# A STUDY OF IRRIGATION PUMPING PLANT PERFORMANCE IN ARKANSAS

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## Abstract

Nearly 100 irrigation pumping plants were evaluated over three irrigation seasons using a network of pump monitoring systems. Seasonal flow change, cost of water per unit volume pumped, and efficiency as a percentage of the Nebraska Pumping Plant Performance Criteria are reported. Seasonal averages and trends in pumping performance values can be used to develop recommendations to producers for improving pumping plant performance and reduce operating costs.

## Introduction

Nearly 100 irrigation pumping plants were evaluated over three irrigation seasons using a network of pump monitoring systems. Pump monitors are a form of informatics for irrigation pumps that include sensors such as flow, pressure, depth, and energy use that acquire, store and data. This data can be used to measure irrigation pump performance and control pumps real time. Seasonal flow change, cost of water per unit volume pumped, and efficiency as a percentage of the Nebraska Pumping Plant Performance Criteria were evaluated for using hourly data. Seasonal averages and trends in pumping plant performance values can be used to develop recommendations to producers for improving pumping plant performance and reduce operating and energy costs.

Operational times observed using pump monitoring ranged from approximately 300 hours to 1500 hours, with an average annual operational time of 907 hours. The study found that electric deep wells (1510 hr/yr, n=5) showed the highest average annual operational time of all system types, but had a smaller sample size than electric alluvial wells (789 hr/yr, n=38) and electric surface relifts (1211 hr/yr, n=10). No values for annual operational time of diesel systems were reported due to issues with pump monitoring systems, but quality control testing values were collected. The few values that were recorded were relatively close to the average value for electric systems of the corresponding system type. The average pumping flow rate of all systems tested was just over 2100 gpm, with values ranging from around 300 gpm to 9000 gpm. Diesel surface relifts showed the highest average flow rate (4631 gpm, n=5), while electric deep wells showed the lowest average flow rate (1142 gpm, n=5). The average electricity consumption rate of electric pumping plants was 47.4 kWh/hr. Electric deep wells (101.4 kWh/hr, n=5) consumed electricity at over twice the rate of electric surface relifts (47.5 kWh/hr, n=10) and electric alluvial wells (39.6 kWh/hr, n=38).The average diesel fuel consumption rate of diesel pumping plants was 2.74 gal/hr. Diesel surface relifts (3.39 gal/hr, n=5) consumed fuel approximately 40% faster than diesel alluvial wells (2.38 gal/hr, n=9). No data were collected for diesel deep wells. The average total dynamic head (TDH) of all systems tested was 70 ft. The average TDH of the deep wells tested (272 ft, n=5) far exceeded the average TDH of the alluvial wells (58 ft, n=47) and surface relifts (37 ft, n=15) included in the study.

Pump monitoring water flow data consistently showed that pumping flow rate over time of alluvial wells followed a pattern of decline that could be characterized using a power function trend line. This analysis showed that it typically takes approximately 6 hours for a well to reach a linear flow loss pattern. This suggests that any instantaneous irrigation pumping plant performance test performed on an alluvial well immediately or shortly after startup will likely result in performance values that do not accurately reflect actual long term performance, an important finding for those estimating flow rates from instantaneous testing.

Water pumping flow data over time of deep well and alluvial well pumping plants showed annual flow declines ranging from 9% to 37% of the original flow rate at the start of the irrigation season. The average annual flow loss for well pumping plants was 19.6%. Since flow loss as a percentage of the initial flow value was largely dependent on operational time and pumping flow rate, annual flow loss was also calculated in terms of flow loss per volume pumped (gpm/acre-in pumped) and flow loss per operational time (gpm/hr). The average flow loss per volume pumped was 0.13 gpm per acre-inch pumped. The average flow loss per operational time was 5.1 gpm per operational hour.

Improper sizing of power units is a source of inefficiency in irrigation pumping plants. In this study, electric motor nameplate motor ratings were compared to actual peak and average energy use from the remote monitors. Of the 31 electric motors analyzed using pump monitoring, 19.4% were undersized, 25.8% were oversized, and 54.8% were appropriately sized. Instantaneous testing showed 41.2% of motors undersized, 17.6% oversized, and 41.2% appropriately sized. In total, these measurements suggest that approximately half of the electric motors tested were inappropriately sized, which could be a sign of a more widespread issue.

Cost of water is a metric that can be used to assess an irrigation pumping plant. While cost of water cannot be used to understand efficiency, pumping plants that have a high cost of water relative to other similar pumps are likely candidates to warrant a more in-depth investigation of pumping plant efficiency. Irrigators can use this concept to focus maintenance and upgrade work on pumps in their operations with the highest cost of water. Also cost of water was available for all of the pumps in the study, while overall efficiency data was limited due to lack of pumping water level. Both pump monitoring and instantaneous testing were used to analyze the cost of water ($/acre-in) of irrigation pumping plants. To account for differences in TDH, these cost values were normalized by TDH by dividing each figure by 1/10 of the actual head at which it was operating, yielding cost of water per 10 feet of TDH. Results, shown in Figure 1 of this analysis indicated that cost of water for diesel systems was about 2.7 times more expensive than pumping plants using electricity as a power source.

These results also indicate that irrigation energy costs using well pumping plants is approximately 30% more costly per unit volume pumped than irrigation using surface water relift systems (reservoirs, canals, ditches, etc.).

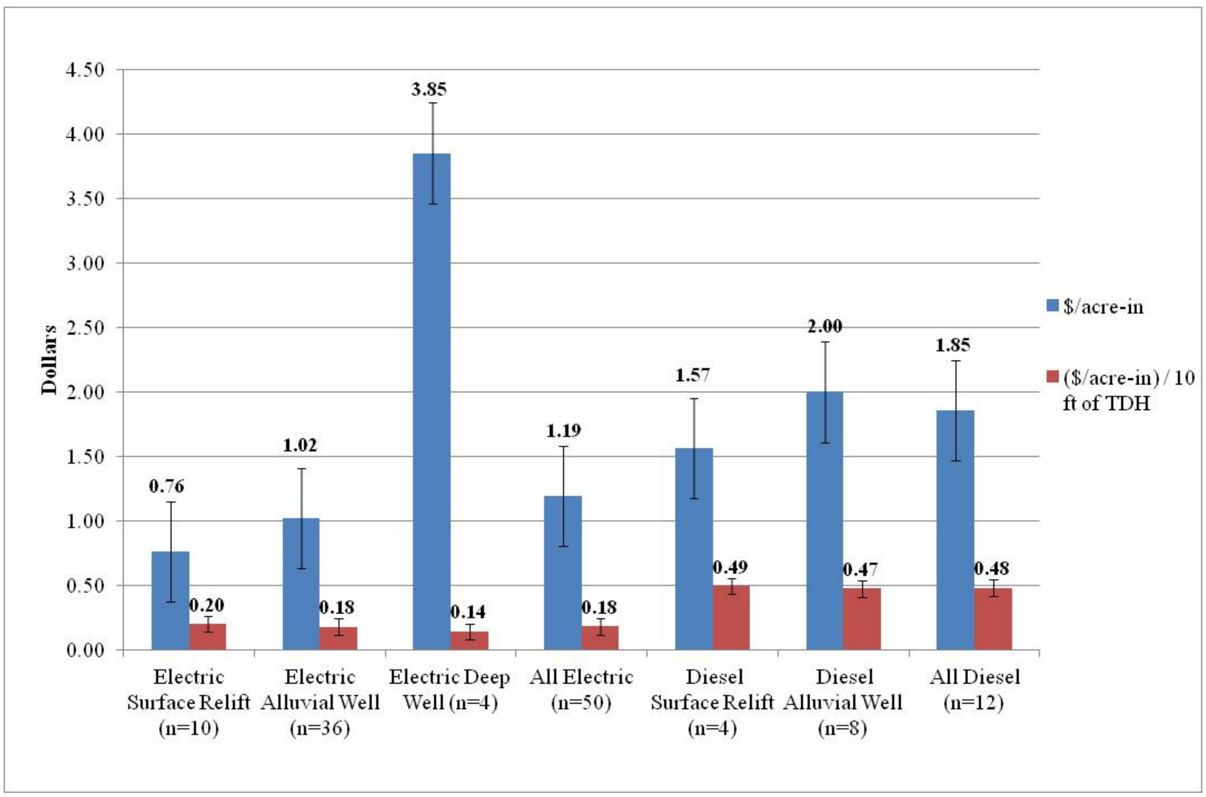


Figure 1. Cost of water for irrigation pumping plants by energy source

Limited data due to issues with continuous diesel fuel flow monitoring instrumentation highlighted the need for a better fuel flow measurement alternative than the one used in this study. Major cost savings potential for diesel irrigation pumping plants were highlighted where the fuel flow sensors were successful in collecting verified data in the field. The diesel pump monitors were also successfully used to remotely adjust speed and provide on/off safety switches for automatic safety shutdown conditions such as low oil, low fuel, low system pressure, etc.

Another metric of evaluating pump adequacy and performance is to assess the water capacity per acre. This is an important metric for assessing the ability of an irrigation pumping plant to meet crop water demand through the season. To evaluate pumping capacity, the pumping capacity during the season was compared to the University of Arkansas recommendation for rice water needs by crop as published in the most recent version of the Rice Production Handbook. Where acreage and pumping water flow rate were known either via pump monitoring or instantaneous testing, an irrigation capacity value (gpm/acre) was calculated and compared to the published values by soil type. Instantaneous testing showed that about 53% of the systems tested were below adequate at the time of the test. 47% showed capacity exceeding the recommended value. Pump monitoring, which provides a continuous test, showed that 46% of the systems tested were always adequate, while 42% were sometimes adequate, and 12% were always below adequate. Pump monitoring data also showed that the average variation of irrigation capacity annually was about 3.6 gpm/acre. These results suggest that an instantaneous test may be misleading in terms of adequacy of irrigation capacity through an entire irrigation season and that many pumps may be inadequate to full irrigate the intended crop.

For pumps in the southern region, which are generally low head high flow pumps, considerable energy savings appear to exist from the study results. Average operational times and input energy usage rates were used to estimate the average amount of input energy and cost savings that would result from improving irrigation pumping plant performance to the Nebraska Pumping Plant Performance Criteria (100% of NPPPC). This standard is very achievable with proper sizing of motors and pumps to the irrigation water demand. It was found that electric deep wells and diesel surface relifts showed the most potential for savings, with the potential to save at least $4,000 dollars per year on average on just energy costs. Diesel systems as a whole ($2,816/yr) showed about twice the potential for savings than electric systems ($1,326/yr), which is driven by the higher relative cost of diesel as compared to electricity. On average, all system categories show significant potential for energy and cost savings by improving performance to meet the NPPPC standard.

Table 1. Potential Annual Savings using % of NPPPC and Annual Operational Time.

| **System Category** | **Energy Usage Rate (kWh/hr or gal/hr)** | **Average Operational Time (hr)** | **Average % of NPPPC** | **Potential Energy Savings (kWh/yr or gal/yr)** | **Potential Cost Savings ($/yr)** |
|---|---|---|---|---|---|
| Electric Alluvial Wells | 39.6 | 789 | 68.2 | 9936 | 994 |
| Electric Surface Relifts | 47.5 | 1211 | 75.1 | 14323 | 1432 |
| Electric Deep Wells | 101.4 | 1510 | 68.2 | 48690 | 4869 |
| Diesel Alluvial Wells | 2.38 | 789 | 62.9 | 697 | 2299 |
| Diesel Surface Relifts | 3.39 | 1211 | 69.8 | 1240 | 4091 |
| All Electric Systems | 47.4 | 908 | 69.2 | 13256 | 1326 |
| All Diesel Systems | 2.74 | 908 | 65.7 | 853 | 2816 |