Conversion to Groundwater Pumping
With Drip/Micro Irrigation Systems

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Public Interest Energy Research (PIER) Program
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IRRIGATION TRAINING AND RESEARCH CENTER

Prepared by

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Irrigation Training and Research Center

June 2008
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District Name
ALTA I.D.
ANDERSON-COTTONWOOD I.D.
ANGIOLA W.D.
ARVIN-EDISON W.S.D.
BANTA-CARBONA I.D.
BELRIDGE W.S.D.
BERRENDA MESA W.D.
BIGGS-WEST GRIDLEY W.D.
BUENA VISTA W.S.D.
CAVELO W.D.
CENTRAL CALIFORNIA I.D.
CENTRAL SAN JOAQUIN W.C.D.
CHOWCHILLA W.D.
CONSOLIDATED I.D.
CORCORAN I.D.
DEL PUERTO WATER DISTRICT
DELANO-EARLIMART I.D.
EASTSIDE W.D.
EXETER I.D. & IVANHOE I.D.
FIREBAUGH CANAL W.D.
FRESNO I.D.
GALT I.D.
GLEN COLUSA I.D.
JAMES I.D.
KERN DELTA W.D.
LAGUNA I.D.
LAKESIDE IRRIGATION WATER DIST
LOST HILLS W.D.
LOWER TULE RIVER I.D.
MADERA I.D.
MERCED I.D.
MODESTO I.D.
NORTH KERN W.S.D.
NORTH SAN JOAQUIN W.C.D.
OAKDALE I.D.
ORANGE COVE I.D.
ORLAND-AROIS W.D.
PANOCE W.D.
PATTERSON W.D.
PIXLEY I.D.
RECLAMATION DISTRICT 108
RICHVALE I.D.
ROSEDALE-RIO BRAVO W.S.D.
SAN LUIS CANAL CO.
<table>
<thead>
<tr>
<th>Name</th>
<th>District</th>
</tr>
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<tbody>
<tr>
<td>Martin Mcintyre</td>
<td>SAN LUIS W.D.</td>
</tr>
<tr>
<td>Paul Oshel &amp; Craig Wallace</td>
<td>SEMITROPIC W.S.D.</td>
</tr>
<tr>
<td>Ron Sutton</td>
<td>SHAFTER-WASCO I.D.</td>
</tr>
<tr>
<td>Paul Lum</td>
<td>SOLANO I.D.</td>
</tr>
<tr>
<td>Mike Gilton, Sam Bologna, &amp; Cheryl Burke</td>
<td>SOUTH SAN JOAQUIN I.D.</td>
</tr>
<tr>
<td>Brad Arnold</td>
<td>SOUTH SUTTER W.D.</td>
</tr>
<tr>
<td>William Carlisle</td>
<td>SOUTHERN SAN JOAQUIN MUD</td>
</tr>
<tr>
<td>John Yoshimura</td>
<td>STOCKTON-EAST W.D.</td>
</tr>
<tr>
<td>Max Sakato</td>
<td>SUTTER MUTUAL WATER COMPANY</td>
</tr>
<tr>
<td>Aaron Fukuda &amp; Wayne Fox</td>
<td>TULARE I.D.</td>
</tr>
<tr>
<td>Brent Graham &amp; Frank Apgar</td>
<td>TULARE LAKE BASIN W.S.D.</td>
</tr>
<tr>
<td>Wilt Fryer, Debbie Liebersbach,</td>
<td>TURLOCK I.D.</td>
</tr>
<tr>
<td>Russ Freeman</td>
<td>WESTLANDS W.D.</td>
</tr>
<tr>
<td>Tom Suggs</td>
<td>WHEELER RIDGE-MARICOPA W.S.D.</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

Twenty one irrigation districts in the Central Valley reported “conversion acres”. Conversion acres are those on which farmers used only groundwater for drip/micro irrigation although surface irrigation water was available.

The twenty one districts include about 2 million acres of irrigated area. Approximately 3.6% of that acreage (73,000 acres) has been “converted” to groundwater when farmers switched to drip/micro. Fourteen of these districts anticipate more conversion in the future. ITRC thinks that the conversion will be more rapid and greater than district personnel suspect.

The dominant factor that influences the conversion was the lack of flexible water delivery service to fields. Districts with rotation schedules had 3.5 times higher conversion rates than did district with 24 hour arranged deliveries. Districts with more flexible (than 24 hour arranged) deliveries did not report any conversion acres.

The conversion trend has been reversed by one district (Chowchilla WD) through a combined program that included district modernization and new pricing policies.

The extra energy required for groundwater pumping on the 73,000 conversion acres is estimated at 76,000,000 kW-hr/yr.
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INTRODUCTION

The Irrigation Training and Research Center (ITRC) at California Polytechnic State University, San Luis Obispo conducted this study on behalf of the PIER program within the California Energy Commission (CEC). This study was performed in the San Joaquin and Sacramento Valleys.

This study began by identifying the conjunctive use irrigation districts in the state. A conjunctive use district is one which uses both groundwater and surface water to supply irrigation needs. This list of irrigation districts was narrowed down to include the top 80% of the acreage. This provided a feasible number of districts to visit to determine trends in drip/micro irrigation and groundwater use. An initial email was sent to a representative of each district. A follow-up call was later made and the survey form was reviewed. In the majority of cases, a personal visit was made each district to review data and district maps.

Land in an irrigation district that converted from surface water supply to groundwater use when a drip/micro system was installed, is referred to as “conversion acres” in this report.

An Overview of the Irrigation District Survey

A representative from the ITRC contacted each district. The main question was “how many acres in your district on drip/micro irrigation choose to not take surface water although it was available?”

Other questions were formulated to lead into the reasoning behind the number of conversion acres. For example, if groundwater is cheap and district water is expensive, the growers might tend to utilize groundwater resources. However, if groundwater quality is bad, the growers might have no choice but to use surface water.

The ITRC also asked about the quality of water delivery service flexibility, because different methods of irrigation require different water delivery flexibility. In some districts the tradition may be to provide water only once every 10 to 15 days for surface irrigation. However, such a low frequency of irrigation (once every 10-15 days) is not compatible with drip/micro irrigation. Changing the flexibility of water delivery can present a major modernization challenge for a district. However, it has been done in many irrigation districts.

Energy Implications of Drip/Micro Conversions to Groundwater.

Figure 1 below illustrates the general situation with irrigation using surface irrigation and surface water. With this combination (surface water and surface irrigation), all the evapotranspiration requirement is met with surface water. Additionally, all or most of the deep percolation ends up in the aquifer. In some areas, such as the eastern side of the San Joaquin Valley, the districts have historically delivered excess water to farms during periods of early spring runoff. By applying that excess water with surface irrigation, the districts were able to recharge the groundwater.
These irrigation systems often had little or no pumping costs. There are sometimes pumping costs by the irrigation district to deliver the surface water to the field turnout.

Figure 1. Surface irrigation with surface water supplies.

Over the past 30 years there has been a large shift to drip/micro irrigation in California. Part of this shift is due to the fact that certain crops can be managed better (control of plant stress, fertigation) with drip/micro than with surface irrigation. The result has been increased yields and/or improved crop quality. Another reason for the shift is the relative ease of irrigating both small and large fields with drip/micro.

Figure 2 illustrates a scenario in which surface water is used for a drip/micro irrigation system. In general (but certainly not always), farmers apply less water with drip/micro than with surface irrigation. Crop evapotranspiration rates tend to be higher under drip/micro than with surface irrigation. The net result is there is less deep percolation of water, which results in less ground water recharge.
Conversion to Groundwater Pumping

ITRC Report No. R 08-001

Drip/Micro/Groundwater Conversions

![Diagram showing reduced groundwater recharge with drip/micro irrigation](image1)

Figure 2. Reduced Groundwater Recharge When Drip/Micro is used with Surface Water.

![Diagram illustrating groundwater-supplied drip/micro system](image2)

Figure 3 illustrates a groundwater-supplied drip/micro system.

![Diagram showing groundwater-recharge, extraction, and energy](image3)

Figure 3. Drip/Micro Irrigation with Groundwater.

Groundwater levels take a “double hit” when growers convert to drip/micro irrigation and groundwater use, because the recharge from flood irrigation is gone, and water is...
extracted from the ground to supply the crop water requirement. When this occurs, the possibility of the groundwater table dropping becomes very likely. Energy consumption increases with these conversions because of three factors:

1. Drip/micro systems typically require about 45 psi at the ground surface, just to operate the system.
2. A well pump is needed to raise the water to the ground surface.
3. Depleted groundwater results in increased lifts (over time) to the ground surface.

Criteria to be labeled as “conversion acres”

In order to be included as conversion acres in this report, the following must be true:

- A farm must have received surface water in the past from an irrigation district, or have easy access to surface water.
- The farm must be utilizing a form of drip/micro irrigation
- On a “normal year” (meaning normal rainfall and surface water supply) all of the farm irrigation water must come from the ground.

If a grower does not have the option to use surface water, but is using drip/micro irrigation and groundwater, then that acreage was not considered as “conversion acreage”.
BASIC DATA

Of the 58 districts contacted,
- 21 reported conversion acres
- 1 district felt it did not have good enough information to participate
- 36 districts reported no conversion acres

Table 1 and Figure 4 provide a summary of conversion acres in the selected districts. The only difference between these two views is that the GIS map does not show conversions by density or percentage of the district. It only shows if there were conversions or not. It is interesting to review Figure 4, because in the San Joaquin Valley, most of the conversions are concentrated along the eastern edge of the valley.

**Table 1. Districts Reporting Conversion Acres**

<table>
<thead>
<tr>
<th>Water/Irrigation District Name</th>
<th>District Size (ac)</th>
<th>Conversion Acres</th>
<th>Conversion Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRESNO I.D.</td>
<td>247,786</td>
<td>9,000</td>
<td>3.6</td>
</tr>
<tr>
<td>GLENN COLUSA I.D.</td>
<td>174,360</td>
<td>3,500</td>
<td>2.0</td>
</tr>
<tr>
<td>CONSOLIDATION I.D.</td>
<td>160,712</td>
<td>4,450</td>
<td>2.8</td>
</tr>
<tr>
<td>MERCEDES I.D.</td>
<td>155,533</td>
<td>5,000</td>
<td>3.2</td>
</tr>
<tr>
<td>ALTA I.D.</td>
<td>134,363</td>
<td>7,780</td>
<td>5.8</td>
</tr>
<tr>
<td>MADERA I.D.</td>
<td>130,741</td>
<td>9,000</td>
<td>6.9</td>
</tr>
<tr>
<td>KERN DELTA W.D.</td>
<td>128,720</td>
<td>960</td>
<td>0.8</td>
</tr>
<tr>
<td>STOCKTON-EAST W.D.</td>
<td>120,406</td>
<td>1,400</td>
<td>1.2</td>
</tr>
<tr>
<td>LOWER TULE RIVER I.D.</td>
<td>103,108</td>
<td>2,800</td>
<td>2.7</td>
</tr>
<tr>
<td>MODESTO I.D.</td>
<td>102,143</td>
<td>1,925</td>
<td>1.9</td>
</tr>
<tr>
<td>SOLANO I.D.</td>
<td>78,070</td>
<td>960</td>
<td>1.2</td>
</tr>
<tr>
<td>TULARE I.D.</td>
<td>73,412</td>
<td>4,275</td>
<td>5.8</td>
</tr>
<tr>
<td>OAKDALE I.D.</td>
<td>73,282</td>
<td>2,280</td>
<td>3.1</td>
</tr>
<tr>
<td>SOUTH SAN JOAQUIN I.D.</td>
<td>72,764</td>
<td>5,025</td>
<td>6.9</td>
</tr>
<tr>
<td>PIXLEY I.D.</td>
<td>69,865</td>
<td>1,930</td>
<td>2.8</td>
</tr>
<tr>
<td>NORTH SAN JOAQUIN W.C.D.</td>
<td>53,313</td>
<td>2,400</td>
<td>4.5</td>
</tr>
<tr>
<td>SHAFTER-WASCO I.D.</td>
<td>38,930</td>
<td>100</td>
<td>0.3</td>
</tr>
<tr>
<td>ANDERSON-COTTONWOOD I.D.</td>
<td>33,404</td>
<td>3,610</td>
<td>10.8</td>
</tr>
<tr>
<td>ORLAND-AROIS W.D.</td>
<td>31,450</td>
<td>2,830</td>
<td>9.0</td>
</tr>
<tr>
<td>ORANGE COVE I.D.</td>
<td>29,231</td>
<td>3,500</td>
<td>12.0</td>
</tr>
<tr>
<td>SAN LUIS CANAL CO.</td>
<td>47,500</td>
<td>490</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>2,059,093</td>
<td>73,215</td>
<td>3.6 (wt. avg.)</td>
</tr>
</tbody>
</table>
Figure 4. Districts with and without conversions.
Reasons for no Conversion Acres in Some Districts

36 out of the 58 surveyed districts (62%) did not report any conversion acres. Each of these districts provided one or more reasons (Table 2) why their growers have not switched to groundwater. These reasons are explained below.

- Not possible to pump groundwater
  - No groundwater available to pump.
  - Groundwater quality is poor (usually too salty).

- The primary crop grown in the district is not compatible with drip (e.g. rice). This is typically determined by climate, location and/or soil type.

- Economics
  - The district may have old and plentiful water rights (usually also meaning inexpensive surface water)
  - The groundwater may be extremely deep (which is expensive to pump).
  - The district may have already encountered a shift to groundwater, but has utilized billing strategies to encourage the use of surface water.
  - Some districts themselves are short of water, so the growers all have well pumps anyway. Therefore, the growers typically will supplement groundwater with district water supplies (taking as much district water as they can get) regardless of irrigation method. There is, then, no “conversion”.

- Excellent water delivery flexibility by the district. This is the largest reason to not convert to groundwater on drip/micro irrigation if groundwater is available. If a grower can obtain irrigation district water whenever he wants it with good service, then the growers typically do not feel a need to switch to groundwater.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Number</th>
<th>Percentage of Stated</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor Quality Groundwater</td>
<td>9</td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td>No Groundwater Available</td>
<td>3</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Excellent District Service</td>
<td>16</td>
<td>34%</td>
<td></td>
</tr>
<tr>
<td>Economics</td>
<td>13</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>Soil/Crop Type Not Compatible w/ Drip</td>
<td>6</td>
<td>13%</td>
<td></td>
</tr>
</tbody>
</table>

1 The “numbers” add up to more than 36 because several districts gave multiple reasons.
Figure 5. Stated Reasons to Not Convert.

Reasons to Convert to Groundwater

21 out of the 58 surveyed districts (36%), reported conversion acres. Table 3 provides a summary of the reasons to convert to groundwater. Each of these districts provided one or more reasons why their growers have begun switching to groundwater. These reasons are explained below:

- The main reason is for grower convenience. Many growers prefer to just turn on a well pump, instead of calling the district and ordering a specific amount of water. With a private well, a grower has ultimate flexibility. He can even automate the irrigation system, so that no work is required except for an occasional checkup of emitters.

- Drip/micro irrigation requires prolonged duration and increased frequency, which is not compatible with some outdated district infrastructure and/or management practices. For example, some districts have reported having small, concrete lined farmer ditches which run a mile or more away from the canal to service remote fields. This worked fine for surface irrigation. However, when the farmer converts to drip, he also needs to change this canal to an underground pipeline. This upgrade would be a significant cost. From the farmer’s point of view, the money may be better spent on a well and pump.

- Uncertainty of surface water supplies in dry years is a major problem for growers – especially those with permanent plantings. Depending on the districts’ water rights, some districts may have access to surface water nearly all year long, while others may be limited to only a few weeks of water use on a dry year.
• Some growers choose to use groundwater due to water quality issues. Many districts must deal with trash/debris removal from canals. In Merced Irrigation District, the trash/debris have grown to such a problem that growers were switching to groundwater to reduce filtration requirements. MID therefore began an aggressive technical assistance program to help farmers with good pre-filtration designs.

• When groundwater is available, many growers will compare the price of surface water to the perceived cost of groundwater. Even if groundwater is slightly more expensive, some growers may choose to go with groundwater due to the convenience of use.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Number</th>
<th>Percentage of Stated Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility/Convenience</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Need Stable Supply</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Dirty District Water</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Economics</td>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>

1 The total number of reasons exceeds 21 because several districts gave multiple reasons.

Case: New Almond Plantings

It is apparent that throughout California, the number of permanent plantings (mostly almonds) is increasing. This is important for this study, because nearly all growers who put in new fields of almonds or other permanent plantings will tend to use drip/micro irrigation, and many of them will use groundwater for reliability and flexibility. When a grower invests in a new planting of almonds and drip irrigation, there is a huge upfront cost, not to mention operating costs, with no payback expected for nearly five years. Therefore, if growers suspect even a hint of insufficient water supplies from the district, they typically will choose to install a well to protect their investment. Since the groundwater well may be required for a reliable supply of water, and dual system hookups may be expensive (or confusing), the grower may just choose to not purchase the additional components that would create a dual system for occasionally utilizing surface water from the district.
Figure 6. Stated Reasons to Convert.
ANALYSIS OF SURVEY FINDINGS

Economics

Initial Costs for Groundwater Pumping. One conversion hurdle for some farmers is the initial cost of drilling a well and buying the pump. Other farmers already have well pumps in place, so this is not a concern.

Quotes were obtained from pump dealers, based on recent installations of vertical turbine pumps in their area. Information is seen in Table 4.

Table 4. Information from pump dealers on recent pump purchases. Does not include the well drilling, casing, or development.

<table>
<thead>
<tr>
<th>Quote #</th>
<th>Q, gpm</th>
<th>Setting Depth, ft.</th>
<th>HP</th>
<th>Material Price, $</th>
<th>Installation Price, $</th>
<th>Total Cost, $</th>
<th>$/HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2000</td>
<td>300</td>
<td></td>
<td>55,000</td>
<td>5,000</td>
<td>60,000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1500</td>
<td>350</td>
<td>250</td>
<td>60,000</td>
<td>5,000</td>
<td>65,000</td>
<td>260</td>
</tr>
<tr>
<td>3</td>
<td>2000</td>
<td>500</td>
<td>200</td>
<td>53,109</td>
<td>3,510</td>
<td>56,619</td>
<td>283</td>
</tr>
<tr>
<td>4</td>
<td>1500</td>
<td>380</td>
<td>150</td>
<td>41,256</td>
<td>4,500</td>
<td>45,756</td>
<td>305</td>
</tr>
<tr>
<td>Avg:</td>
<td>1750</td>
<td>382</td>
<td>200</td>
<td>52,341</td>
<td>4,503</td>
<td>56,844</td>
<td>282</td>
</tr>
</tbody>
</table>

The cost for a typical 450’ deep well with a 16” casing is about $47,000 – although properly designed and developed wells can easily cost twice that.

In summary, a “typical” cost for a well plus pump is about $100,000.

Annualized Groundwater Pumping Costs. Beyond the initial cost of a pump and well, it is interesting to examine annualized own/operation expenses. Figure 7 reflects information received from pump dealers. Assumptions included:

- Power cost of 0.16 $/kW-hr
- Pump life = 25 years
- Well life = 40 years
- Maintenance interval = 10 years
- Interest rate = 7%
- 2000 hrs/year of operation
- Pumping plant efficiency = 50%
- TDH = 170’ (weighted average in the 21 districts with conversion acres)
Figure 7. Annualized Groundwater Pumping Costs.

**Costs In Individual Districts.** District and groundwater prices vary according to location. There are many irrigation water billing rates and billing methods across the state, and it is difficult to generalize them into one comparable number. However, irrigation districts typically charge for water in two ways. One billing method uses dollars per acre foot of water delivered (volumetric). The other type of billing method charges an assessment on the land - usually per acre of irrigable land. Many irrigation districts use a combination of the two methods.

Table 5 shows an approximate comparison of groundwater versus surface water costs – excluding filtration costs for the surface water.
Table 5. Comparison of groundwater price vs. district water price for districts with conversion acres.

<table>
<thead>
<tr>
<th>Irrigation District</th>
<th>Depth to Groundwater, ft.</th>
<th>Approx. Groundwater Price, $/ac-ft</th>
<th>Groundwater plus Annualized costs, $/ac-ft</th>
<th>Reported District Water Price, $/ac-ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALTA I.D.</td>
<td>165</td>
<td>65</td>
<td>76</td>
<td>10</td>
</tr>
<tr>
<td>ANDERSON-COTTONWOOD I.D.</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>CONSOLIDATED I.D.</td>
<td>165</td>
<td>65</td>
<td>76</td>
<td>6</td>
</tr>
<tr>
<td>FRESNO I.D.</td>
<td>170</td>
<td>67</td>
<td>79</td>
<td>13</td>
</tr>
<tr>
<td>GLENN COLUSA I.D.</td>
<td>30</td>
<td>12</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>KERN DELTA W.D.</td>
<td>270</td>
<td>106</td>
<td>125</td>
<td>20</td>
</tr>
<tr>
<td>LOWER TULE RIVER I.D.</td>
<td>115</td>
<td>45</td>
<td>53</td>
<td>72</td>
</tr>
<tr>
<td>MADERA I.D.</td>
<td>160</td>
<td>63</td>
<td>74</td>
<td>50</td>
</tr>
<tr>
<td>MERCED I.D.</td>
<td>50</td>
<td>20</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>MODESTO I.D.</td>
<td>50</td>
<td>20</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>NORTH SAN JOAQUIN W.C.D.</td>
<td>160</td>
<td>63</td>
<td>74</td>
<td>17</td>
</tr>
<tr>
<td>OAKDALE I.D.</td>
<td>80</td>
<td>31</td>
<td>37</td>
<td>6</td>
</tr>
<tr>
<td>ORANGE COVE I.D.</td>
<td>360</td>
<td>141</td>
<td>166</td>
<td>71</td>
</tr>
<tr>
<td>ORLAND-ARTOIS W.D.</td>
<td>125</td>
<td>49</td>
<td>58</td>
<td>39</td>
</tr>
<tr>
<td>PIXLEY I.D.</td>
<td>150</td>
<td>59</td>
<td>69</td>
<td>79</td>
</tr>
<tr>
<td>SAN LUIS CANAL CO.</td>
<td>350</td>
<td>138</td>
<td>162</td>
<td>6</td>
</tr>
<tr>
<td>SHAFTER-WASCO I.D.</td>
<td>270</td>
<td>106</td>
<td>125</td>
<td>61</td>
</tr>
<tr>
<td>SOLANO I.D.</td>
<td>120</td>
<td>47</td>
<td>55</td>
<td>26</td>
</tr>
<tr>
<td>SOUTH SAN JOAQUIN I.D.</td>
<td>150</td>
<td>59</td>
<td>69</td>
<td>8</td>
</tr>
<tr>
<td>STOCKTON-EAST W.D.</td>
<td>164</td>
<td>64</td>
<td>76</td>
<td>20</td>
</tr>
<tr>
<td>TULARE I.D.</td>
<td>120</td>
<td>47</td>
<td>55</td>
<td>44</td>
</tr>
</tbody>
</table>

Almost without exception, groundwater costs are greater than district (surface) water. It is possible that many farmers do not understand the true cost of groundwater pumping. However, if they do understand the difference in cost between groundwater and surface water, there must be reasons other than pumping costs to justify converting to groundwater.

Figure 8 does not include the impact of groundwater pumping costs, but it does indicate that there is no uniform relationship between irrigation district water prices and conversion acres.
Some districts mentioned that if adequate supplies of both district (surface) water and groundwater are available, the price of the district water must be competitive in order to maintain customers on surface water.

However, in districts with limited water supplies, district water may be quite expensive but farmers will still purchase the district water – especially in the case of poor or limited groundwater availability.

**District Delivery Flexibility**

Every district that reported a rotation delivery schedule to field turnouts also reported conversion acres. On the other hand, every district that has modernized to the flexible arranged schedule has zero conversion acres. The most prominent reason to convert is the existence of an inflexible district water delivery schedule.
Figure 9. District Water Delivery Flexibility (note that there are no conversion acres if a “flexible arranged” schedule is available).

Figure 9 shows how closely the district delivery flexibility is tied to the amount of conversion acres. This figure was created by averaging the percentage of conversion acres per district for each category of flexibility. The bar which represents the flexible arranged schedule is missing from the chart, because there are zero conversions in every single district that has this high level of flexibility.

Figure 10 provides a view of this same information on a map of California. This map clearly shows each district and its flexibility (by color), and the approximate location of conversion acres across the state. Each yellow dot represents the percentage of conversions in a particular district. The dots are typically concentrated in districts with either rotation or 24 hour arranged schedules.
Figure 10. District Flexibility vs. Conversion Percentages.
**Case Study: Fresno Irrigation District**

Fresno Irrigation District is a large district. So large in fact, that the upstream and the downstream ends of the district have completely different water delivery flexibilities to fields. During irrigation season, water is always flowing through the canals at the upstream end of the district (because the required flow for Fresno ID is so large), while on the downstream end, water is delivered on rotation schedule. Due to the layout of the district, the upstream end is effectively a flexible arranged schedule, while the downstream end is by default (and district policies) a rotation schedule. Therefore, there are no conversion acres in the upstream end of the district. Rather, they are all concentrated in the middle to lower end of the district. This reinforces the observation that growers who have flexible water delivery service have a low tendency to switch to groundwater.

**The Influence of Groundwater Quality**

Figure 11 shows the percentage of conversions in each district with a scaled yellow dot that represents the percentage of conversion acres in each district. In addition, the reported water quality of the district is represented by the color of each district. This map shows that districts with very low quality groundwater will not have conversion acres.
Figure 11. Groundwater Quality vs. Conversions.
TRENDS

Approximately 2/3 of the districts that reported conversion acres also indicated a concern that more acreage will convert in the future (see Figure 12).

Fresno Irrigation District (FID) is perhaps the most at-risk district for large scale future conversions. FID is on a rotation schedule. FID currently bills using only an assessment charge per acre of land in the district. Growers in Fresno ID currently pay the same amount to the district whether they take water or not, and no matter how much they take (they only have to wait for their turn in the rotation schedule). The combination of (i) per acre billing rather than volumetric billing, (ii) rotation delivery, and (iii) inexpensive water, encourages growers to stay with surface irrigation methods.

Fresno ID is considering a switch to volumetric billing. If this occurs, groundwater may appear to be a better choice for growers, since they cannot get “free excess” district water anymore. Some in FID estimate that as many as 60,000 acres could convert to drip/micro and groundwater if FID switches to volumetric billing without a corresponding improvement in water delivery flexibility. FID is beginning a modernization program to address the flexibility issue.

![Figure 12. Future Conversions Expected (out of 21 districts reporting conversions).](image-url)
SUMMARY

The acreage under drip/micro irrigation will increase in the near and distant future. There is no single reason to switch irrigation methods, but reasons include perceptions of less labor, less fertilizer consumption, and higher yields and better crop quality.

- It appears that groundwater levels will continue to decrease with time. Reasons include:
- Less water available for surface diversion to agriculture.
- Large acreages exist outside of irrigation district boundaries. These acreages depend upon groundwater only.

Less groundwater recharge when individuals convert to drip/micro.

Overall, there is only a finite volume of irrigation district water available in the irrigated areas of California. From a water supply standpoint, one could legitimately ask if there is really impact on water supplies if farmers switch to groundwater. The answer is “yes”, but it is complicated. The major points are as follows:

- This volume of district-supplied water can vary tremendously from year to year. Therefore, irrigation districts depend on internal groundwater recharge during wet years. Although some irrigation districts have recharge basins, most of the districts depend upon over-irrigation with surface irrigation during the spring and early summer (when high runoff rates are available) to achieve much of the recharge. If fields are not set up for surface irrigation, this is problematic.
- If districts are unable to utilize these occasional very high flood flows for recharge, the water is “lost” to the ocean. In other words, the “finite volume” of water is reduced.
- If there is a major shift away from surface irrigation supplies, even during the summer months some irrigation districts may have difficulty selling surface water that is available. If that water is not used, it will be lost to the area – meaning that overall, the groundwater overdraft will accelerate.
- As urbanization increases, there are less good groundwater recharge sites available for irrigation districts to purchase as recharge ponds. This means that even if the districts would embark on large recharge projects, it may be difficult to implement them successfully because of the lack of good sites.

Impacts on Energy Consumption

More pumping energy is required for use of groundwater than surface water in almost all cases. One exception may be in Anderson Cottonwood Irrigation District. Due to the proximity of the district to the Sacramento River, the depth to groundwater there can range from 0-10 feet deep. In this case, the energy required to lift the water only 10 feet or so is very minimal. However, district canals convey irrigation water long distances with high seepage rates – and some of that water is pumped from the river. Therefore, district water that is pumped will in some cases represent an inefficient use of energy, because so much water is lost to seepage.
Table 6 provides an estimate of the extra energy used per year on existing “conversion acreage”. The computation process that was used included the following steps:

- The depth to groundwater needed to be determined. One source for groundwater depth is the Department of Water Resources. In addition to this information, the ITRC asked the districts for an average depth to groundwater in their area.
- To account for column losses, bearing friction, drawdown, and other losses, 20% was added to the groundwater depth to come up with Total Dynamic Head (TDH).
- The overall pumping plant efficiency was assumed to be 50%, based on reported on-farm pumping plant efficiency measurements.
- An average volume of water pumped per acre was 3 acre-feet.

Table 6. Direct Energy Impact of Existing Conversion Acres.

<table>
<thead>
<tr>
<th>District Name</th>
<th>Conversion Acres</th>
<th>Depth to Groundwater, ft</th>
<th>Groundwater Energy (kW-hr/ac-ft)</th>
<th>Conversion Acre Energy/year (kW-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHAFTER-WASCO I.D.</td>
<td>100</td>
<td>270</td>
<td>663</td>
<td>198,886</td>
</tr>
<tr>
<td>SAN LUIS CANAL CO.</td>
<td>490</td>
<td>350</td>
<td>859</td>
<td>12,63,291</td>
</tr>
<tr>
<td>KERN DELTA W.D.</td>
<td>960</td>
<td>270</td>
<td>663</td>
<td>1,909,301</td>
</tr>
<tr>
<td>SOLANO I.D.</td>
<td>960</td>
<td>120</td>
<td>295</td>
<td>848,578</td>
</tr>
<tr>
<td>STOCKTON-EAST W.D.</td>
<td>1,400</td>
<td>164</td>
<td>403</td>
<td>1,691,263</td>
</tr>
<tr>
<td>MODESTO I.D.</td>
<td>1,925</td>
<td>50</td>
<td>123</td>
<td>708,990</td>
</tr>
<tr>
<td>PIXLEY I.D.</td>
<td>1,930</td>
<td>150</td>
<td>368</td>
<td>2,132,495</td>
</tr>
<tr>
<td>OAKDALE I.D.</td>
<td>2,208</td>
<td>80</td>
<td>196</td>
<td>1,301,153</td>
</tr>
<tr>
<td>NORTH SAN JOAQUIN W.C.D.</td>
<td>2,400</td>
<td>160</td>
<td>393</td>
<td>2,828,594</td>
</tr>
<tr>
<td>LOWER TULE RIVER I.D.</td>
<td>2,800</td>
<td>115</td>
<td>282</td>
<td>2,371,894</td>
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<td>ORLAND-ARTOIS W.D.</td>
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<td>125</td>
<td>307</td>
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<td>GLENN COLUSA I.D.</td>
<td>3,500</td>
<td>30</td>
<td>74</td>
<td>773,444</td>
</tr>
<tr>
<td>ORANGE COVE I.D.</td>
<td>3,500</td>
<td>360</td>
<td>884</td>
<td>9,281,324</td>
</tr>
<tr>
<td>ANDERSON-COTTONWOOD I.D.</td>
<td>3,610</td>
<td>5</td>
<td>12</td>
<td>132,959</td>
</tr>
<tr>
<td>TULARE I.D.</td>
<td>4,275</td>
<td>120</td>
<td>295</td>
<td>3,778,825</td>
</tr>
<tr>
<td>CONSOLIDATED I.D.</td>
<td>4,450</td>
<td>165</td>
<td>405</td>
<td>5,408,034</td>
</tr>
<tr>
<td>MERCED I.D.</td>
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<td>123</td>
<td>1,841,533</td>
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<td>SOUTH SAN JOAQUIN I.D.</td>
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<td>150</td>
<td>368</td>
<td>5,552,221</td>
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<td>ALTA I.D.</td>
<td>7,780</td>
<td>165</td>
<td>405</td>
<td>9,455,901</td>
</tr>
<tr>
<td>FRESNO I.D.</td>
<td>9,000</td>
<td>170</td>
<td>417</td>
<td>11,270,179</td>
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<tr>
<td>MADERA I.D.</td>
<td>9,000</td>
<td>160</td>
<td>393</td>
<td>10,607,227</td>
</tr>
</tbody>
</table>

TOTAL, kW-hr/yr: 75,962,000

Table 6 shows that the total amount of energy spent on conversion acres (found in districts through this survey) is 75,962 MW-hr. However, this is an understatement for two reasons.

- First, this only includes 80% of district land.
Second, if this trend continues in this way, the groundwater levels will drop. This increase in energy consumption will be compounded because everyone that pumps groundwater will be using more electricity.
  - The growers who are pumping groundwater (included in this report)
  - All well pumps outside of district boundaries
  - Cities that rely on groundwater for their supply

Therefore, the effect of dropping groundwater levels will increase statewide energy consumption.

**Preventing an increase in conversion acreage**

**District modernization**
Growers want flexible district service in order to accommodate the requirements of drip/micro irrigation. The results of this study indicate that irrigation district modernization may be the best defense against drip/micro irrigated farmland converting to groundwater use.

**Certainty of Surface Water Availability**
Growers need a reliable source of irrigation water. Almond trees, for example, do not typically begin producing until five years after planting. With a large investment on their hands, growers must have a guarantee that they will have enough water to keep their trees alive for the long term. Since surface water is sometimes unreliable (on a dry year), and it may be expensive to purchase and maintain the hardware for a dual irrigation system (one that uses both groundwater and surface water), some growers of permanent plantings will choose to utilize groundwater only. This shift to groundwater is a simple (albeit sometimes more expensive) solution if groundwater is available.

Unfortunately, the present hydrologic status of California indicates that little will be done to guarantee stable surface water supplies.

**Incentive and Grant Programs.**
The CEC and other organizations can use incentives to encourage surface water use by growers who are on drip/micro irrigation. These incentives should most likely come in the form of grants to irrigation districts for modernization. If the districts are able to update their infrastructure and operations, it will lead to better utilization of surface water on fields with drip/micro irrigation.

Incentive programs may have unexpected consequences. An existing program that is worth mentioning is the Ag ICE program sponsored by PG&E. If growers signup, PG&E will buy and destroy their old diesel engine, and then the growers are required to use a certain amount of electricity. This can unintentionally result in increased groundwater pumping, because the only way that the growers can use the required amount of electricity is to pump groundwater.
**Successful Case Study: Chowchilla Water District.**

Chowchilla Water District has a critically over-drafted groundwater basin. The groundwater levels have dropped as much as 80 feet in the last 30 years in the Chowchilla area. This rapid drop in water levels was due to major new extraction that was occurring. When the district realized this problem, three things occurred to reverse the problem:

- The district adjusted its billing strategy to include an assessment charge of $40/ac that gets billed whether the growers take surface water or not. This revenue can be used to lower the volumetric rates on water or to implement new groundwater recharge projects. The effect of this billing strategy is to make district water use more attractive to growers. Also, the farmers tend to think that since they are paying for the water anyway – so why not use it?

- The Chowchilla Water District began a process of modernization. The first step involved switching from a rotation schedule to a 24 hour arranged schedule, which requires growers to call in and order water 24 hours before they take it. They are also working on increasing allowable flexibility for volume of water delivered and flow rate. The district modernization has included extensive buffer reservoirs, flow measurement, excellent water level control with long crested weirs and ITRC flap gates, plus SCADA.

- In addition to the above changes made by the district, growers began finding that they were spending more and more on electricity due to the dropping groundwater elevations. This increase in pumping costs has helped the problem to self correct, by making it more obvious to farmers that there is significant energy cost to groundwater.

Now, Chowchilla Water District does not report any conversion acres. The shift in water use has been reversed. However, the groundwater elevations do not appear to be rising. This is due in part to groundwater pumping by farmers outside the district. It is also due to the fact that the district cannot meet the peak summer demands of ET, so everyone has a well in conjunction with the surface water. The district water shortage will be worsened if in the future more water must be released into the San Joaquin River for salmon run restoration.
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