	1.21	-	-	-	-	-	-	-	-	-	-
30	0.56	2.65	0.22	1.81	0.08	1.22	-	-	-	-	-	-	-	-
40	0.95	3.54	0.38	2.42	0.14	1.63	-	-	-	-	-	-	-	-
50	1.44	4.42	0.57	3.02	0.22	2.04	-	-	-	-	-	-	-	-
60	2.01	5.31	0.80	3.62	0.31	2.45	-	-	-	-	-	-	-	-
70	2.68	6.19	1.06	4.23	0.41	2.85	0.12	1.73	-	-	-	-	-	-
80	3.43	7.08	1.35	4.83	0.52	3.26	0.15	1.97	-	-	-	-	-	-
90	-	-	1.69	5.44	0.65	3.67	0.19	2.22	-	-	-	-	-	-
100	-	-	2.05	6.04	0.79	4.08	0.23	2.46	-	-	-	-	-	-
120	-	-	2.87	7.25	1.10	4.89	0.32	2.96	0.05	1.37	-	-	-	-
140	-	-	-	-	1.47	5.71	0.43	3.45	0.07	1.59	-	-	-	-
160	-	-	-	-	1.88	6.52	0.55	3.94	0.08	1.82	-	-	-	-
180	-	-	-	-	2.34	7.34	0.69	4.44	0.10	2.05	-	-	-	-
200	-	-	-	-	-	-	0.83	4.93	0.13	2.28	-	-	-	-
220	-	-	-	-	-	-	1.00	5.42	0.15	2.50	-	-	-	-
240	-	-	-	-	-	-	1.17	5.92	0.18	2.73	-	-	-	-
260	-	-	-	-	-	-	1.36	6.41	0.21	2.96	-	-	-	-
280	-	-	-	-	-	-	1.56	6.90	0.24	3.19	-	-	-	-
300	-	-	-	-	-	-	1.77	7.39	0.27	3.41	0.07	2.01	-	-
320	-	-	-	-	-	-	-	-	0.30	3.64	0.08	2.15	-	-
340	-	-	-	-	-	-	-	-	0.34	3.87	0.09	2.28	-	-
360	-	-	-	-	-	-	-	-	0.38	4.10	0.10	2.42	-	-
380	-	-	-	-	-	-	-	-	0.42	4.32	0.12	2.55	-	-
400	-	-	-	-	-	-	-	-	0.46	4.55	0.13	2.68	-	-
450	-	-	-	-	-	-	-	-	0.57	5.12	0.16	3.02	-	-
500	-	-	-	-	-	-	-	-	0.69	5.69	0.19	3.35	0.07	2.16
550	-	-	-	-	-	-	-	-	0.83	6.26	0.23	3.69	0.08	2.38
600	-	-	-	-	-	-	-	-	0.97	6.83	0.27	4.03	0.09	2.59
650	-	-	-	-	-	-	-	-	1.13	7.40	0.31	4.36	0.11	2.81
700	-	-	-	-	-	-	-	-	1.30	7.97	0.36	4.70	0.12	3.02
750	-	-	-	-	-	-	-	-	1.47	8.53	0.41	5.03	0.14	3.24
800	-					-	-	-	-	-	0.46	5.37	0.16	3.46
850	-					-	-	-	-	-	0.51	5.70	0.18	3.67
900	-					-	-	-	-	-	0.57	6.04	0.20	3.89
950	-					-	-	-	-	-	0.63	6.37	0.22	4.10
1000	-					-	-	-	-	-	0.69	6.71	0.24	4.32
1100	-	-	-	-	-	-	-	-	-	-	0.83	7.38	0.28	4.75
1200	-	-	-	-	-	-	-	-	-	-	0.97	8.05	0.33	5.18
1400	-	-	-	-	-	-	-	-	-	-	-	-	0.44	6.05
1600	-	-	-	-	-	-	-	-	-	-	-	-	0 57	6.91
1800	-	-	-	-	-	-	-	-	-	-	-	-	0.71	7.77
2000	-	-	-	-	-	-	-	-	-	-	-	-	0.86	8.64

Friction losses calculated with the Hazen-Williams Equation with C = 150

Friction Loss: Portable aluminum pipe with couplings - pressure loss in psi per 100 feet of pipe.

Nominal Pipe ID Pipe OD	**2"** 1.914 2.000		**3"** 2.914 3.000		**4"** 3.906 4.000		**5"** 4.896 5.000		**6"** 5.884 6.000		**7"** 6.872 7.000		**8"** 7.856 8.000		**10"** 9.818 10.000	
Flow GPM	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS
10	0.33	1.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	1.19	2.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	2.52	3.35	0.33	1.44	-	-	-	-	-	-	-	-	-	-	-	-
40	4.30	4.46	0.56	1.93	-	-	-	-	-	-	-	-	-	-	-	-
50	6.50	5.58	0.84	2.41	-	-	-	-	-	-	-	-	-	-	-	-
60	9.11	6.69	1.18	2.89	-	-	-	-	-	-	-	-	-	-	-	-
70	12.12	7.81	1.57	3.37	0.38	1.88	0.13	1.19	-	-	-	-	-	-	-	-
80	15.52	8.93	2.01	3.85	0.48	2.14	0.16	1.36	-	-	-	-	-	-	-	-
90	19.30	10.04	2.50	4.33	0.60	2.41	0.20	1.53	-	-	-	-	-	-	-	-
100	23.46	11.16	3.03	4.81	0.73	2.68	0.24	1.71	-	-	-	-	-	-	-	-
120	-	-	4.25	5.78	1.02	3.21	0.34	2.05	0.14	1.42	-	-	-	-	-	-
140	-	-	5.66	6.74	1.36	3.75	0.45	2.39	0.19	1.65	-	-	-	-	-	-
160	-	-	7.25	7.70	1.74	4.29	0.58	2.73	0.24	1.89	-	-	-	-	-	-
180	-	-	9.01	8.66	2.17	4.82	0.72	3 07	0.30	2.12	0.14	1.56	-	-	-	-
200	-	-	-	-	2.63	5.36	0.88	3.41	0.36	2.36	0.17	1.73	-	-	-	-
220	-	-	-	-	3.14	5.89	1.05	3.75	0.43	2.60	0.20	1.90	-	-	-	-
240	-	-	-	-	3.69	6.43	1.23	4.09	0.50	2.83	0.24	2.08	-	-	-	-
260	-	-	-	-	4.28	6.96	1.43	4.43	0.58	3.07	0.27	2.25	-	-	-	-
280	-	-	-	-	4.91	7.50	1.64	4.77	0.67	3.31	0.31	2.42	-	-	-	-
300	-	-	-	-	5.58	8.04	1.86	5.12	0.76	3.54	0.36	2.60	0.19	1.99	-	-
320	-	-	-	-	-	-	2.09	5.46	0.86	3.78	0.40	2.77	0.21	2.12	-	-
340	-	-	-	-	-	-	2.34	5.80	0.96	4.01	0.45	2.94	0.23	2.25	-	-
360	-	-	-	-	-	-	2.61	6.14	1.07	4.25	0.50	3.12	0.26	2.38	-	-
380	-	-	-	-	-	-	2.88	6.48	1.18	4.49	0.55	3.29	0.29	2.52	-	-
400	-	-	-	-	-	-	3.17	6.82	1.29	4.72	0.61	3.46	0.32	2.65	-	-
450	-	-	-	-	-	-	3.94	7.67	1.61	5.31	0.76	3.89	0.39	2.98	-	-
500	-	-	-	-	-	-	4.79	8.53	1.96	5.90	0.92	4.33	0.48	3.31	0.16	2.12
550	-	-	-	-	-	-	5.71	9.38	2.33	6.49	1.10	4.76	0.57	3.64	0.19	2.33
600	-	-	-	-	-	-	-	-	2.74	7.08	1.29	5.19	0.67	3.97	0.23	2.54
650	-	-	-	-	-	-	-	-	3.18	7.67	1.49	5.63	0.78	4.30	0.26	2.76
700	-	-	-	-	-	-	-	-	3.65	8.26	1.71	6.06	0.89	4.64	0.30	2.97
750	-						-	-	4.15	8.85	1.95	6.49	1.02	4.97	0.34	3.18
800	-						-	-	-	-	2.20	6.92	1.14	5.30	0.39	3.39
850	-						-	-	-	-	2.46	7.36	1.28	5.63	0.43	3.60
900	-						-	-	-	-	2.73	7.79	1.42	5.96	0.48	3.82
950	-						-	-	-	-	-	-	1.57	6.29	0.53	4.03
1000	-	-	-	-	-	-	-	-	-	-	-	-	1.73	6.62	0.58	4.24
1100	-	-	-	-	-	-	-	-	-	-	-	-	2.07	7.28	0.70	4.66
1200	-	-	-	-	-	-	-	-	-	-	-	-	2.43	7.95	0.82	5.09
1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.09	5.94
1600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.40	6.78
1800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.74	7.63
2000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.11	8.48

Friction losses calculated with the Hazen-Williams Equation with C = 90

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COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS
The University of Tennessee Institute of Agriculture, U.S. Department of Agriculture,
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Charles L. Norman, Dean