furrow irrigation system at this site. Either a
direct and sizeable cost for disposal of added
drainwater generated from the furrow sys-
tems, substantially higher yields, or changes
crop rotations to higher-value crops may
increase the economic viability of subsur-
facedrip at this site.
Future on-farm demonstration needs.
Additional commercial demonstrations are
now underway within drainage problem
areas, supported by the DWR, the USDA-
ARS, Cooperative Extension, and the U.S.
Soil Conservation Service. Future needs to
be addressed include: overcoming inconve-
nient set times for furrow systems
with shortened furrow lengths; developing
drainage reduction methods for surge flow
irrigation of sandier soils; determining fer-
tilization and chemigation requirements of
subsurface drip irrigation; learning the
nominal lifespan of subsurface drip systems;
managing salinity with subsurface drip sys-
tems, particularly where water tables are
shallower than those encountered in this
field project, and optimizing subsurface drip
system design (spacing and depth) for use
with alternative crop rotations.

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A. Goldhammer is Irrigation Extension Specialist,
Kearney Agricultural Center.
The authors gratefully acknowledge the assis-
tance of Charles McNish, on-site demonstration
manager, the Claude Laval Corporation, Netafim
Irrigation Incorporated, Stone Land Company,
and Westlands Water District.

Subsurface drip produced
highest net return in Westlands
area study

Richard B. Smith  J. D. Oster  Claude Phene

Cotton was produced using sub-
surface drip, low-energy precision
application (LEPA), scheduled fur-
row, and conventional furrow irri-
gation systems in 1989. Subsur-
facedrip irrigation produced the
highest net return to the grower
through increased cotton yields.
Significant water conservation was
achieved with both pressurized irri-
gation systems (subsurface drip
and LEPA). However, computer-
aided scheduling of furrow irriga-
tion did not result in significant wa-
ter savings. Pressurized irrigation
systems may offer the flexibility
and control necessary to signifi-
cantly limit unnecessary water addi-
tions to the shallow groundwater
table.

In evaluating how drainwater disposal
costs affect farm profits, the University of
California Committee of Consultants on
Drainwater Reduction concluded that
maximum profits are achieved with furrow
irrigation systems where there is no cost
associated with drainwater disposal. Prof-
ittiability decreased with increasing disposal
costs; the rate of decrease was dependent on
the infiltration uniformity achievable for each
system. The lower the uniformity, the greater
the rate of decrease. Where drainwater dis-
posal costs exceeded about $75 per acre-
foot, two pressurized irrigation systems
— subsurface drip and low-energy precision
application (LEPA) — were projected to be
more profitable than furrow systems.

Boyle Engineering Corporation, under
contract with the California Department of
Water Resources Water Conservation Of-
Office, is testing this economic analysis (DWR
project). The objective of this on-farm dem-
stration is to evaluate the effectiveness of
subsurface drip and LEPA irrigation sys-
tems on reducing deep percolation losses
and increasing grower profitability. These
pressurized irrigation systems are also com-
pared to existing and scheduled furrow irri-
gation systems. This paper summarizes
data obtained during the first year (1989) of
this project and compares them to those
reported in the previous paper.
The DWR project site is located at Harris
Farms in Westlands Water District, about 6
miles southwest of Five Points. The site con-
ists of about 160 acres equally divided into
four irrigation treatments. Soils are fine-
textured with average soil profile salinity (0 to
24 inches) generally less than about 4
decisiemens per meter (ds/m). The project
site is underlain by a shallow saline water
table. Depth to groundwater ranges from
about 24 to 30 inches in spring and early
summer to about 72 to 84 inches in fall and
early winter. The average shallow water table
salinity ranges from about 4 to 11 ds/m.
The site was planted to cotton (Acala SJ-2)
in 1989.

Irrigation systems

Subsurface Drip. The subsurface drip
system uses 0.4 gallon-per-hour in-line
emitters spaced at 40 inches along 0.52-inch
inside diameter x 0.62-inch outside diameter
polyethylene tubing. Spacing between tub-
ing laterals is 80 inches. Tubes were buried
18 inches deep (62 inches in nonwheel rows
to minimize compaction problems.
Two buried PVC submain supply irri-
gation water to the laterals. Each submain
isregulated by a 4-inch pressure-regulating
valve. The drip tube is connected to the
buried PVC pipe with a polyethylene hose
riser. The riser is connected to a saddle
 glued onto the PVC pipe. Lateral runs are
approximately 450 feet. The ends of each
lateral are connected to a PVC pipe flush
manifold. Each manifold has two manually
operated flush valves.

A 30-horsepower booster pump supplies
water to the system from a small reservoir.
Filtration is performed by media filters filled
with No.20 crushed silica media. The media
has an approximate filtration capability of
200- to 250-mesh. The filtered water is me-
tered before going into the PVC mainline.
Nitrogen and phosphorus fertilizers, and
sulfuric acid to prevent root intrusion, are
injected with a venturi connected across the
discharge and inlet of the booster pump.
The pressure-regulating valves at the
submain inlets are set to regulate pressure at
25 psi. This corresponds to a system average
discharge of 0.56 gallon per hour per emit-
ter. The average application rate is 0.04 inches
per hour. Overall calculated emission uni-
formity is 93%. The system runs approximately 8.5 hours per day to meet the average peak cotton evapotranspiration of 0.32 inches. Preirrigation was applied using hand-move sprinklers.

LEPA. The low-energy precision application (LEPA) system is a linear converted to hose-drag operation. It is approximately one-quarter mile long and is constructed of 6%-inch piping. There are seven spans of 178 feet each with a 40-foot overhang at the end. There are 43 booms attached to the main linear pipe. Most of the booms have nine outlets spaced 40 inches apart. At each outlet, there is a ¼-inch, 15-psi pressure regulator and ½-inch brass nozzle connected to a ¼-inch by 7-foot drop tube, and a furrow bubbler.

Water is pumped from a small reservoir using a diesel engine driven pump. The water is filtered by a rotating suction screen. This 18-mesh screen has interior water jets that rotate the screen and remove exterior debris. Pressurized water for the jets is supplied by the pump discharge. The pump feeds a surface aluminum pipe mainline going to the LEPA system. Six-inch riser valves are located about 340 feet from each end of the field, providing an attachment point for a 4-inch, 360-foot flexible drag hose.

The approximate discharge rate of each drop tube is 1.6 gallons per minute. Overall system capacity is about 610 gallons per minute. Assuming 85% to 90% uniformity, the system must be operated 10.5 to 11 hours per day to meet the average peak cotton evapotranspiration of 0.32 inches. Preirrigation was applied using hand-move sprinklers.

Furrow. Both the scheduled and existing furrow irrigation systems consisted of 10-inch gated pipe used on 40-inch beds. The scheduled furrow plot consisted of computer-aided irrigation scheduling, whereas the existing furrow plot was managed by the grower (check plot). Furrow length was approximately 1,190 feet with a slope of about 0.2%. Energy dissipation socks were placed on the gates to prevent soil erosion. Water supply was provided through a buried PVC pipeline connected to Westlands Water District facilities. A 10-inch flow meter was connected at the pipeline discharge to record the volume of irrigation water applied.

Preirrigation was applied using all furrows. Alternate furrows were used for each of the four crop irrigations. The field was irrigated using blocked ends because tailwater collection/reuse facilities were not available. Set times were determined based on soil-water depletion and estimated soil intake rates.

Irrigation scheduling
Water content of the soil was monitored weekly with a neutron probe at three locations in each irrigation treatment with two access tubes per location. Irrigation scheduling was based on measured soil-water content, weather, and predicted plant evapotranspiration. Climate data was provided by the U. S. Department of Agriculture's California Irrigation Management Information System (CIMIS) weather station located at the University of California Westside Field Station. A computer program was used to model plant evapotranspiration.

For the subsurface drip and LEPA irrigation systems, the computer program was used to predict the total number of operating hours needed to satisfy plant evapotranspiration for the next 7 days. A water balance for the previous week was used to check the accuracy of the irrigation schedule. For the scheduled furrow irrigation system, the computer program was used to predict frequency and duration of irrigation. The prediction limits were set by inputting the allowable soil moisture depletion, which was based on root zone depth, soil water-holding capacity, estimated soil intake rate, and irrigation system design and performance. Irrigations were scheduled by the grower on the existing furrow irrigation system based on experience.

Irrigation water application
Irrigation water applications summarized in table 1 were based on meter readings from each irrigation treatment. Preirrigation for the subsurface drip and LEPA treatments was applied using hand-move impact sprinklers. Lateral spacing was 45 feet with a 24-hour set time using ¾-inch nozzles. Both furrow treatments were preirrigated using gated pipe and all furrows. The LEPA irrigation system had the lowest infiltrated water, which reflects operational and mechanical problems that constrained our abil-
ity to properly apply irrigation water. Irrigation scheduling provided little benefit with water infiltrated for both furrow treatments being nearly equivalent at 29.6 and 30.5 acre-inches per acre for the scheduled and existing furrow systems, respectively.

Net income for 1989

Crop yield and value for each irrigation treatment are summarized in table 2. The treatments were harvested individually using grower-owned and -operated equipment, and yield and value were determined from grower records. Variable and fixed crop production costs were obtained from grower records. Net crop return for the different irrigation treatments is summarized in table 3. Crop yield increases for the subsurface drip and decreases for the LEPA irrigation system affected the net income. Subsurface drip irrigation had the highest net income in 1989 ($268.58 per acre). The furrow plots had nearly identical net incomes: $130.03 per acre for the existing furrow and $127.65 per acre for the scheduled.

The LEPA irrigation system did not recover the production costs (net loss of $81.63 per acre). Operational and mechanical problems caused irrigation interruptions, which may have resulted in plant stress and subsequent reduced boll set. The 1989 results from the LEPA treatment do not fairly represent yields and returns that may be achieved from this system under normal operating conditions.

Summary and conclusions

Based on the 1989 results from the DWR demonstration project, the following conclusions can be drawn:

- Pressurized irrigation systems are more costly to install, operate, and maintain compared to furrow irrigation.
- Increased crop yield and gross returns are needed to compensate for increased subsurface drip and LEPA irrigation system costs.
- Computer-aided scheduling of furrow irrigation did not result in significant water savings.
- Reductions in subsurface drainwater disposal costs and increases in the ability to sustain long-term irrigation and agriculture in the western San Joaquin Valley may be additional economic benefits.
- Pressurized irrigation systems need further evaluation under western San Joaquin Valley conditions to develop a better understanding of the long-term management requirements and profitability.

Richard B. Smith is a Senior Agronomist at Boyle Engineering Corporation, Fresno; J. D. Oster is Extension Soils and Water Specialist at UC Riverside, and Claude Phene is a Research Leader at USDA-ARS, Fresno.

<table>
<thead>
<tr>
<th>Irrigation system</th>
<th>Preirrigation</th>
<th>Crop irrigation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsurface drip</td>
<td>5.8</td>
<td>17.3</td>
<td>23.1</td>
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<tr>
<td>LEPA</td>
<td>5.8†</td>
<td>14.4†</td>
<td>20.2</td>
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<tr>
<td>Scheduled furrow</td>
<td>8.8‡</td>
<td>20.8</td>
<td>29.6</td>
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<tr>
<td>Existing furrow</td>
<td>9.4†</td>
<td>21.1</td>
<td>30.5</td>
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</table>

*Preirrigation by hand-move sprinklers.
†Low crop irrigation applications for the LEPA system reflect operational and mechanical problems that constrained the ability to properly schedule and apply irrigation water.
‡Preirrigation by furrow.

<table>
<thead>
<tr>
<th>Irrigation system</th>
<th>Yield*</th>
<th>Value†</th>
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<tbody>
<tr>
<td></td>
<td>Seed</td>
<td>Lint</td>
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<tr>
<td>Subsurface drip</td>
<td>2,884</td>
<td>1,527</td>
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<tr>
<td>LEPA</td>
<td>1,641</td>
<td>1,016</td>
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<tr>
<td>Scheduled furrow</td>
<td>2,168</td>
<td>1,064</td>
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<tr>
<td>Existing furrow</td>
<td>1,975</td>
<td>1,081</td>
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*Cotton seed and lint yield from grower records for each irrigation treatment.
†Value estimates based on assuming seed at $170/ton and lint at $0.75/lb.

<table>
<thead>
<tr>
<th>Irrigation system</th>
<th>Subsurface drip</th>
<th>LEPA</th>
<th>Improved furrow</th>
<th>Historic furrow</th>
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<tr>
<td>Variable costs:</td>
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<td>Water</td>
<td>102.78</td>
<td>89.93</td>
<td>131.59</td>
<td>135.97</td>
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<td>Irrigation labor</td>
<td>12.10</td>
<td>13.57</td>
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<tr>
<td>Fertilizer</td>
<td>48.85</td>
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<td>Fumigant</td>
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<td>0.00</td>
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<tr>
<td>Cultivar</td>
<td>667.94</td>
<td>667.94</td>
<td>583.16</td>
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<td>773.83</td>
<td>789.01</td>
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<td>Fixed costs:</td>
<td></td>
<td></td>
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<td>Irrigation system†</td>
<td>287.70</td>
<td>206.39</td>
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<td>Equipment</td>
<td>39.50</td>
<td>39.50</td>
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<td>245.89</td>
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<td>Total production cost</td>
<td>1,190.11</td>
<td>1,000.12</td>
<td>853.78</td>
<td>848.60</td>
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<td>Loss seed credit</td>
<td>243.44</td>
<td>156.49</td>
<td>183.43</td>
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<td>Net cost of production</td>
<td>876.67</td>
<td>843.63</td>
<td>670.35</td>
<td>680.72</td>
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<td>Total income</td>
<td>1,145.25</td>
<td>762.00</td>
<td>798.00</td>
<td>810.75</td>
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<td>Net return or (loss)</td>
<td>266.56</td>
<td>[81.63]</td>
<td>127.65</td>
<td>130.03</td>
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</table>

*Based on crop yield and production cost data from grower records provided for each irrigation treatment.
†Capital recovery assuming 10 years at 10% interest.
‡Irrigation system capital cost estimated at $1,350 per acre for subsurface drip, $584 per acre for LEPA, and $155 per acre for furrow. A detailed irrigation system cost estimate is available from the authors by request.

CALIFORNIA AGRICULTURE, VOLUME 45, NUMBER 2