ENERGY CONSERVATION WITH IRRIGATION WATER MANAGEMENT

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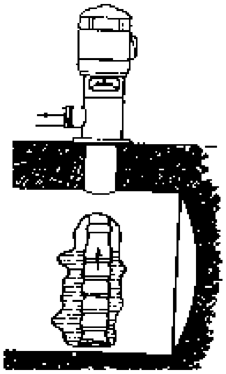
Irrigators in Utah experienced rapidly increasing energy costs from the mid 1970s to the late 1980s. These costs remain relatively high. Those who are pumping from deep wells are particularly interested in ways to cut back on energy use without doing away with profitability or production.

The general ways where energy conservation can happen with irrigation systems include:

1. No pumping—revert back to rainfed cropping.
2. Pump only what is necessary to meet crop water requirements—use weather, soils and crop information to estimate crop needs.
3. Evaluate your irrigation system—know how much water you are applying and adjust hardware and management if necessary.
4. Test your pump operation—adjust to keep efficiency at or above 65 percent.
5. Practice flow load management—operate the pump at 80 percent or more of design flowrate capacity.
6. Use low cost energy—take advantage, where possible, of electric power rate reductions for shutting off during the week or for pumping during off peak electrical demand.

This worksheet guides an irrigator through a basic assessment of his irrigation system. He will compare the answer he gets from the worksheet with his power bill for the season. The irrigator will then have some idea whether his system is performing at a proper level. Because electricity serves the majority of pumping in Utah, the worksheet example uses electrically powered pumps. For other energy sources use appropriate fuel costs and ignore kilowatt conversions.



The most important items to consider with irrigation energy use include:

* Total dynamic head (TDH)

- Pump life
- Sprinkler operating pressure
- Hydraulic friction head losses

- Minor Losses in valves and joints
- Elevation differences across farm
- Pump horsepower requirements
- Kilowatt "demand" by pump
- Crop irrigation water needs
- Application efficiency
- Seasonal hours of operation

Each of the above areas is calculated in the worksheet or is given an average value for systems that are working satisfactorily. For example, the pump efficiency is needed to calculate horsepower requirements. Farmers may not know the pump efficiency. A "desired" value of 70% is used in the worksheet. If a farmer's pump is operating at much less than this efficiency, the difference will show up when he compares the worksheet answer to his power bill.

Steps in Evaluating Potential Irrigation Energy Reduction

To illustrate, let's determine the seasonal energy requirements of 400 irrigated acres, 260 acres of alfalfa and 140 acres of spring grain, in an area where:

a. The normal annual precipitation is 10 inches (October - March, 6 inches and April - September, 4 inches).
b. Seasonal alfalfa crop water use (evapotranspiration, ET) is 36 inches. (Table 1.)
c. Seasonal spring grain ET is 20 inches.
d. The pumping level in the well is 120 feet.
e. Average sprinkler operating pressure is 50 psi.
f. The hydraulic friction headloss, elevation difference and minor losses are 40 feet.
g. The system was designed to meet a peak period ET rate of 0.30 inches per day at 68% irrigation application efficiency. (See Table 2.)

Determine System Flowrate and Seasonal Operating Hours

The seasonal crop water requirement supplied by irrigation equals the crop water use (evapotranspiration) minus the sum of stored soil water from winter precipitation and effective summer rainfall. As a rule of thumb, about two-thirds of the winter precipitation and four-fifths of the summer rainfall can be used by the crop. The required irrigation water delivery to the field equals the irrigation requirements divided by the irrigation system application efficiency.

		Example	Your Value
Stored winter precipitation [0.67 x (Oct - March Precip)]	0.67 x 6" =	4	_______
Effective summer rainfall [0.80 x (Apr - Sep Rain)]	0.80 x 4" =	3.2"	_______
Total usable natural moisture = (deduct Aug. and Sep. for Grain, use 6.0" in this example)		7.2"	_______

Crop water use supplied by irrigation equals crop ET minus usable natural moisture.

		Example	Your Value
Alfalfa (ET = 36")	36 - 7.2 =	28.8"	_______
Spring Grain (ET = 20")	20 - 6.0 =	14.0"	_______

Table 1. **Typical Monthly Alfalfa Water Use (Evapotranspiration) Estimates for Selected Utah Locations.**

Location	Peak ET In Days*	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Season Total
		- - - - - - - - - - - - - - - - - - Inches - - - - - - - - - - - - - - - - - -									
Beaver	.33		0.05	5.29	6.17	7.50	6.73	2.71			28.5
Blanding	.31		2.80	6.31	5.61	7.54	6.49	3.86	1.70		34.3
Castle Dale	.35		0.48	5.49	6.95	8.47	7.04	4.52	1.30		34.3
Cedar City	.32		1.79	6.66	6.13	7.39	7.23	4.19	0.99		34.4
Corinne	.34	0.19	2.89	5.33	7.78	7.12	6.46	4.70	2.43		36.9
Delta	.35		2.72	6.53	7.43	7.52	6.55	5.02	0.96		36.7
Duchesne	.30		1.20	6.56	6.19	7.21	6.43	3.79	1.93		33.3
Escalante	.31		2.87	7.66	6.27	6.87	7.35	3.90	1.79		36.7
Farmington	.32	0.27	3.19	5.44	7.08	6.78	5.66	3.73	1.95		34.1
Green River	.36		3.09	7.45	6.77	7.69	7.96	4.49	2.64		40.1
Heber	.29		0.13	5.07	6.52	7.58	5.58	4.27	0.33		29.5
Kanab	.33	0.66	4.03	7.03	7.19	7.01	6.64	4.65	2.33		39.6
Koosharem	.27			3.04	7.37	6.13	5.94	3.44			25.9
Logan	.30		2.25	5.92	5.65	6.61	6.60	3.90	0.43		31.4
Manti	.34		1.20	6.69	6.23	7.77	7.79	4.57	1.31		35.6
Milford	.34		0.85	6.61	6.57	7.45	6.55	5.00			33.1
Moab	.34	0.98	4.23	6.88	7.10	7.15	6.05	4.74	3.22		40.4
Pleasant Grove	.33		2.37	5.97	6.87	6.86	5.61	4.05	1.10		32.9
Richfield	.32		1.05	6.48	6.25	6.99	6.08	4.43	0.43		31.7
Roosevelt	.34		1.97	7.15	6.52	7.48	7.07	3.86	0.95		35.0
St. George	.39	2.47	4.65	7.24	8.14	8.27	7.26	5.45	3.21	0.38	47.1
Snowville	.34		0.54	5.67	7.76	7.84	7.54	3.38	1.04		32.8
Tooele	.32		2.76	5.90	7.60	6.83	6.11	4.28	1.34		34.8
Vernal	.33		1.62	6.63	6.15	8.14	6.85	3.84	2.53		35.8
Woodruff	.28			1.93	6.73	6.00	5.77	3.13			23.6

*Average daily crop water use for the 14-day peak water use period.
Adapted from: Consumptive Use of Irrigated Crops in Utah, UT. Ag. Exp. Stn. Res. Report No. 145. Reference 1 at end of this worksheet.

Table 2. Water Application Efficiencies (Ea) for Properly Designed Sprinkler Irrigation Systems.

Depth of water applied per irrigation (ac in/acre)	Peak Use, Inches Per Day		
	0.20 or Less	0.20 - 0.30	0.30 or more
	Average Wind Movement, 0-4 mph		
1"	68%	65%	62%
2"	70	68	65
4"	75	70	65
6"	80	75	70
	Average Wind Movement, 4-10 mph		
1"	65%	62%	60%
2"	68	65	62
4"	70	68	65
6"	75	70	68
	Average Wind Movement, 10-15 mph		
1"	62%	60%	58%
2"	65	62	60
4"	68	65	62
6"	70	68	65

From Ames Irrigation Handbook

Field irrigation delivery requirement equals crop water use supplied by irrigation divided by application efficiency (Ea, %/100) expressed as acre-inches/acre (which is equivalent to inches).

Alfalfa	28.8 ÷ 0.68 =	42.4"	________
Spring Grain	14.0 ÷ 0.68 =	20.6"	________

Required field irrigation delivery volume in acre-feet equals acre-inches divided by 12.

		Example	Your Value
Alfalfa (260 acres)	Vol = 260 x 42.4/12 =	919 ac-ft	________
Spring Grain(140 acres)	Vol = 140 x 20.6 =	240	________
Total for farm		1159	________

System Flowrate

Every pump and irrigation system has a flowrate capacity which is based on a design flowrate (q). This flowrate is calculated by dividing peak period (7 to 14 days) average daily crop water use by the expected application efficiency and by an adjustment for system off-time for maintenance or sprinkler moves, etc. The design flowrate (q) is typically expressed as gpm/acre.

$$\mathbf{q = \frac{452.5 \times peak\ ET\ (inches/day)}{Ea \times daily\ operating\ hours}}$$

	Example	Your Value
$q = \frac{452.5 \times 0.30}{0.68 \times 23} =$	8.7 gpm/ac	________

The corresponding pumping capacity (Q) is determined by multiplying q by the irrigated area (400 acres in the example).

Q = 8.7 x 400 =	3480 gpm	________

Seasonal Hours

Seasonal operating hours (t) equals 5430 times field delivery (acre-feet) divided by system flowrate
(Q, gpm).

t = 5430 x 1159/3480 =	1808 hrs	________

CALCULATE TOTAL DYNAMIC HEAD

Pumping lift, sprinkler pressure, friction losses and elevation differences are all expressed in feet of head.

		Example	Your Value
1.	Total pumping water lift	120 ft	________
2.	Column friction head. Column losses typically vary from 3 to 8 feet per 100 ft of column. We'll use a value of 4.5 feet per 100 ft length, and assume the bowls are set 40 feet bellow the pumping water level (160 = 120 + 40). 4.5 x 160/100 =	7.2 ft	________
3.	System operating pressure converted to feet of head (50 psi x 2.31) =	115.5 ft	

	Your sprinkler pressure _____ x 2.31 ft.		________
3.	Pipeline hydraulic friction head loss,	_____ ft	________
	minor losses and elevation difference.	_____ ft	________
		_____ ft	________
	Subtotal	40 ft	________

Total dynamic head (120 + 7.2 + 115.5 + 40) = 282.7 ft ________

CALCULATE POWER REQUIREMENTS

Pump horsepower requirements include the water horsepower and the electrical horsepower.

Water horsepower (Whp)

Whp is determined by multiplying the pump flowrate (Q, gpm) by the total dynamic head (TDH ft) and dividing by 3960.

	Example	Your Value
Whp = 3480 x 282.7/3960 =	248.4 hp	________

Electrical power (Ehp)

Ehp is electrical power needed to meet the Whp requirement. It is calculated by dividing Whp by the pumping plant (pump and motor) efficiency (Ep).

Ehp = 248.4/0.7 = 354.9 hp ________

NOTE: A desired Ep is 0.7 (70%) for systems that operate efficiently. If the final answer of the worksheet shows a big difference from your power bill, then tests should be run to determine actual pump efficiency.

CALCULATE KILOWATT DEMAND

	Example	Your Value
kW = (Ehp x .746) = 354.9 x .746 =	264.8 kW	______

NOTE: Actual kW demand can be measured during pump operation as part of a pump test.

SEASONAL ENERGY USE

Estimated energy costs include demand, energy and often, service charges. The energy usage depends on the kW demand and number of hours operated. For this example we will assume an average cost of 0.06$/kW-hr including demand, energy and service charge.

Seasonal kilowatt hours equal demand kW times pump hours.

	Example	Your Value
264.8 x 1808 =	478,758 kW-hr	_______ KWh

The estimated seasonal bill equals kilowatt hours times energy cost per kW-hr.

478,758 x $.06 =	$28,725	$_______

Cost per ac-ft of pumped water equals energy cost divided by acre-feet.

$28,725/1159 =	$25 /ac-ft	$_______/ac-ft

SUMMARY

This example illustrates the steps necessary to evaluate the potential for reducing irrigation energy consumption on a given farm. With minor adjustments, energy consumption can be decreased. For example, if sprinklers were changed to low pressure nozzles (30 psi) instead of the assumed 50 psi, then the pump head could be reduced by 46 feet (46 = (50 - 30) * 2.31). For our example this is equivalent to reducing the demand by 43 kW with a potential savings of $4,591 per season.

Changes in the efficiencies of the pumping plant and irrigation system application could show significant cost differences. For example, a pumping plant with 65% (instead of 70% which we use) efficiency would indicate a 36,200 kW-hr increase in one season. Which, at $0.06/kW-hr would reflect an increased billing of $2,171.

If actual energy usage is lower than what was calculated, then the pumping and application efficiencies may be greater than what was assumed and/or actual crop water use may be less than the assumed value. If crop yields are lower than expected then, perhaps, a deficit irrigation situation exists.

Many factors influence irrigation system application efficiency. For sprinkler systems, these include pressure, nozzle size and spacing, wind, air temperature (day versus night), interval between irrigations and maintenance condition. In some cases, more energy savings may be realized by management changes than by pump repairs. Pumping less water (possibly at lower pressures) through improved irrigation procedures and pumping plant improvement will aid in decreasing our continuing energy needs.

REFERENCES

1. Hill, R.W. 1994. Consumptive Use of Irrigated Crops in Utah. Utah. Agr. Exp. Stn. Res. Rpt. #145. Utah State University, Logan, UT. This report is available on the Web at: http://nrwrtl.nr.state.ut.us/manuals/consumpt/cfwea.htm

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