China, and Japan, maintained their import demand for California's agricultural products. Overall, the major export commodities such as cotton, almonds, wine, beef and oranges did not suffer a significant reduction in demand due to the Asian crisis. Those commodities that did suffer a decline in demand are a relatively small share of California's overall agricultural export value, with table grapes a possible exception. Our conclusion is that California exports dropped little as a consequence of the crisis.

Within Asia, currency devaluations improved agricultural export competitiveness, and at the same time, increased the domestic prices (in local currency) of agricultural products. So many local Asian farmers actually benefited from the financial crisis. While we cannot make the same claim for California farmers, at least they were not unduly harmed.

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Pumping energy costs, frost protection and irrigation blocks are major factors to consider

Costs of pressurized orchard irrigation vary with system design

Larry Schwankl ❑ Terry Prichard ❑ Blaine Hanson ❑ Ilene Wellman

The costs of solid-set sprinkler and microirrigation (drip, microsprinkler and minisprinkler) systems are a major factor in the adoption of these irrigation technologies. Following design criteria provided to them, an irrigation design firm prepared 22 different designs for the same almond orchard. Initial and annualized costs for each of these designs are presented and discussed. The costs were highest for the solid-set sprinkler systems. The inclusion of frost protection substantially increased the costs of the solid-set sprinkler, microsprinkler and minisprinkler systems. Designs allowing the 40-acre orchard to be irrigated in two 20-acre irrigation blocks significantly reduced the costs. Pumping energy costs were a major portion of the annualized costs for all designs.

The costs of pressurized irrigation systems (solid-set sprinklers and microirrigation) for orchards are a major limitation to their adoption. However, these systems can provide a number of benefits, including the potential for improved crop yield and quality, high irrigation uniformity and efficiency, the capability to inject chemicals through the irrigation system (chemigation), fewer weeds, and the ability to deal with water infiltration issues. For some orchards on hilly terrain, flood irrigation systems are not feasible and only pressurized systems provide adequate irrigation capability.

Due to cost and time constraints, the full range of irrigation system designs and costs (including initial costs and operating expenses) for a single orchard is seldom available to most growers. Instead, previously developed design and cost estimates from other orchards are generally used. But the other irrigation system often differs from what is needed in the proposed orchard, and a true cost comparison is difficult to come by.

A project was undertaken in which multiple pressurized-irrigation-system designs were developed for the same proposed orchard. Golden State Irrigation Services, a highly qualified design and supply firm, developed these designs based on a realistic set of criteria provided to them:

- Orchard size is 40 acres.
- The water source is groundwater with a pumping depth of 115 feet. Operating pressures should be specified in the final designs.
- Microirrigation systems (drip, microsprinkler and minisprinkler)

TABLE 1. Useful lives and annual repair and maintenance costs of irrigation system components

Irrigation system component	Useful life	Annual repair and maintenance cost (% of initial cost)
	years	%
Pump	20	5
PVC pipelines	30	0.5
Microirrigation emitters	15	8
Polyethylene drip tubing	15	3
Impact sprinklers	20	1
Valves	20	1
Filters	20	7
Flowmeters	15	5
Controller	15	1
Chemigation system	10	3
Minisprinklers	15	8

should be automated with solenoid control valves and a controller.

- Designs should apply water at an emission uniformity of 85% or greater.
- Systems should be capable of meeting a peak evapotranspiration (ETo) demand of 0.35 inches/day at 85% efficiency.
- Designs should each be done for two tree spacings: a hedgerow-type spacing of 16 feet by 25 feet and a conventional spacing of 26 feet by 26 feet.

Irrigation system designs

In 1997, we received 22 designs from Golden State, each with a detailed drawing and a complete parts and costs list. Where appropriate, the following elements were included: sprinklers or emission devices, irrigation controller, pipelines and fittings, chemigation system, polyethylene drip hose, pump, valves, flow meter, filters and system installation. The analyses did not include costs for the well or any groundwater extraction fees.

Cost comparisons. While the initial capital costs of irrigation systems are often used for comparison, annualized costs are a better standard. Annualized costs account for the differing useful lives of various system components, and include maintenance and repair, energy for water pumping, and tax and insurance (assumed to be 2% of the system's initial hardware costs (UC DANR 1976)). Agricultural pumping energy rates vary widely depending on the source, utility and agricultural rate schedule. For this study, we based pumping energy costs on $0.09/kilowatt-hour (kWh) and did not include customer or demand charges.

The useful lives assumed for the major system components (table 1) were based on estimates by Jensen (1983), the UC Committee of Consultants (1988) and the San Joaquin Valley Drainage Program (1989). Maintenance and repair costs were calculated based on a percentage of the initial cost for system components, using the same references as above (table 1).

Annualizing capital costs for irrigation equipment requires the selection of a discount or interest rate. The discount frequently used for such analyses is the "real interest rate." For this study, we selected a 5% interest rate to determine annualized cost values.

The cost annualization was also done using a 10% interest rate to evaluate the sensitivity of the analysis to interest-rate selection. The annualized hardware costs increased about 33% for solid-set sprinklers and 29% for other microirrigation systems with the 10% rate (compared to 5%), while total annualized costs increased by 17% for the solid-set and 11% to 12% for microirrigation systems. The more expensive an irrigation system is initially, the more sensitive the annualization of the cost analysis is to interest-rate selection.

Frost protection considerations. Solid-set, microsprinkler and minisprinkler systems can provide frost protection if they (1) have a water application rate above a minimal level — usually 35 to 40 gallons per minute (gpm)/acre — and (2) irrigate the entire orchard as a single block. Both of these require increased capacity in pipelines, filters, valves and pump, which increases cost. To evaluate the impact on costs, we included frost-protection capabilities in some designs.

Jack Kelly Clark

Initial and annualized costs were compared for several irrigations for the same almond orchard.

Solid-set sprinkler systems

Solid-set sprinkler systems are characterized by pipelines, including lateral lines, buried underground with only a portion of the riser and impact sprinkler head exposed aboveground. The impact sprinkler heads are located in the tree row. Solid-set systems are full-coverage systems, wetting the entire orchard floor, often with an overlap between adjacent sprinkler wetting patterns to improve water application uniformity. We evaluated four solid-set sprinkler designs (table 2).

Initial capital costs. A breakdown of initial system component costs (table 3, fig. 1) shows that pipelines plus sprinkler heads account for about 40% of the initial costs; miscellaneous system components, 7%; pump, 7% to

TABLE 2. Design characteristics of solid-set sprinkler systems

Design	Description	Application rate	System flow	Irrigation set flow
		inch/hr	*gpm/ac*	*gpm*
1	Impact sprinklers with frost protection — 16' × 25' tree spacing	0.11	50.0	2,000
2	Impact sprinklers operated in two 20-acre irrigation blocks — 16' × 25' tree spacing	0.09	20.1	805
3	Impact sprinklers with frost protection - 26' × 26' tree spacing	0.11	47.7	1,910
4	Impact sprinklers operated in two 20-acre irrigation blocks — 26' × 26' tree spacing	0.08	17.6	705

TABLE 3. Initial costs of irrigation system components

Design	Pipelines	Sprinklers or tubing & emission devices	Misc. equipment*	Filters†	Installation	Pump	Total
				$/acre			
Solid-set 1‡§	447	372	138	129	674	289	2,046
Solid-set 2¶	442	358	165	77	680	138	1,875
Solid-set 3‡§	401	440	160	134	648	289	2,072
Solid-set 4¶	347	215	125	77	637	120	1,530
Drip 1§	71	173	107	189	258	91	890
Drip 2§	78	165	119	189	262	91	904
Drip 3§	71	345	107	189	258	91	1,062
Drip 4§	78	330	119	189	262	91	1,069
Microsprinkler 1§	117	155	131	253	307	146	1,110
Microsprinkler 2¶	92	155	155	131	307	91	907
Microsprinkler 3§	82	125	115	189	200	120	830
Microsprinkler 4¶	66	125	115	131	200	84	721
Microsprinkler 5§	117	221	133	250	281	143	1,146
Microsprinkler 6¶	92	221	133	131	281	91	950
Microsprinkler 7§	117	159	132	250	281	143	1,082
Microsprinkler 8¶	106	165	137	128	281	91	909
Microsprinkler 9‡§	191	223	179	433	281	254	1,561
Microsprinkler 10‡§	158	164	175	397	250	254	1,399
Minisprinkler 1‡§	191	409	179	134	253	254	1,420
Minisprinkler 2¶	149	329	187	77	254	91	1,167
Minisprinkler 3‡§	158	276	175	134	239	254	1,236
Minisprinkler 4¶	106	276	138	49	245	91	904

*Includes miscellaneous PVC fittings, valves, flowmeter, controller, and supplies.
†Screen filters used for impact sprinklers and minisprinklers. Sand media filtration used for drip and microsprinkler systems.
‡Provides frost protection
§Orchard irrigated as single, 40-acre set
¶Orchard irrigated as two, 20-acre sets

Table 4. Annualized costs for the irrigation system designs

Design	Irrigation system hardware	Electrical energy for pumping	Maintenance	Tax and Insurance	Total
			$/acre		
Solid-set 1*†	159	174	48	41	442
Solid-set 2‡	146	215	42	38	440
Solid-set 3*†	162	182	48	41	434
Solid-set 4‡	119	183	35	31	368
Drip 1†	80	174	39	18	311
Drip 2†	81	155	39	18	294
Drip 3†	97	174	49	21	341
Drip 4†	97	155	48	21	322
Microsprinkler 1†	98	169	36	22	325
Microsprinkler 2‡	82	203	25	18	328
Microsprinkler 3†	74	174	46	17	311
Microsprinkler 4‡	65	233	40	14	352
Microsprinkler 5†	102	177	41	23	343
Microsprinkler 6‡	86	212	30	19	348
Microsprinkler 7†	96	177	36	22	331
Microsprinkler 8‡	82	229	26	18	355
Microsprinkler 9*†	134	138	60	31	364
Microsprinkler 10*†	120	165	53	28	366
Minisprinkler 1*†	125	138	54	28	346
Minisprinkler 2‡	91	182	30	20	323
Minisprinkler 3*†	109	165	44	25	342
Minisprinkler 4‡	83	229	29	18	359

*Provides frost protection
†Orchard irrigated as single, 40-acre set
‡Orchard irrigated as two, 20-acre sets

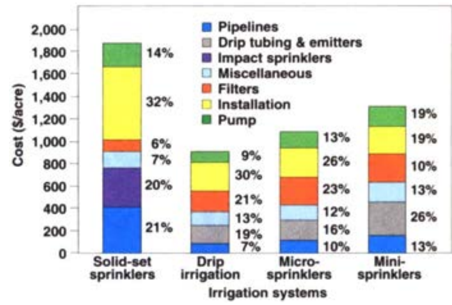

Fig. 1. Average capital cost breakdown for irrigation systems.

14%; and installation costs, 30% to 40%. Including frost protection in the design increased initial costs by 10% to 25%.

Installation costs — including trenching and placement of PVC pipe belowground, sprinkler and filter installation, and other installations at the system head — are an appreciable portion of the initial cost of solid-set sprinklers, regardless of whether the grower chooses to utilize in-house labor or pay an outsider.

Annualized costs. Pipelines/sprinkler heads and installation costs still make up a substantial portion of the annualized costs, 15% to 20% each. Pumping energy is the major cost component though, accounting for nearly half of annualized costs (table 4).

Drip irrigation systems

Drip irrigation systems have drip emitters installed in polyethylene drip tubing. The tubing, often referred to as the lateral lines, is placed in the tree row. Drip emitters, whose discharge rates are measured in gallons per hour (gph), are either built into the tubing at the time of manufacture (in-line or integrally constructed products), or punched into the tubing, either by the manufacturer or in the field during installation. The PVC submain and main supply lines are buried. In the drip system designs, sand media filtration was used.

Drip and microsprinkler systems provide partial coverage, supplying the tree's water needs by wetting only a portion of the orchard floor while keeping the wetted soil volume near optimal moisture conditions for growth. Trees grow well under partial-coverage systems, but a minimum wetted area (40% to 50% of the orchard floor) should be maintained.

The design criteria specified that the drip systems should operate no more than 16 hours/day to meet peak ETo demands. Irrigation of a mature orchard would require daily irrigation during peak ETo periods.

All four drip designs are similar, except that double lateral lines per tree row are used in designs 3 and 4 (table 5). Application and flow rates remained the same for comparable designs, since 0.5 gph drip emitters were used in the double-lateral-line designs as opposed to 1 gph emitters in the single-lateral-line/tree-row designs.

Initial capital costs. As expected, the costs of the double-lateral-line designs (designs 3 and 4) are slightly higher due to the doubling of the lateral lines/drippers (fig. 1, table 3).

Three items are of particular note. First, filter costs are a significant component, approximately 20% of the overall capital costs. Second, installation, while still a substantial cost at approximately $260/acre, was significantly less expensive than installation for the solid-set systems. Finally, the initial costs associated with drip system components that are long-lived (such as pipelines, filters, valves and pump) are approximately 60% to 70% of the total cost. Due to damage and clogging, the lateral lines and emitters are likely to need replacement over the life of the orchard, costing approximately $178/acre for the single-lateral-line/tree-row systems or $340/acre for the double-lateral-line systems, plus some additional installation costs.

Annualized costs. The annual cost that again stands out is the pumping energy cost (table 4), making up approximately half of the total. As noted before, the energy cost is for pumping 42 inches of water annually at an irrigation efficiency of 85%. If less water is applied due to increased irrigation efficiency or reduced tree water requirements, the pumping energy costs will be less.

Microsprinkler systems

Microsprinklers also wet only a portion of the orchard floor. They can be purchased with different emitter orifice sizes and operated at various pressures so that discharge rates vary from 4 to 30 gph and subsequent wetted diameters range from 6 to 35 feet. The microsprinkler (including spinner and fixed-head models which throw out "fingers" of water) is selected considering both tree spacing/wetted diameter and ETo demands/application rate.

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Above, **solid state sprinklers, which are trenched and buried, are most expensive. The majority of capital costs for drip, *upper right,* and microsprinkler systems, *right,* are in the filters and pipelines.**

The two most common microsprinkler placement options are reflected in the study's 10 designs (table 6). The first is a single microsprinkler per tree placed midway between trees in the row, with either spinner-style or fixed-head microsprinklers. The second uses two microsprinklers per tree, placed on either side and throwing away from the tree in a partial circle pattern (such as a 270-degree pattern). Only fixed-head microsprinklers can be used in this configuration if the tree's crown is to be kept dry.

Because they have higher application rates than drip systems, microsprinklers can be operated in irrigation blocks. For example, a 40-acre orchard can be divided into two 20-acre blocks, each irrigated separately. Microsprinklers can be designed to provide limited frost protection, but the system must be operated so that the entire orchard is irrigated simultaneously with a flow rate above a minimum level (specified as 35 to 40 gpm/acre in this study).

Initial capital costs. Like the drip systems, the majority of capital costs for microsprinklers are contained in components with substantial longevity (table 3). The shorter-life polyethylene lateral lines and microsprinklers make up approximately 15% to 20% of the capital costs (fig. 1).

Of the designs without frost protection (designs 1 through 8), the higher-cost systems have closer tree spacing (16 feet by 25 feet) and are operated as a single 40-acre block (designs 1 and 5). These systems have more trees per acre compared to the 26-feet-by-26-feet-spaced orchards, and subsequently, more microsprinklers per acre. However, the microsprinkler cost alone does not make these designs more expensive. More microsprinklers per acre result in greater flow rates (if the discharge is kept constant), which requires increased capacity and expense for other components such as the pipelines, filters and pump.

By comparing microsprinkler designs for a 40-acre irrigation block to those for two 20-acre blocks (designs 1 vs. 2, 3 vs. 4, 5 vs. 6, and 7 vs. 8), it is evident that irrigating as two blocks can reduce capital costs nearly 20%. This lower cost is due primarily to a reduction in filter and pump capacity.

Designing a microsprinkler system to provide frost protection increases the capital costs considerably, by 40% to 50%. When the size of system components depends on the flow rate — especially pipelines, filters and pumps — all must be larger with costs increasing accordingly.

Annualized costs. Pumping energy costs make up nearly 50% of the annual costs for the microsprinkler designs without frost protection (designs 1 through 8) (table 4). Pump selection is limited to discrete horsepower (hp) models (such as 50 hp, 60 hp, 75 hp or 100 hp), each with a separate flow-rate/pressure/efficiency relationship. Pump selection was made based on specified flow and pressure requirements. Pump flow rates were the required irrigation flow rates plus additional flow for filter backwashing (approximately 250 gpm) where required.

Splitting the 40-acre system into two 20-acre blocks does not necessarily result in the selection of a pump with half the horsepower. While close, the required flow-rate and pressure requirements determined which pump was ultimately specified. For example, design 2 is for operation in two 20-acre blocks while design 1 is for a single 40-acre block. The flow rate required for design 2 is half of that for design 1, but flow requirements for filter backwash and final pump selection resulted in a 60 hp pump for design 2 and a 100 hp pump for design 1. The result is increased pumping energy costs for design 2.

The designs incorporating frost protection (designs 9 and 10) remain the most expensive microsprinkler systems when costs are annualized, due to high hardware expenses.

Minisprinkler systems

Minisprinklers bridge the gap between microsprinklers and full-coverage solid-set sprinklers. Minisprinklers, with wetted diameters ranging from 20 to 50 feet, wet a larger area of the orchard floor than microsprinklers and their discharge rates range from 25 to 75 gph. The Nelson R10 minisprinkler, a typical model, was used in four designs (table 7). Designs 1 and 3 have frost protection capability, while designs 2 and 4 operate as two 20-acre blocks.

Initial costs. A major portion (25% to 30%) of the hardware costs for minisprinklers is associated with the polyethylene tubing (fig. 1, table 3). Minisprinklers are installed into the same polyethylene tubing used in drip and microsprinkler systems, so installation is less expensive than solid-set sprinklers where all PVC lateral lines are trenched in and covered. In addition, minisprinkler filtration costs are significantly less than those of drip or microsprinkler systems since their larger discharge orifices require less filtration and allow the use of lower-priced screen or disk filters. Finally, for the systems incorporating frost protection and operating as a single 40-acre block (designs 1 and 3), the flow rates are high, requiring larger and more expensive pumps.

The least expensive is design 4, which is broken into two 20-acre blocks and uses minisprinklers with low discharge rates.

Annualized costs. Pumping energy costs are a major component (40% to 55%) of the annual system costs (table 4) for minisprinklers. The higher end of this pumping-energy-cost range is associated with the designs using 20-acre blocks (designs 2 and 4). Because the final pump selection is restricted to discrete horsepower sizes (such as 60 hp, 75 hp or 100 hp), there are differences in pumping energy costs. For example, designs 2 and 4 specify a 60 hp pump, but their application rates are different; as a result, design 4 is operated more seasonal hours at a higher cost than design 2.

Cost comparisons

Solid-set sprinklers. Solid-set sprinklers were the most expensive system investigated, in terms of both initial and annualized costs, because of their greater flow rates compared to

TABLE 5. Design characteristics of drip irrigation systems

Design	Description	Application rate	System flow	Irrigation set flow
		inch/hr	*gpm/ac*	*gpm*
1	Single lateral surface drip (1 irrig. set) on 16' × 25' tree spacing	0.033	15.1	600
2	Single lateral surface drip (1 irrig. set) on 26' × 26' tree spacing	0.032	14.4	575
3	Double lateral surface drip (1 irrig. set) on 16' × 25' tree spacing	0.033	15.1	600
4	Double lateral surface drip (1 irrig. set) on 26' × 26' tree spacing	0.032	14.4	575

TABLE 6. Design characteristics of microsprinkler systems

Design	Description	Application rate	System flow	Irrigation set flow
		inch/hr	*gpm/ac*	*gpm*
1	Single microsprinkler (one 40-ac. set) on 16' × 25' tree spacing.	0.057	25.6	1,025
2	Single microsprinkler (two 20-ac. sets) on 16' × 25' tree spacing.	0.057	12.8	510
3	Single microsprinkler (one 40-ac. set) on 26' × 26' tree spacing.	0.041	18.8	750
4	Single microsprinkler (two 20-ac. set) on 26' × 26' tree spacing.	0.041	9.4	375
5	Double microsprinkler (one 40-ac. set) on 16' × 25' tree spacing.	0.054	24.3	970
6	Double microsprinkler (two 20-ac. set) on 16' × 25' tree spacing.	0.054	12.1	485
7	Double microsprinkler (one 40-ac. set) on 26' × 26' tree spacing.	0.054	24.1	965
8	Double microsprinkler (two 20-ac. set) on 26' × 26' tree spacing.	0.050	11.2	450
9	Double microsprinkler (w/ frost protection) on 16' × 25' tree spacing.	0.104	46.8	1,870
10	Double microsprinkler (w/ frost protection) on 26' × 26' tree spacing.	0.087	40.0	1,600

TABLE 7. Design characteristics of R10 minisprinkler systems

Design flow	Description	Application rate	System flow	Irrigation set
		inch/hr	*gpm/ac*	*gpm*
1	With frost protection on 16' × 25' tree spacing	0.104	46.8	1,872
2	Two 20-acre sets on 16' × 25' tree spacing	0.063	14.1	570
3	With frost protection on 26' × 26' tree spacing	0.087	39.3	1,570
4	Two 20-acre sets on 26' x 26' tree spacing	0.050	11.3	450

microirrigation systems. Higher-flow-rate systems require increased hydraulic capacity in many of the system components, such as pipelines, filters, valves and pump. PVC lateral-line pipe and sprinkler heads are major components of the solid-set system's cost. While this cost is appreciable, the resulting benefits, such as low labor requirements for maintenance, high reliability, and full orchard-floor irrigation coverage, are significant. Finally, the installation costs are two to three times those of the microirrigation systems, primarily due to the lateral-line trenching costs.

Drip and microirrigation. The initial and annualized costs of the drip and no-frost-protection microsprinkler and minisprinkler systems are comparable. The least expensive microirrigation systems are those with the lowest application rates. Low application rates result in low flow rates and allow the use of smaller pipes along with less filter and pump capacity, but also require longer and often more frequent irrigation times to meet tree water needs. Managing other orchard cultural practices around frequent, long irrigation sets can also be inconvenient.

For the drip, microsprinkler and minisprinkler systems, the cost of the drip tubing and emission devices accounted for approximately 25% of the initial expense. These components have the shortest lives and generally need replacement during the life of the orchard.

Frost protection. Adding frost protection to the microsprinkler and minisprinkler systems increases initial costs by 30% to 40% while increasing annualized costs approximately 10%. Based on both initial and annualized costs, solid-set systems with frost-protection are substantially more expensive than microsprinkler or minisprinkler systems with frost protection, due to their higher initial installation costs.

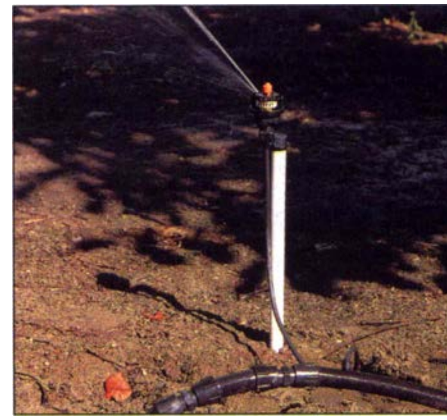
Filters. For the drip and microsprinkler systems, filter costs are substantial, approximately 25% to 30% of initial costs. Filter expenses were reduced significantly for microsprinklers operated in smaller irrigation blocks, due to the lower flow rate. Filtration costs for the solid-set and minisprinkler systems were lower because these systems are less susceptible to clogging and can use screen filtration.

Sprinkler and tree spacing. The two tree-by-row spacings, 16 feet by 25 feet and 26 feet by 26 feet, did not significantly affect the cost of the designs. While the solid-set-sprinkler spacing differed for the two tree spacings (sprinklers at 32 feet by 25 feet for the 16-feet-by-25-feet tree planting, and 26 feet by 26 feet for the 26-feet-by-26-feet tree planting), the nozzle orifice sizes also differed, such that the application rate and thus the initial cost were nearly identical. (Sprinkler application rate is often constrained by soil infiltration characteristics and the desire to minimize runoff.)

Tree spacing also did not significantly impact the cost of the microirrigation systems. The designs of microirrigation systems are tree-row oriented, with polyethylene lateral lines and emitters laid along each row. Tree-row spacing is often limited by equipment (particularly harvesting) access requirements. The most basic design criteria of all microirrigation systems is that they meet the orchard water demands, which are determined not by row spacing but rather by the amount of orchard area covered by trees measured as the percentage of the orchard floor shaded. Once approximately 60% of the orchard floor is shaded, the orchard is considered to be at full ETo demand.

To keep costs down, drip systems are designed to operate for as many as 16 to 18 hours per day (more is not recommended) during peak tree-water-demand periods. Drip systems used on orchards with wider tree-row spacing often have closer spacing of emitters along the lateral line, or double lateral lines per tree row, so that the application rate (inches/hour or gpm/acre) meets peak orchard water demands. Drip systems of similar application rates will have similar costs.

The same may be true of microsprinkler and minisprinkler systems. While these systems often have a single emission device per tree (microsprinklers may have two heads per tree), the number of trees per acre seems to have a large impact on system cost. However, the discharge rate of a microsprinkler or minisprinkler can also vary. Orchards with wider tree spacing are often irrigated with higher-discharge-rate heads while orchards with closer spacing often are designed with lower-discharge-rate heads. As a result, the application rate is often similar between designs. Since microsprinkler or minisprinkler costs account for less than 20% of the initial cost and less than 10% of the annualized cost, overall costs are often similar.



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Filtration costs are significantly less for minisprinklers than for drip or microsprinkler systems.

Installation. Installation costs for all the pressurized systems investigated were a very significant portion of the overall initial expense. Installation costs were based on a turnkey (ready-to-go) system provided by a professional installation firm. Most growers choose to do at least a portion, if not all, of the installation using in-house labor. This may reduce installation costs, but by no means eliminates them.

Pumping energy. Pumping energy costs, based on an ETo requirement of 42 inches/year, make up a substantial portion (one-third to one-half) of the annualized costs. Energy cost estimates were based on providing a 42-inch net irrigation amount at 85% efficiency, requiring the application of about 49 inches of irrigation water. Less water can be applied if tree water requirements are lower, such as in a young orchard, or if a portion of tree water demand can be supplied by stored soil moisture.

At $0.09/ kWh, pumping energy costs averaged approximately $3.70/ acre-inch ($44/acre-foot) of applied water. This expense can be substantially reduced if growers take advantage of off-peak rates offered to agricultural customers. In a separate analysis done by the authors, there was a nearly 100% difference in seasonal pumping energy costs between the least expensive agricultural rate and the agricultural flat-rate schedule ($0.09/kWh). Taking advantage of off-peak rate schedules generally restricts irrigation to weekday afternoons, which can be inconvenient. Pumping energy costs would also increase if efficiency were less than the assumed 85% — an excellent rate that may be difficult for some systems to achieve.

Decision making. As these 22 designs demonstrate, variables such as system design, pumping energy costs, frost protection and irrigation-block size can have a significant impact on the overall cost of pressurized irrigation systems. Growers must make the important decision on which irrigation system to select based on a careful comparison of all relevant factors, including intended uses, labor requirements and costs.

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Lead leaching in ceramics difficult to predict

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From 1993 to 1997, UC nutrition, family and consumer sciences advisors in 21 counties tested nearly 6,000 items of ceramic ware, of which 14.2% leached lead. More than half of the items manufactured in Mexico (51.9%) tested positive for leached lead with the UC Quick Lead Test. Ceramic ware from other countries, including the United States, also tested positive. No factors, other than being made in Mexico, were found to be useful predictors for lead leaching on any individual piece of ceramic ware. Consumers concerned about the possible leaching of lead from their ceramic ware should test each item individually.

Lead toxicity is now recognized to be much more widespread than originally believed. In recent years, the "cut-off" blood lead level for defining lead "poisoning" was reduced from 15 µg/dl to 10 µg/dl, and thus more children are considered to be at greater risk of suffering adverse effects from lead exposure. Lead can be found throughout our environment, mostly as a result of Industrial Age (1800 to present) uses and practices. Sources of lead include soil, paint manufactured before 1978, water, leaded gasoline, and paints and glazes used in the production of ceramic ware. Certain hobbies that use lead, such as soldering stained glass, casting of fishing weights, shooting and reloading, and home remodeling, may also result in exposure.