Proceedings of the 32nd Annual Central Plains Irrigation Conference, Kearney, NE, Feb.18-19, 2020
Available from CPIA, 760 N. Thompson, Colby, Kansas

IRRIGATION PUMPING PLANT CALCULATOR

J Schneekloth
Water Resources Spec
Joel.Schneekloth@Colostate.Edu
Colorado State University
Akron, Colorado
(970) 345-2259

L Wheeler
Lee Wheeler Eng.
leeawheeler@gmail.com
Hesston, KS

Introduction

Irrigation costs can be one of the highest input costs in irrigated agriculture. Efficient use of water includes irrigation scheduling to minimize the amount of water applied to the crop. Another factor is the efficiency of the pumping plant and the irrigation system itself. Everything within the irrigation system ties within itself for an efficient system and minimizing operating costs.

The Irrigation Pumping Plant Calculator was based upon the IRRICOST calculator developed by the University of Nebraska Lincoln (www.lancaster.unl.edu/ag/crops/irrigate.shtml). Irricost calculated the annualized cost of owning and operating an irrigation system. This spreadsheet was useful in comparison of energy costs of alternative sources as well as looking at potential costs of installing a new system. It did not look at the comparison of current costs and potential savings directly.

Energy Requirements

Energy is the largest cost in operating an irrigation system (Martin et al. There are several factors that go into the energy requirements for pumping. The main factors are 1) lift, 2) pressure and 3) efficiency of the pumping plant. The main calculation for determining energy requirements is Total Dynamic Head (ft) which incorporates lift, pressure and friction losses.

Lift is one factor that is generally not manageable in most systems and can be the major energy requirement. Every foot of lift is equivalent to 0.43 psi or 2.31 ft of water is equal to 1 psi of pressure. The only time where lift can be manipulated is with over capacity systems, lowering irrigation design capacity can decrease lift.

Once the total dynamic head is calculated, it can then be converted to water horsepower (wHp) which is the amount of work needed to lift and pressurize the system and then to brake horsepower (bHp) which is the engine requirement.

Overall Calculator

The calculator is an excel based spreadsheet which allows producers to input information to allow for the comparison of current operating conditions of the pumping plant system and several key conditions of the center pivot system. This will allow producers to make educated decisions as to potential upgrades to the irrigation pumping plant or irrigation system on an economic basis. There are six sheets for the calculator: Opening page, Preface, Instructions, Input, Output and References.

The preface gives the producer an overall guide to how the pumping plant works in conjunction with the irrigation system. The next sheet is the instructions. This gives the producer the proper data to collect and the correct units to input within the input sheet.

Inputs

The inputs sheet is broken into several sections that cover the field, well information, current operating conditions, economic information on the well system itself, past irrigation costs along with energy consumption of the current system. This input section also allows you to enter alternative energy sources and costs that are associated with those alternative energy source to make economic comparisons of either electric, natural gas or diesel for operating costs.

The field ID will allow the producer to enter the field location/name as well as the permit and allotted water rights information. The field information is the current irrigated acres which may be different from the permitted acres. The average irrigation applied will be calculated by the past 3 years of operating conditions.

Well information can be collected by the well log. The well log will have the depth of the well, where the screens are located within the well as well as original static water level, pumping water level and pumping capacity at the test when the well was installed. This information is important and is utilized in the output sheet to show original well conditions for a comparison to the current well conditions.

The current information for static water level and pumping water level is important information and needs to be as correct as possible. This information will show the current well operating condition as compared to the original well operating conditions. The current pumping water level is also important in calculating the horsepower requirements as well as energy requirements to lift the water to the irrigation system.

The irrigation system information is the design flow rate for the sprinkler package as well as the operating pressure that the system is designed for. This information can be found on the sprinkler package design sheets that were given to you for that sprinkler package. The original flow rate can be found on the well log.

The next section is the operational information. These are the current operating conditions of the system and well output. The flow rate of the well should be a timed measurement if you have a meter on the system. Do not utilize the needle as the accuracy of this is not good enough. To get the average flow rate, do a timed test with the accumulator. There are several locations to take pressure for monitoring the system operation. Places to take pressure are at the well, at the base of the pivot, at the top of the pivot point and at the end of the pivot. You should also note the pressure regulator that is located at the last span of the pivot.

Inputs for Determining Annualized Energy Cost of Operating an Irrigation System

Field ID			
	Name		
	Location	Burlington	
	Permitted acres	320	
	Permitted Water	400	
	Well Permit #		
Field Information			
	Acres Irrigated	217.00	
	Average Gross Depth applied, inches	14.2	
	Return on Invest. (R.O.I), %	5%	
Well Information		**Current Reading**	**Original Condition**
	Depth of Well, ft	335	
	Static Water Level, ft	238	238
	Pumping water level, ft.	301	295
	Screening depth - Top, ft	277	
	Screening depth - Bottom, ft	335	
Irrigation System Information			
	Design Flowrate, gpm	500	625
	Design Pressure, psi	20	
Operational Information			
	System Flowrate - meter, gpm	479	
	System Pressure at well, PSI	19	
	System Pressure at base of pivot , PSI	24	
	System pressure on top of pivot, PSI	18	
	System pressure at end of pivot, PSI	9	
	Pressure Regulators, PSI	10	

Figure 1. Input page of calculator with field, well and system information.

Figure 2 shows the economic input into the calculator. These are the infrastructure costs that are associated with a pumping plant as well as the past 3 years of energy costs associated with the pumping plant. The past 3 years of costs are important as pumping amounts can change depending upon weather/precipitation. If the base costs associated with an energy source are relatively high and fixed, years with low pumping can increase the average cost per acre-inch pumped. Utilizing more than 1 year will even those associated costs.

Electric Motor				
	Initial Cost	Life	Salvage	
Irrigation Pump	$ 25,000.00	25	$ 1,250.00	
Gear Head	$ -	15	$ -	
Pump Base, etc.	$ 1,000.00	25	$ 50.00	
Electric Motor and Switches	$ 5,000.00	30	$ 250.00	
Diesel Engine				
	Initial Cost	Life	Salvage	
Irrigation Pump	$ 25,000.00	25	$ 1,250.00	
Gear Head	$ 2,800.00	15	$ 140.00	
Pump Base, etc.	$ 1,100.00	25	$ 55.00	
Diesel Engine & Tank	$ 11,500.00	12	$ 575.00	
Natural Gas Engine				
	Initial Cost	Life	Salvage	
Irrigation Pump	$ 25,000.00	25	$ 1,250.00	
Gear Head	$ 2,800.00	15	$ 140.00	
Pump Base, etc.	$ 1,100.00	25	$ 55.00	
Natural Gas Engine	$ 8,000.00	6	$ 400.00	
Average Electric Cost	*Utilize the last 3 years of usage and total paid including hook up/meter charges*			
Irrigation Pumping	2 years ago	Previous	Current Year	Average
Acres Irrigated	217	217	217	217.00
Ac-Ft applied (total)	231.64	271.13	267.34	256.70
Water Pump ac-in/ac	12.81	14.99	14.78	14.20
Total Charges	$ 13,983	$ 15,347	$ 15,743	$ 15,024
kWh	134,123	160,688	158,734	151,182
$ per kWh	$ 0.10	$ 0.10	$ 0.10	$ 0.099
$/kWh	$ 0.099	*If you do not have previous energy usage for this, enter an estimated value per unit of energy*		

Figure 2. Input page of calculator with economic input.

System Output

The system output sheet is where comparisons of your current irrigation system/pumping plant operating conditions are compared to what the design and optimal energy input. This sheet will give you ideas of where to improve the system and pumping plant to improve irrigation application and operating costs.

The first section (Figure 3) looks at the current well output compared to the original output. This comparison is made with the gpm per foot of drawdown. This will show the potential degradation of the output that could be due to several factors. In many regions, declining groundwater levels will potentially decrease the output per foot of drawdown and show the future output of the well if declines continue. Second is the potential for plugging. If groundwater levels are not declining within your region, severe declines in the output per foot of drawdown can show clogging issues with the screening of the well which may dictate remediation. A second comparison can show the impact to drawdown if the system capacity is adjusted. If well output is decreased by a new design, lift can be estimated by this component and entered for a new operating conditions.

Field ID	0	
Well Performance	Compare to well driller log for original conditions	
Current GPM per ft drawdown	7.60 fair	Well Performance Ranges - Pumping Rate per ft of Drawdown
Original GPM per ft drawdown	10.96 fair	<5 Poor; 5 -20 Ok; 20 -50 Good; >50 Excellent
Information that is relevant to the system performance. Please look at these potential issues regarding pressure differences and design flow vs measured flow that can be fixed before looking at switching pumping plant/energy sources.		
Pressures difference that are negative may result in irrigation uniformity issues that well result in inefficient water applications. **Pressure differences that are positive may result in excessive energy usage.**		
Potential Pressure Issues		
End of pivot minus pressure regulator (PSI)	-6	Minor Low Pressure Issues
Design Pressure vs observed Top of Pivot (PSI)	-2	Pressure adequate
Design Flow vs measured flow (gpm)	21	nozzle package design greater than meter flow
Water Horsepower	41.7	Useful work that the pump is doing at these conditions
Brake Horsepower	55.5	Compare to the name plate horsepower - Calculated should not be greater than the name plate hp. Optimum conditions for electric motor is to not exceed the brake hp on the name plate.

Figure 3. Operational output for the well and irrigation system.

The next section shows potential operating condition issues related to the current operating pressures vs the design pressures and well output. Comparison of operating pressures at the end of the pivot and top of the pivot vs design pressures can show if your system is operating efficiently and economically. Pressures lower than the design pressure can indicate uniformity issues. Portions of the field may be receiving less than water than what the operator is wanting. Is this area within the area where soil moisture monitoring equipment is located? If so, then less water applied is indicating the producer to irrigate more which can then be over irrigating areas of the field. Comparison of the design outflow and operating pressure can also show the potential for replacement of the sprinkler package due to worn components. Higher flowrates than design while still maintaining design pressures can indicate that sprinklers or leaks are a problem with the system and maintenance, or replacement is needed.

Finally, the next section shows the calculated horsepower at the operating conditions, this will allow for the producer to choose the proper motor size for greatest efficiency. This can also lower operating costs as many times with electric motors, there is a charge for peak demand which is based upon the name plate horsepower.

Operating and ownership costs are important in economics of irrigation. The calculator estimates the operating costs based upon the Nebraska Pumping Plant Standards (Figure 4). The calculator can show the operating costs (energy) and ownership costs of the irrigation system based upon 3 different energy sources that may be available. Inclusion of the ownership costs is important when considering energy source changes as well as operating costs of that energy source. When making changes in an energy source, new equipment may be needed such as the gear head and new motor. There is also additional infrastructure costs that may be associated with developing a new energy source that also need to be considered.

Based on Nebraska Standard

Costs based upon delivery of energy source is currently in position. Added costs will be incurred if infrastructure is needed to deliver energy to well. Labor costs are not factored into the total costs of operating.

	Ownership Costs			Operating Costs			
Electric Motor	R.O.I.	Insurance + tax	Depreciation	Repairs	Electric	Energy $	Total Costs
	Cost				kW-hr		
Irrigation Pump	$ 656.25	$ 250.00	$ 950.00	$1,240.07			$ 3,096.32
Gear Head	$ -	$ -	$ -	$ -			$ -
Pump Base, etc.	$ 26.25	$ 10.00	$ 38.00	$ 30.80			$ 105.05
Electric Motor and Switches	$ 131.25	$ 50.00	$ 158.33	$ 308.04	136417	$ 13,557.00	$ 14,204.62
Infrastructure Cost							$ -
Total Costs							$ 17,406.00
						Cost per ac-in	$ 5.65

	Ownership Costs			Operating Costs			
Natural Gas Motor	R.O.I.	Insurance + tax	Depreciation	Repairs	Natural Gas	Energy $	Total Costs
	Cost				MCF		
Irrigation Pump	$ 656.25	$ 250.00	$ 950.00	$1,240.07			$ 3,096.32
Gear Head	$ 73.50	$ 28.00	$ 177.33	$ 71.88			$ 350.71
Pump Base, etc.	$ 28.88	$ 11.00	$ 41.80	$ 33.88			$ 115.56
Natural Gas Engine	$ 210.00	$ 80.00	$ 1,266.67	$ 492.87	1810	$ 9,050.13	$ 11,099.67
Infrastructure Cost							$ 943.93
Total Costs							$ 15,606.19
						Cost per ac-in	$ 5.07

	Ownership Costs			Operating Costs			
Diesel Engine	R.O.I.	Insurance + tax	Depreciation	Repairs	Diesel	Energy $	Total Costs
	Cost				gallons		
Irrigation Pump	$ 656.25	$ 250.00	$ 950.00	$1,240.07			$ 3,096.32
Gear Head	$ 73.50	$ 28.00	$ 177.33	$ 71.88			$ 350.71
Pump Base, etc.	$ 28.88	$ 11.00	$ 41.80	$ 33.88			$ 115.56
Diesel engine & tank	$ 301.88	$ 115.00	$ 910.42	$ 708.50	9658	$ 24,145.75	$ 26,181.54
Infrastructure Cost							$ 283.18
Total Costs							$ 30,027.32
						Cost per ac-in	$ 9.75

Figure 4. Calculated operating and ownership costs of an irrigation system with 3 potential energy sources.

The final section of the output section is looking at the efficiency of the pumping plant as compared to the Nebraska Standard (Figure 5). This will give the producer a preliminary estimate of the efficiency. There will also be an estimate of what a producer can spend today to increase the efficiency of the irrigation system and recoup that investment in 5 years with the potential energy savings. This is the minimum timeframe for recouping costs associated with improving the efficiency. Depending upon what is being changed within the system to improve efficiency, a longer timeframe can be considered.

Operating an efficient pumping plant is critical to optimizing irrigation. However, pumping plants are generally neglected as many of the components are not easily accessed. Also, the time period to make measurements and access the system is also a time period where producers time is limited. This calculator gives producers a quick estimator to determine if their system is operating correctly and efficiently. If concerns are shown by this calculator, the producer should bring in a person who has expertise in irrigation system audits to look more closely at the system to determine what the corrections should be to decrease operating costs.

	Electric	Natural Gas	Diesel
Efficiency compared to Neb Standard	90.2%		
Energy Improvement Cost for 5-year return	$ 6,353		
The energy improvement cost will give you an estimate of how much money you can invest in improvements to bring the pumping plant efficiency up to the Nebraska Standard with an estimated payback of 5 years at the interest rate you			
	lbs. CO_2 emissions per year		
CO_2 emissions in lbs.	Electric	Natural Gas	Diesel
Current	212,259		
Nebraska Standard	191,529	219,013	216,346
	tons CO_2 emissions per year		
CO_2 emissions in tons	Electric	Natural Gas	Diesel
Current	106		
Nebraska Standard	96	110	108

Figure 5. Calculation of efficiency and economics of updating the system to improve efficiency.

Limitations

The calculator is based upon a seasonal average of pumping. There are limitations of the calculator because of the inputs that are needed. Systems that have large changes in pumping output where producers change nozzles multiple times per year. Also, systems with end guns that are not operating continuously will change the dynamics of the pumping system which will limit the use of the calculator.

References

Martin, D.L., T.W. Dorn, S.R. Melvin, A.J. Corr and W.L. Kranz. 2011. Evaluation energy use for pumping irrigation water. Proceedings of the 23rd annual CPIA, Burlington, CO Feb. 22-23, 2011.