# CHARACTERISTICS OF IRRIGATION PUMP PERFORMANCE IN MAJOR IRRIGATED AREAS OF CALIFORNIA

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## ABSTRACT

Well pump tests (12,876) in three Central California groundwater basins were characterized and described according to their spatial distribution. The average overall pumping plant efficiency (wire-water, not including column losses and velocity head) was about 56%. Characteristics such as drawdown, total dynamic heads, kW, and flow rate vary greatly between pumps within and between sub-basins. This is the first well pump characterization of its type in California, although irrigation pump tests have been conducted for over 70 years in California. This paper provides a summary of the spatial variation of well pump performance and characteristics.

## Background

In work sponsored by the Public Interest Energy Research (PIER) program of the California Energy Commission, ITRC analyzed information recovered from over 15,000 electric irrigation pump tests in Central California. The pump tests were located throughout the Sacramento, Salinas, and San Joaquin Valley groundwater basins of California. These large groundwater basins are each also divided into a number of subbasins. A map depicting this is shown as Figure 1 (gray lines outside of basins represent county lines; gray lines inside basins represent subbasins).

Data was analyzed by basin and subbasin for well pumps and non-well pumps. For each pump type, averages were calculated based on:

- The whole basin
- Overall pumping plant efficiency (OPPE)
- kWh/AF
- Subbasins

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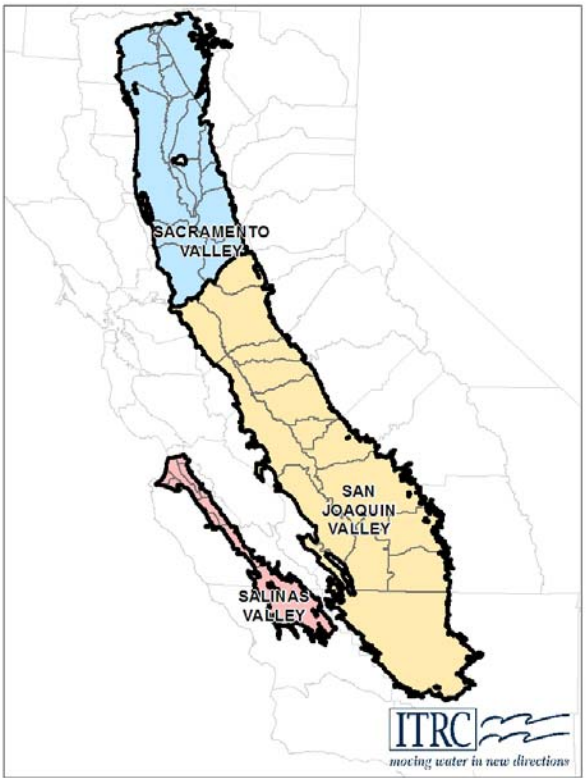


Figure 1. Groundwater Basins in California

## Well Pump Subbasin Comparisons

Throughout the three groundwater basins, data from 12,876 well pump tests was analyzed. Table 1 summarizes the averages of a variety of factors from well pump tests in each of the three groundwater basins.

Table 1. Summary of Regional Well Pump Test Data

| | Average Input Power [kW] | Average Weighted[1] kWh/AF | Average Weighted[1] TDH[2] [ft] | Average Weighted[1] Flow Rate [GPM] | Average Weighted[1] SWL[3] [ft] | Average Weighted[1] Drawdown [ft] | Average Weighted[1] Motor HP | Average Weighted[1] OPPE[4] [%] |
|---|---|---|---|---|---|---|---|---|
| Salinas | 65 | 451 | 244 | 1,197 | 117 | 33 | 111 | 56 |
| Sacramento | 56 | 289 | 156 | 1,553 | 62 | 35 | 93 | 56 |
| San Joaquin | 56 | 478 | 260 | 1,099 | 189 | 43 | 116 | 57 |

[1] All weighted values are weighted by input power (kW)
[2] Total Dynamic Head
[3] Distance from Surface to Standing Water Level
[4] Overall Pumping Plant Efficiency

When comparing the data from the three basins, some general observations regarding the well pump data can be made:

1. All three basins have very similar average OPPEs (~56%).
2. The Salinas basin's well pump tests had a slightly higher average input power than the well pump tests in the other basins.
3. The Sacramento basin's well pump tests had a higher average flow rate and lower average kWh/AF, total dynamic head, motor HP, and depth to standing water level than the well pump tests in the other basins.
4. The San Joaquin basin's well pump tests had a greater average depth to standing water level and average drawdown than the well pump tests in the other basins.

## Regional Comparison by Overall Pumping Plant Efficiency (OPPE)

The data for each basin was compared with overall pumping plant efficiency (%) to the data displayed in Figures 2-9. The values are grouped into 10% ranges, with the data value displayed on the chart at the midpoint of the range (for example, the average value for the 21-30% range is placed at the 25% point). The grayed areas show the ranges where a majority of the values lie.

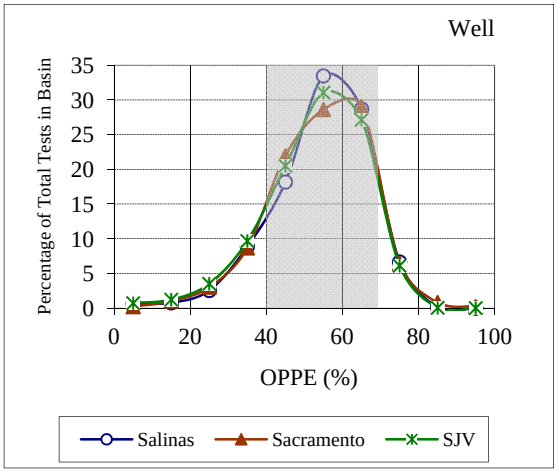


Figure 2. Test Distribution

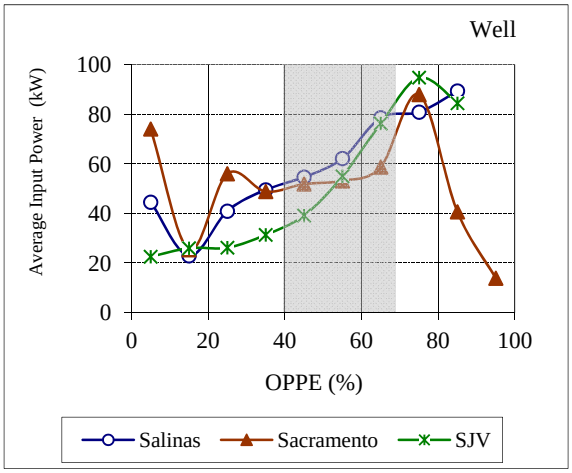


Figure 3. Average Input Power [kW]

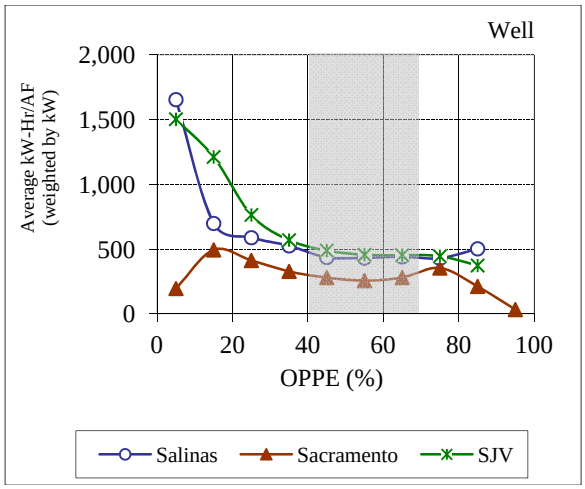


Figure 4. Average kWh/AF (Weighted by Input Power)

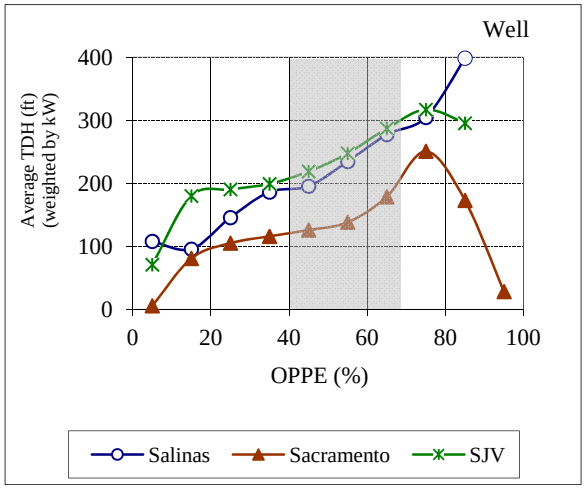


Figure 5. Average Total Dynamic Head (TDH) [ft] (Weighted by Input Power)

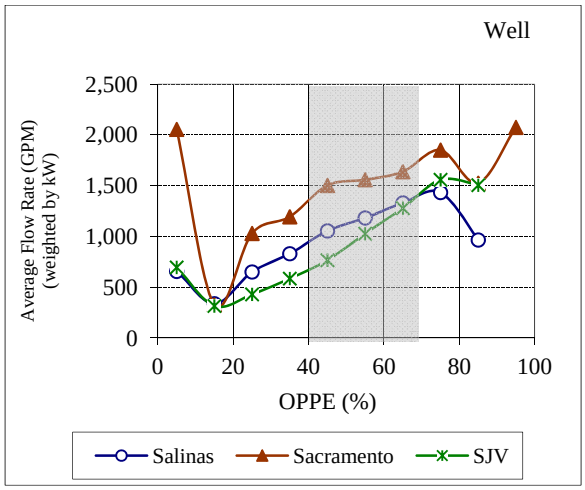


Figure 6. Average Flow Rate [GPM] (Weighted by Input Power)

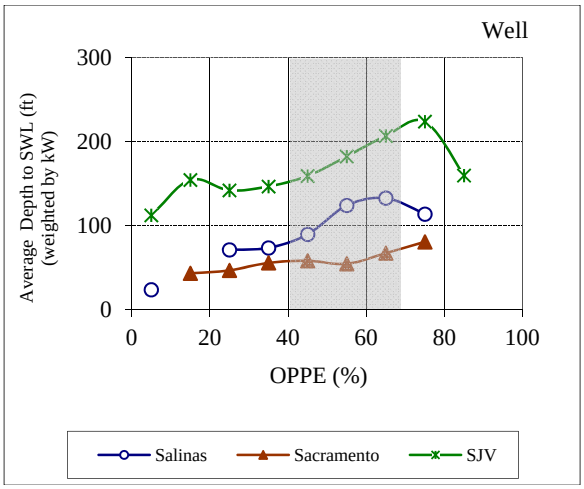


Figure 7. Average Depth to Standing Water Level (SWL) [ft] (Weighted by Input Power)

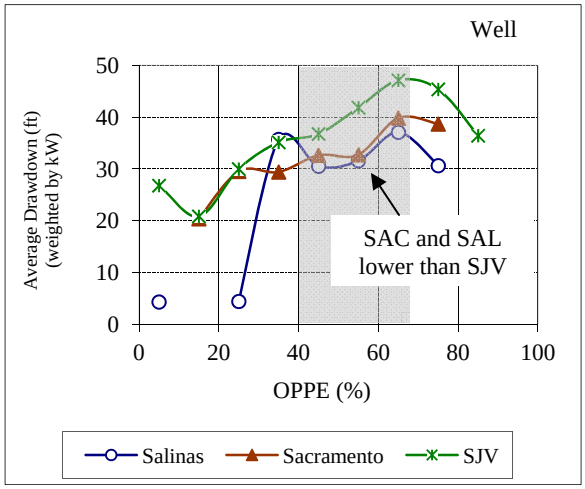


Figure 8. Average Drawdown [ft] (Weighted by Input Power)

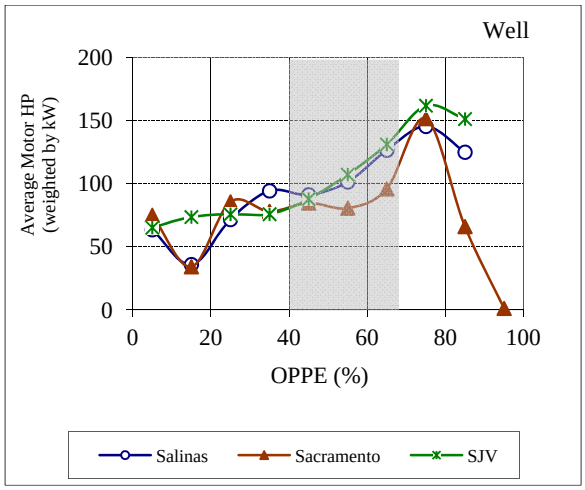


Figure 9. Average Motor HP (Weighted by Input Power)

When comparing the data from the three basins to the overall pumping plant efficiency, some general observations regarding the well pump data can be made:

1. A majority of the well pump tests fall between the 40-70% overall pumping plant efficiency ranges.
2. Across nearly all of the overall pumping plant efficiency ranges, the Sacramento basin's well pump tests have a higher flow rate, and a lower kWh/AF and total dynamic head than the well pump tests in the other basins.
3. The San Joaquin basin's well pump tests had higher average drawdown values than the well pump tests in the other basins.
4. The average depth to the standing water has a lot of variation between basins.

## Regional Comparison by Energy Consumption per Volume Pumped

The data for each basin was compared with kWh/AF to the data shown in Figures 10-17. Each basin had a single data point placed at 1000 kWh/AF that represents the y-axis average value for all data points greater than 1,000 kWh/AF. The values are grouped into ranges of 100 kWh/AF with the data value displayed at the midpoint of the range (e.g., the average value for the 201-300 kWh/AF range is placed at the 250 kWh/AF point). The grayed areas show the ranges where a majority of the values lie.

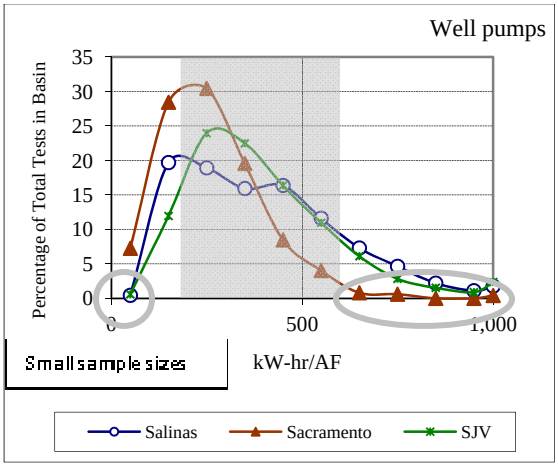


Figure 10. Test Distribution

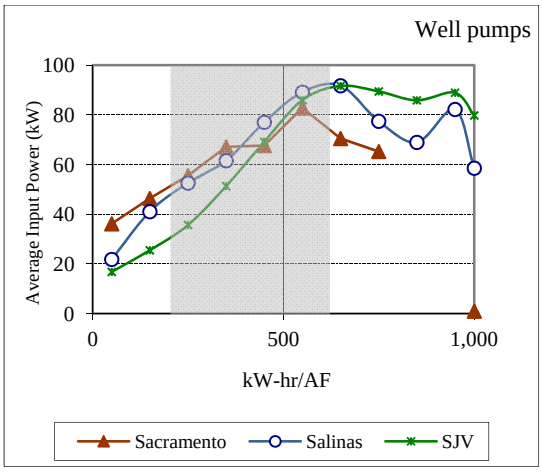


Figure 11. Average Input Power [kW]

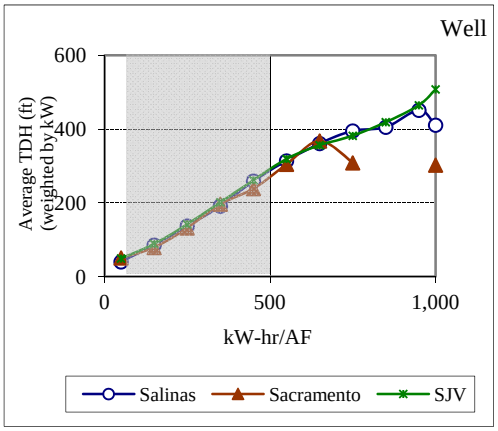


Figure 12. Average Total Dynamic Head (TDH) [ft] (Weighted by Input Power)

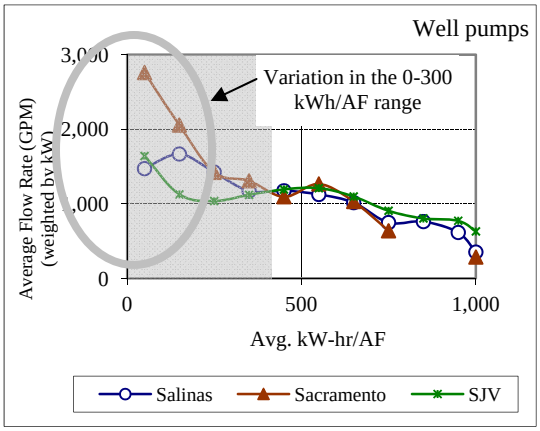


Figure 13. Average Flow Rate [ft] (Weighted by Input Power)

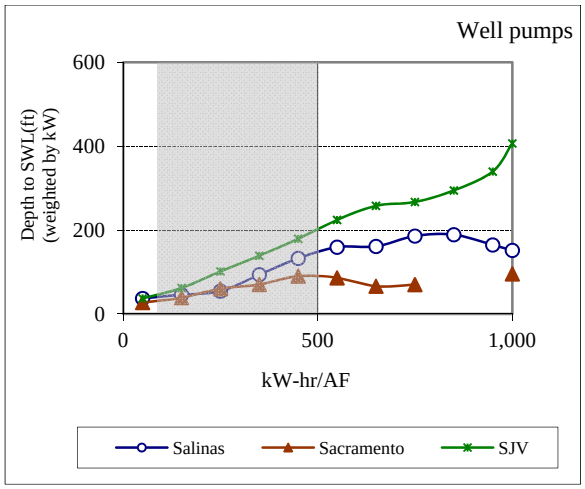


Figure 14. Average Depth to Standing Water Level (SWL) [ft] (Weighted by Input Power)

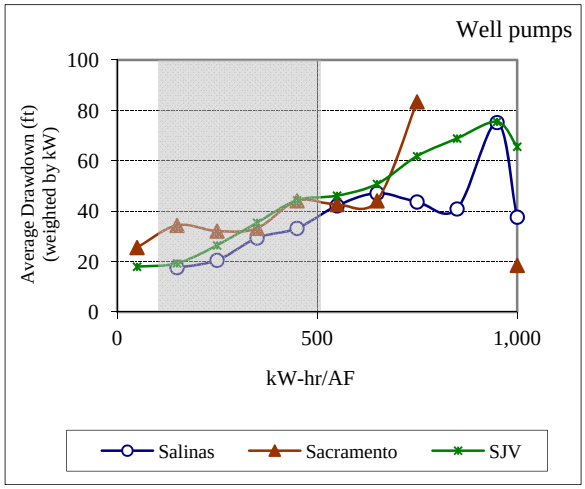


Figure 15. Average Drawdown [ft] (Weighted by Input Power)

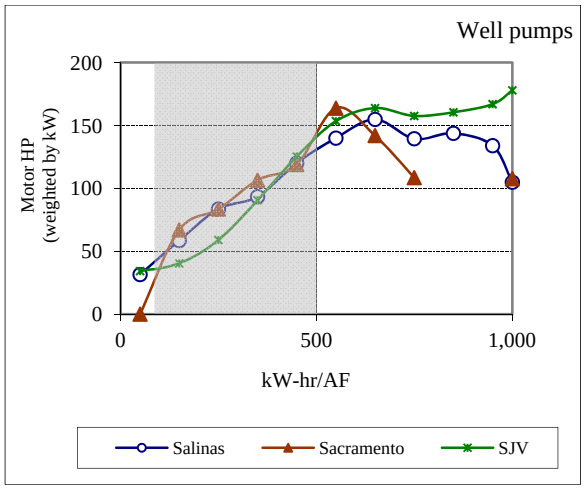


Figure 16. Average Motor HP (Weighted by Input Power)

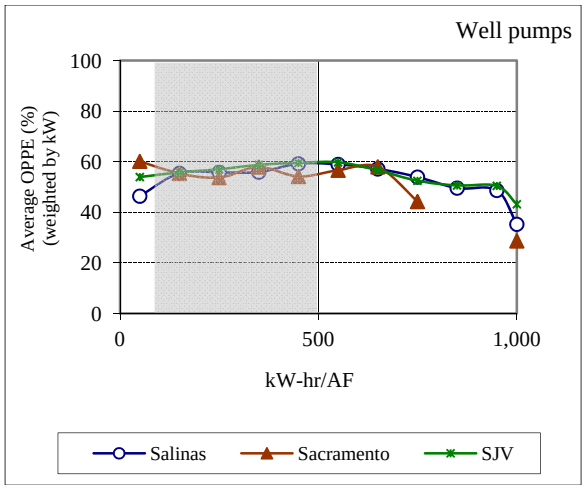


Figure 17. Average Overall Pumping Plant Efficiency (OPPE) [ft] (Weighted by Input Power)

When comparing the data from the three basins to the kWh/AF, some general observations regarding the well pump data can be made:

1. A majority of the well pump tests fall between 200 and 500 kWh/AF.
2. The Sacramento basin well pump tests differ from the well pump tests in other basins at higher (600+) kWh/AF in all categories. No conclusions are drawn from this data due to the small sample sizes in those ranges.
3. The well pumps tested in the Sacramento and Salinas basins have higher average input power in the 200-500 kWh/AF range than the well pumps in the San Joaquin basin. However, the average input power increases with kWh/ah, and the Salinas and San Joaquin basins have more tests in the higher ranges (400+) than the Sacramento basin. This could explain why the Sacramento and San Joaquin basin-wide averages are nearly equal, and the Salinas basin average is slightly higher.
4. Average regional flow rates vary significantly at low (0-300) kWh/AF, but match well at higher (400+) kWh/AF. Only the Sacramento basin has a significant number of well pump tests in that range (see Figure 10). These low kWh/AF, high flow rate pumps are probably causing the Sacramento basin tests' average flow rate to be so much higher than the test averages in the other basins.
5. The San Joaquin basin's well pump tests do not appear to have a significantly greater drawdown than the other basins (see Figure 15). This can be explained mainly by the distribution of tests. The San Joaquin basin has a significant percent of its tests in the 500-800 kWh/AF range (see Figure 10), and the tests in those ranges have higher drawdown values than the 0-500 kWh/AF ranges and the Salinas basin (which also has a significant percent of its tests in the higher range) and input power (what the average drawdown values are weighted by) than in the 0-500 kWh/AF ranges. This could cause the basin's overall higher value, without making the values in the 200-500 range significantly higher in comparison to the other two basins.
6. The average total dynamic head in each kWh/AF range is almost identical for the three basin averages, even though the average total dynamic head of the Sacramento basin well pump tests was lower than the tests other basins. This is probably due to the fact that the majority of the well pump tests in the Sacramento basin had slightly lower kWh/AF than the well

pump tests in the other basins; the lower kWh/AF ranges had lower average total dynamic heads for all basins.

7. The average depth to standing water level increases with the kWh/AF, possibly indicating the effect larger pumps are having on their local water tables.

## Regional Comparison by Subbasin

Maps were created characterizing the groundwater subbasins according to available pump data. The Central Valley of California can be divided into three basins (Salinas, Sacramento, and San Joaquin Valley), each divided into a number of subbasins to examine the validity of the regional conclusions. The following maps (Figures 18-25) illustrate the three groundwater basins (and their subbasins) with varying parameters.

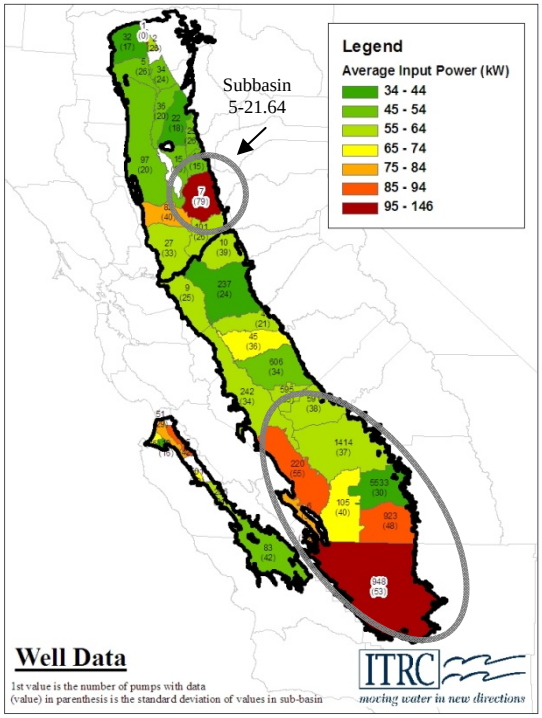


Figure 18. Average Input Power [kW]

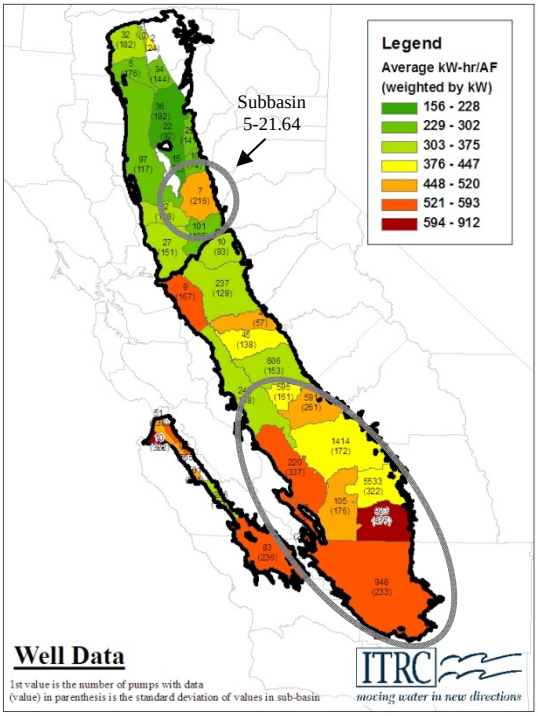


Figure 19. Average kWh/AF (Weighted by Input Power)

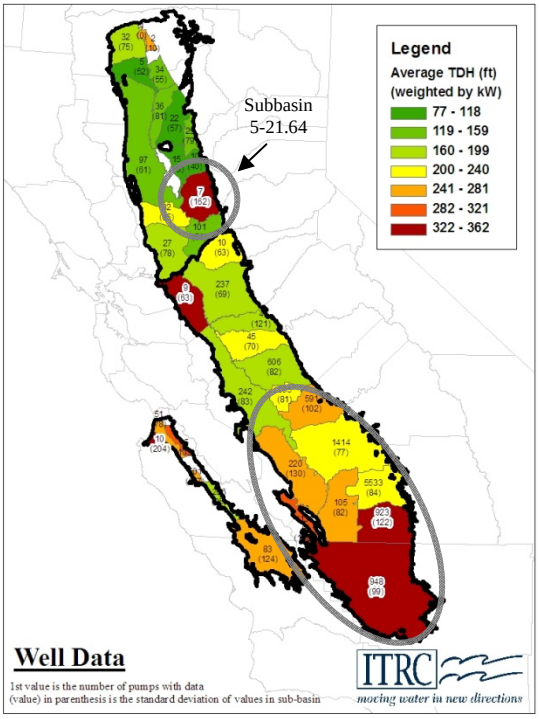


Figure 20. Average Total Dynamic Head (TDH) [ft] (Weighted by Input Power)

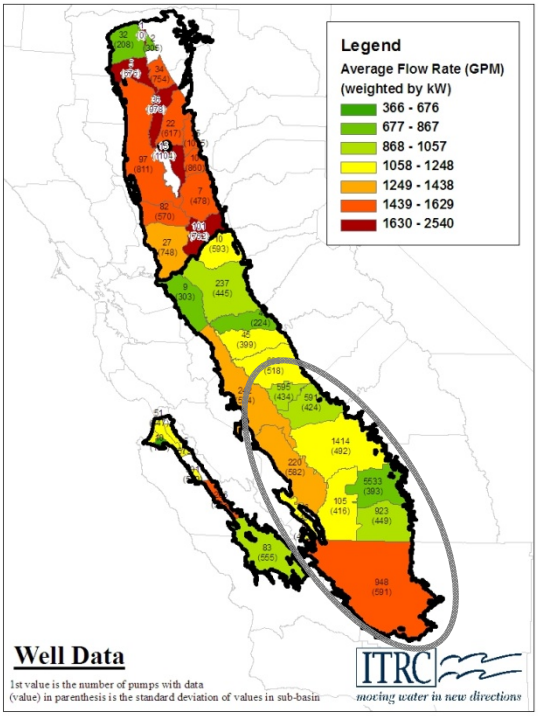


Figure 21. Average Flow Rate [ft] (Weighted by Input Power)

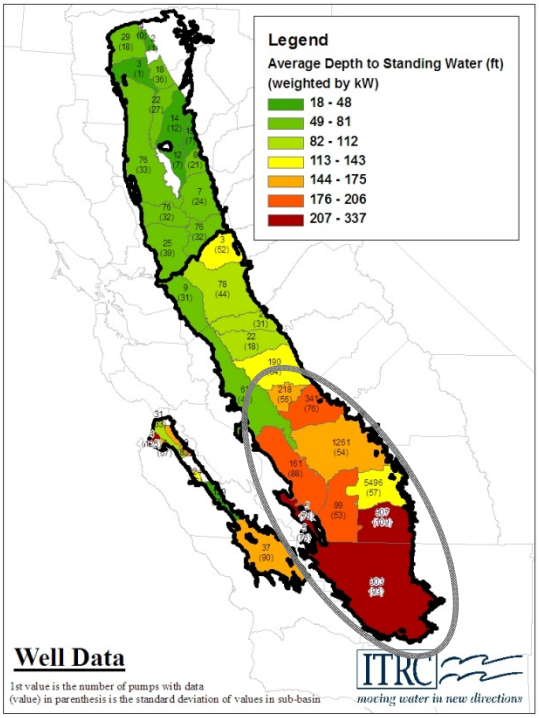


Figure 22. Average Depth to Standing Water Level (SWL) [ft] (Weighted by Input Power)

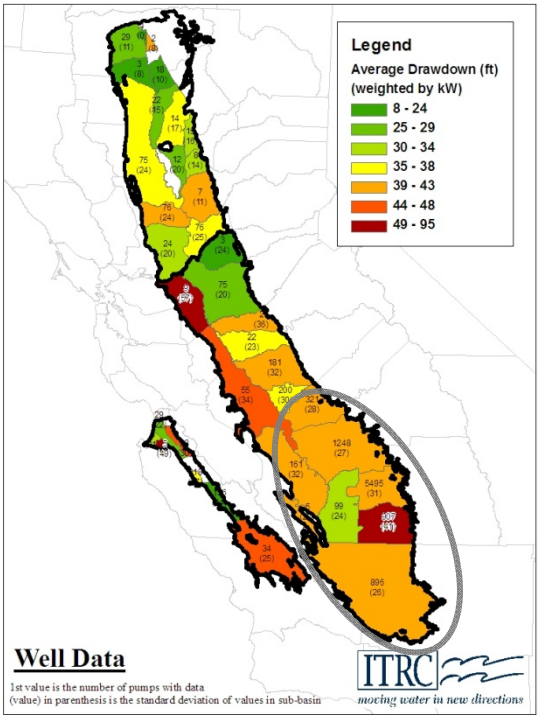


Figure 23. Average Drawdown [ft] (Weighted by Input Power)

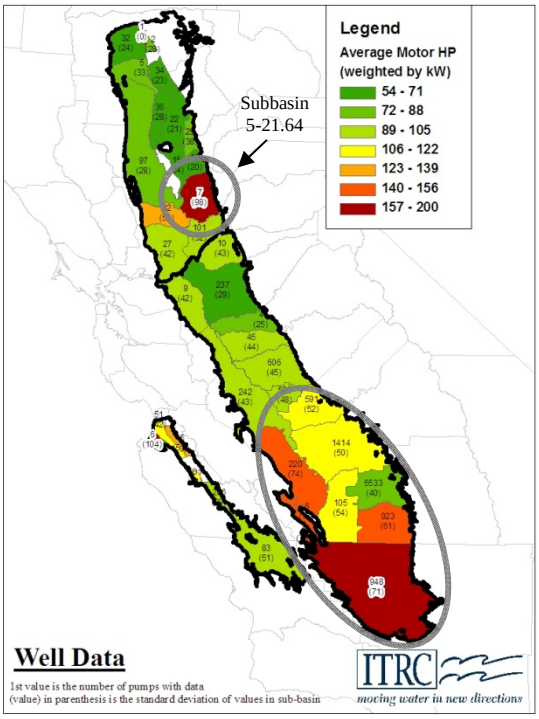


Figure 24. Average Motor HP (Weighted by Input Power)

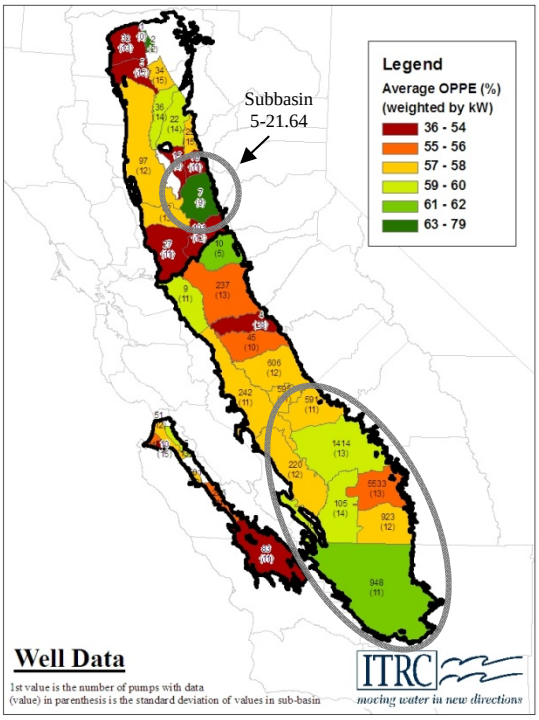


Figure 25. Average Overall Pumping Plant Efficiency (OPPE) [%] (Weighted by Input Power)

When comparing the data from the three basins by subbasin, some general observations regarding the well pump data can be made:

1. There are clear basin trends for average input power, kWh/AF, total dynamic head, flow rate, depth to standing water, and motor HP (it does not appear that certain sub-basins are heavily skewing the data).
2. The Sacramento basin has one subbasin (5-21.64) that has well pump test values that differ greatly from the rest of the basin. This subbasin has only 7 tests, 3 of which are very large pumps (input power greater than 100 kW, motor HP greater than 100, discharge pressure greater than 100 psi, flow rate greater than 1000 GPM, total dynamic head greater than 375 ft, and kWh/AF greater than 500) with high overall pumping plant efficiencies (greater than 68%).
3. The San Joaquin basin appears to have more extreme well pump test values in the southern portion compared to the northern portion.
4. When comparing the overall pumping plant efficiency (OPPE) (a calculation based on the input power, flow rate, and total dynamic head), the Salinas and Sacramento basins' well pump tests have a slightly lower average OPPE than the San Joaquin basin; however, the majority of subbasin average OPPEs can be contained between 54% and 62%.

## CONCLUSION

The major conclusions drawn from the well pump test data include:

1. All three basins' well pump tests have very similar average weighted overall pumping plant efficiencies (~56%), with the majority of the values contained between 54% and 62%.
2. A majority of the well pump tests fall between 200 and 500 kWh/AF.
3. There are noticeable trends in data between the Sacramento, Salinas, and San Joaquin basins.

   a. In general, the Salinas basin well pump tests had, in relation to the well pump tests in the other basins:
      i. Slightly higher input power
   b. In general, the Sacramento basin well pump tests had, in relation to the well pump tests in the other basins:
      i. Lower kWh/AF
      ii. Lower total dynamic head
      iii. Higher flow rates
      iv. Lower depths to the standing water level
      v. Slightly lower motor HP
   c. In general, the San Joaquin basin well pump tests had, in relation to the well pump tests in the other basins:
      i. Greater depths to the standing water level
      ii. Higher drawdown
4. The San Joaquin basin's well pump tests had more extreme values in most categories in the southern region as compared to the northern region.
5. The Sacramento basin has one subbasin (5-21.64) that has well pump test values that differ greatly from the rest of the basin. However, data from only 7 tests within this subbasin were found, 3 of which are very large pumps.
6. The average depth to standing water level varies greatly between basins.
7. Within each basin, the average depth to standing water level increases with the kWh/AF, possibly indicating the effect larger pumps are having on their local water tables.
8. About 7% of the Sacramento basin's well pump tests are low (0-100) kWh/AF, high (>2000) flow well pumps.

## ACKNOWLEDGEMENTS

This study was funded by contract 500-06-040 of the Public Interest Energy Research (PIER) program under the California Energy Commission. The opinions and conclusions expressed in this paper are entirely those of the authors.