Row Crop Drip Irrigation on Peppers Study

High Rise Farms

REPORT

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California Energy Commission

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EXECUTIVE SUMMARY

High Rise Farms, located just north of Morgan Hill installed a new buried row crop drip irrigation system in 1993. The amount of the CEC loan was $42,700.

The installation of the drip irrigation system on the Peppers did provide significant improvements in the amount of water use, energy required and yield increases especially in the first year of operation (1993) and the third year of operation (1995). The second year of the project (1994) did not have yield increases. The primary lessons learned from this project included:

- The yield differential between drip and the furrow irrigation methods was attributed to the ability to irrigate during multiple pickings with drip. Using furrow irrigation, the ranch has experienced tremendous losses between pickings.

- The problem encountered in the second year was root intrusion of the drip tape. This problem was alleviated in 1995 by replacing the original tape with tape having improved root intrusion prevention characteristics along with maintaining a lowered irrigation system pH. In addition, the grower modified the operation to use a removable surface drip system. This reduced the plugging problems and added more flexibility for the purpose of crop rotation.

- The grower plans on increasing the drip irrigation acreage by another 100 acres in 1996. This CEC project helped provide the seed money to get the farm involved with drip irrigation.

- Energy Use Efficiency, Water Use Efficiency and Yield, all of which relate production to resource, were significantly improved on average over the three study years under the drip irrigation.

- Excellent irrigation management of the bell peppers results in yield increases. The yields can be maintained at high levels if the drip irrigation system is carefully watched and correctly operated.

The average water and energy use efficiencies for 1993:

Item	Before CEC Project	After CEC Project	% Change
Water Use (Acre-feet/acre)	2.7	2.4	-11
Energy Use (MBtu/acre)	21.2	24.5	16
Yield (Tons/acre)	18	23.5	31
Water Use Efficiency (Tons/AF)	6.7	9.8	46
Energy Use Efficiency (Tons/MBtu)	0.85	0.96	13

The average water and energy use efficiencies for 1994:

Item	Before CEC Project	After CEC Project	% Change
Water Use (Acre-feet/acre)	2.7	2.4	-11
Energy Use (MBtu/acre)	21.2	24.5	16
Yield (Tons/acre)	18	18	0
Water Use Efficiency (Tons/AF)	6.7	7.5	12
Energy Use Efficiency (Tons/MBtu)	0.85	0.74	-13

The average water and energy use efficiencies for 1995:

Item	Before CEC Project	After CEC Project	% Change
Water Use (Acre-feet/acre)	2.7	3.1	15
Energy Use (MBtu/acre)	21.2	27.6	30
Yield (Tons/acre)	18	32.5	81
Water Use Efficiency (Tons/AF)	6.7	10.5	56
Energy Use Efficiency (Tons/MBtu)	0.85	1.12	39

The average water and energy use efficiencies before buried and after buried drip:

Item	Before CEC Project	After CEC Project	% Change
Water Use (Acre-feet/acre)	2.7	2.6	-2
Energy Use (MBtu/acre)	21.2	25.5	21
Yield (Tons/acre)	18	24.7	37
Water Use Efficiency (Tons/AF)	6.7	9.5	38
Energy Use Efficiency (Tons/MBtu)	0.85	0.95	13

A summary of the water and energy use efficiencies consist of:

- The buried drip irrigation system resulted in a 2% reduction in total water use and a 38% increase in Water Use Efficiency when compared to the previous furrow irrigation system. It should also be noted that water use in 1995 increased 15% due to a doubling of the planting density and the use of a different hybrid pepper plant. However, the Water Use Efficiency in 1995 improved by 56% over the furrow system.

- Even though averaged '93-'95 energy use went up significantly, the tons of peppers produced per unit of energy (Energy Use Efficiency) improved by 13%. A further improvement in energy efficiency will be realized in 1996 when the buried drip will be used initially on the pepper transplants, eliminating the need for any sprinkler irrigation.

- The drip irrigation system aided to bring a 1993 - 1995 averaged yield increase of 37% in bell pepper production. The yield increase is principally due to the farmer's ability to irrigate and pick the crop simultaneously.

BACKGROUND

The project site is located just north of Morgan Hill, California. The original CEC project field used in 1993 and 1994 was a 40 acre site supplied with a new buried row crop drip irrigation system. However, the original project field was flooded in 1995 and the irrigation system was expanded to a 45 acre field on higher ground using the original mainline, filter station, and pumps.

High Rise Farms is primarily a row crop farming operation. It was started in 1980 on 65 acres of leased property. Primary crops are red bell and chili peppers. Bells are packed and sold by High Rise Farms under the Nobell label. Approximately 20-25% of bell pepper acreage is slated for sales in the fresh market. The remainder of the bell peppers and all of the chili peppers are sold under contract to processors. Rotational crops include sugar beets, cabbage, and sweet corn. Small plots of seed crops are also grown. High Rise also operates a retail sales outlet on the premises.

The project field has very heavy clay soils and a shallow water table, with occasional damage due to flooding. The poor drainage causes noticeable yield differences throughout the field, even when under drip. The original field for this project could not have been planted to peppers without the drip system, due to the heavy clay soil and Phytophthora problems associated with that type of soil.

Irrigation water is entirely from ground water sources. All primary pumping plants are electric motor driven (power supplied by PG&E) for a total of 125 HP. Additionally, there are three booster pumps available to provide sufficient line pressure for sprinkler irrigation. These pumps are powered by diesel, propane and gasoline, for a total secondary pumping power plant capacity of 200 HP.

The planting schedule for the farm varies for individual crops and weather patterns. Plant/transplant dates for the peppers are targeted for early to mid-April. A combination of transplants (35% acreage) and direct seeded fields are planted to provide for an extended harvest season. Red bell peppers are usually harvested from mid-August till late November. Chili peppers are usually harvested from mid-July till late November or the first hard frost.

Conventional irrigation is traditionally provided by sprinklers until first fruit development. Traditional fields are then furrow irrigated for the remainder of the season. For the new row crop irrigation system, water is provided by sprinklers until first fruit development (between June 10 and July 20) then the drip system is used for the remainder of the season.

The mainline and filter station were installed in 1992 and the tape was installed for the 1993 crop season. The grower experienced excellent increases in yield and profitability in 1993 and 1995 on red bell and chili peppers. In 1994 they did not experience the yield increases due to plugging problems with the original tape. The sites are shown in Figure 1.

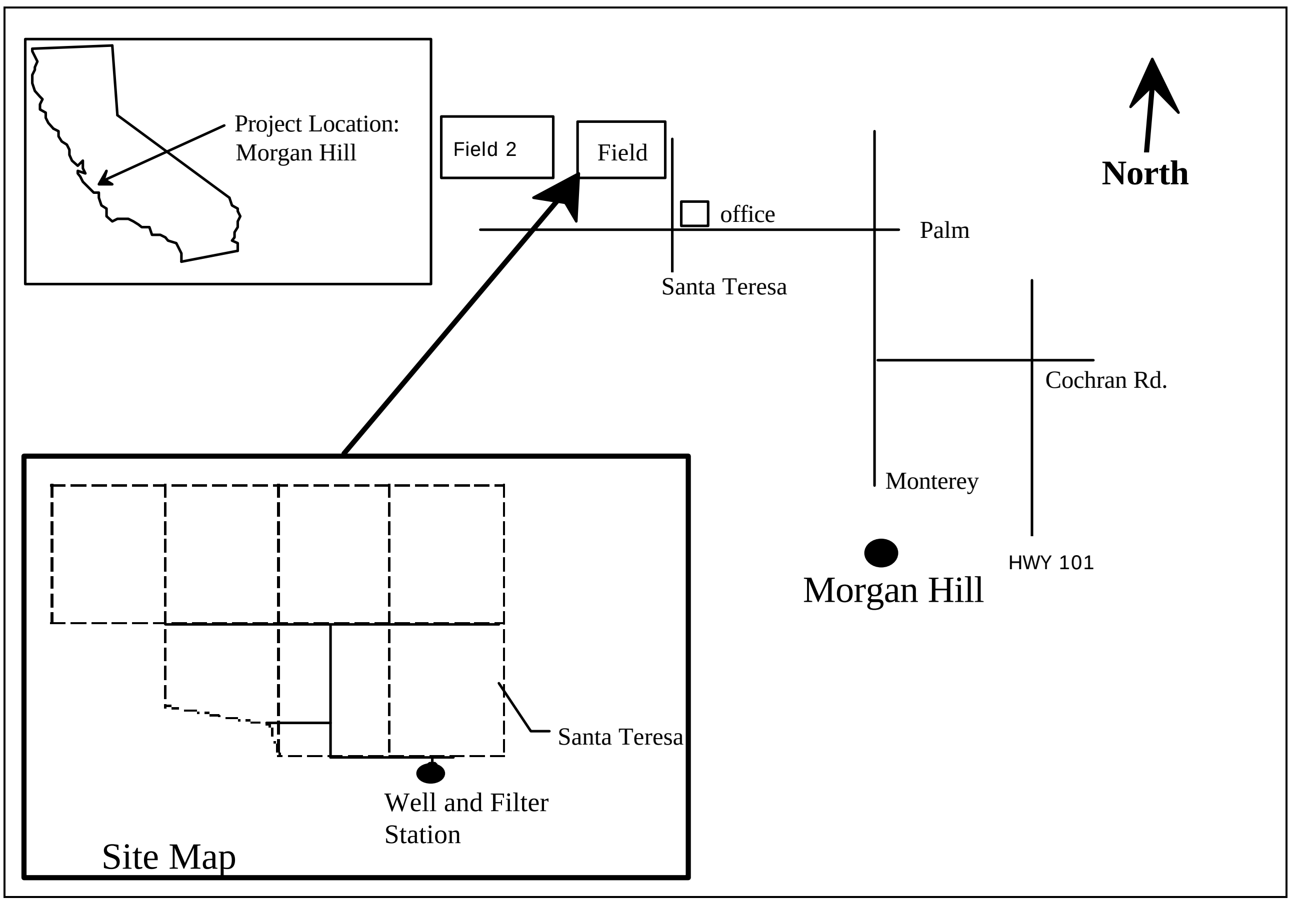

Figure 1. High Rise Ranches - CEC project field location.

The system was designed by Gonzales Irrigation Systems of Gonzales, California. The amount of the CEC loan was $42,700. The loan was for the purchase and installation of a pump/filter station, buried mainline, buried manifolds and drip tape. The actual cost of the installation for the dealer supplied components was $37,743. The contractor cost of installation was $4,960. The total capital cost was $42,703 or about $1,068 per acre. The tape installed was medium flow (0.43 gpm/100'), 8 mil, .625" ID drip tape manufactured by Chapin. The buried mainline consisted of 10" (340 ft), 8" (700 ft), and 6" (1,260 ft). The grower used a 4" diameter Oval Hose header manifold (total of 2,900 ft) and connected to the tape as shown in Figure 2. The grower plans to install a 2" diameter Oval Hose flushout manifold (total of 2,700 feet) for 1996.

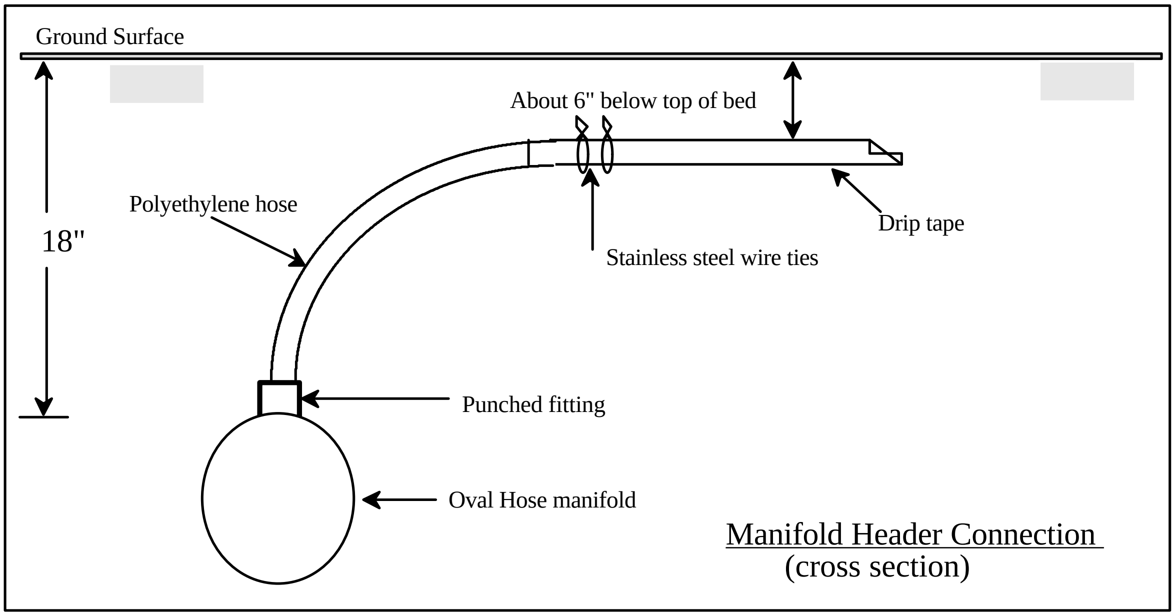

Figure 2. High Rise Farms - Typical manifold connection to under ground tape.

Three 48" diameter filter tanks were installed for the filtration. The tanks were manufactured by Atek. The backflush valves supplied were manual. These tanks are black painted steel.

SITE INVESTIGATIONS

The design and part of the installation were completed on this project prior to ITRC involvement with the CEC program. At the time of the loan approval, the High Rise drip design was fairly typical of many of the buried drip designs installed to date in the Salinas Valley and Gilroy areas.

Buried row crop drip systems bring a multitude of new considerations to farming, including filtration, chemical injection, new ways of scheduling, and new tillage techniques. It appeared from an early visit by the ITRC that this system was managed in a manner typical of many first time users of row crop drip. For example, this was not a model system in terms of pumped energy savings, because the inlet pressure to the system were 70 psi, whereas only 20 psi was needed downstream of the filter. However, this was only one field of several being serviced by the pump, and it would not have been worthwhile for the grower to optimize energy efficiency during these initial trials -- the primary concern is to just keep the system functioning.

Water and energy records (historical and present) are also somewhat nebulous because the water source and pump are used for several fields. The installation of a flow meter for the loan field was recommended several times.

The ITRC provided the grower with some information regarding fertigation practices on bell peppers. This included information on prevention of blossom end rot, achieving a better fruit set, and thickening the walls of peppers.

Irrigation Evaluation

An irrigation evaluation was performed on July 26, 1994, in the middle of the second pepper season. The evaluation took several days because of problems with the pressure regulators, and the difficulties of digging up buried tape in very heavy clay soil.

The primary observations were as follows:

- The pressure regulators were a poor design. They were unable to maintain the desired pressure. This confirmed observations on other farms in the area.
- It is probable (but not confirmed) that the oval hose was compressed in the soil, thereby increasing friction. This would be consistent with other designs in the area. It should be noted that the findings regarding oval hose and the particular pressure

regulator in question were not common knowledge when the loan was approved. In fact, at that time, the oval hose was considered to be a good option.

- The measured distribution uniformity (DU) was only 28%. Figure 3 is a graph of the emitter flow rates that were measured in the field from 60 emitters. Some of the emitters were removed and found to be totally plugged.

- The primary cause of plugging appeared to be root intrusion. Since the beginning of this project, it has been learned that root intrusion is a common problem for growers starting out on drip irrigation. It is now known that root intrusion is generally caused because the grower will stress the plants at some point in time. This can also occur at the end of the season if the plants are left to wilt in the field. The plants will draw water from the soil reservoir and also move into the emitters. It was recommended that stress be avoided, and that N-pHuric be applied to kill roots around the tape.

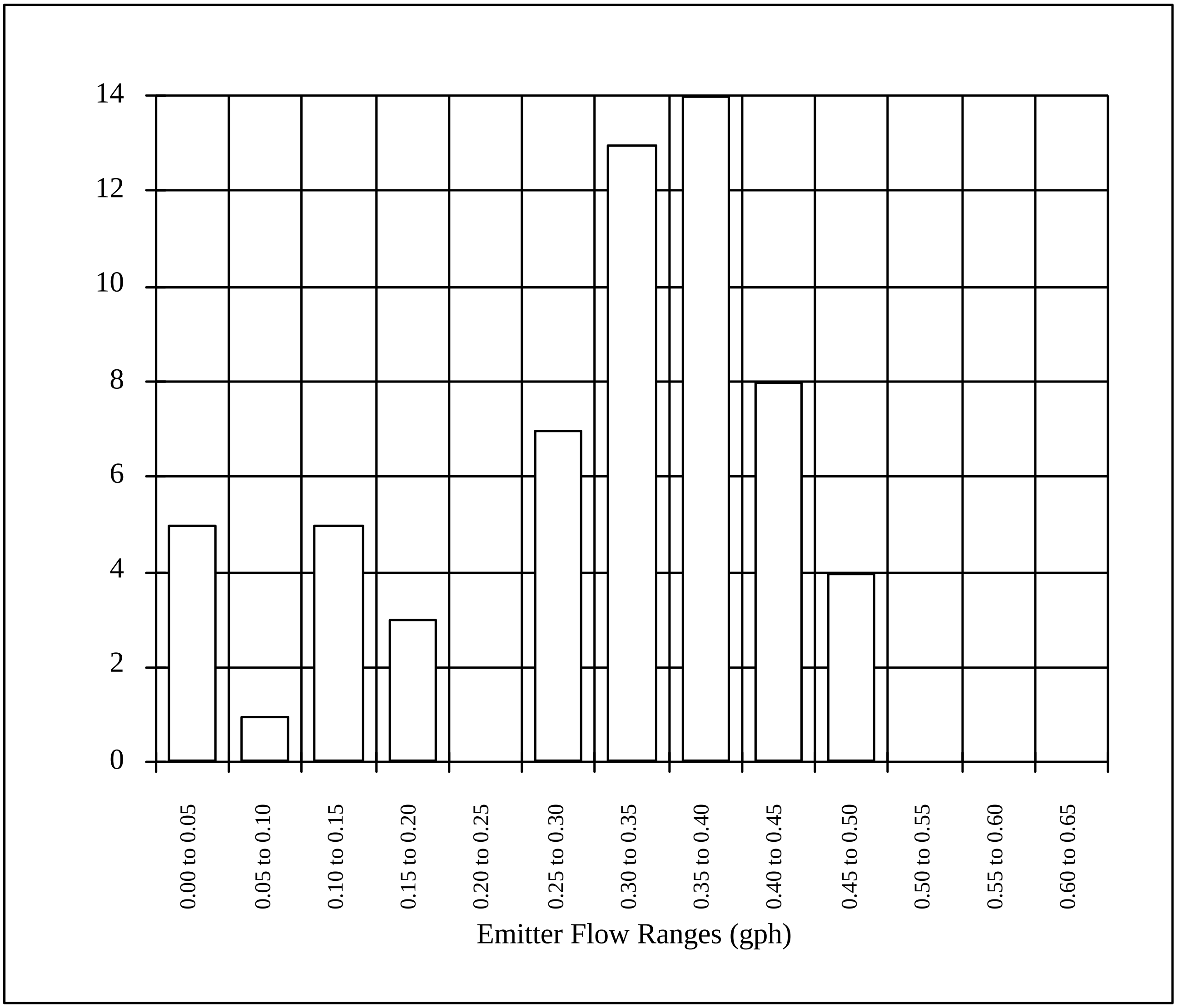

Figure 3. Graph of the frequency of the emitter flow rates on High Rise Farms.

In a later visit (1993) to the site, the affects of plugging were clearly visible by observing the growth of plants in the field. About 1/2 of the field was planted to red bell peppers and the other half was planted to chili peppers. In the areas that were receiving excessive water, the mustard was growing vigorously. In the areas of root intrusion and plugging, there was a visual indication of stress and less vigorous plant growth.

ENERGY AUDIT

The energy audit compared subsurface row crop drip and sprinkler/furrow irrigation systems. This energy audit comparison included on-farm pumping energy, field operations energy, pipe installation energy, pipe manufacturing energy, and fertilizer manufacturing energy. The comparison does not include the energy required for the following:

- Manufacture of the pump or pump appurtenances
- Manufacture of field equipment, such as tractors and implements

The energy required for these items can be substantial. For this report, they were assumed to be similar for both systems.

The drip energy audit is based on actual experience from the first year of operation using the system. The sprinkler/furrow energy audit is based on past practices by the grower and practices on other fields using conventional irrigation.

To facilitate the analysis of energy use, a detailed estimate of the costs associated for both systems was completed. The results are shown in Table 1 and Table 2. The irrigation system cost included the annualized capital, water, energy, maintenance, and labor expense. The annualized irrigation system cost for drip irrigation was $694/acre in 1993 - 1994 and $756/acre in 1995. The annualized irrigation system cost for the sprinkler irrigation system was $526/acre. The cost does not reflect all of the operation costs associated with growing peppers. It does reflect the differential in cost for operating the drip system.

Key assumptions used in the determination of the energy used included the following:

Material	Energy	Unit
Manufacture of:		
Steel:	29,000	Btu/Lb
PVC:	52,000	Btu/Lb
Aluminum:	123,000	Btu/Lb
PE:	68,000	Btu/Lb
N-Fertilizers:	24,600	Btu/Lb of N
Fuel:		
Electricity:	3,410	Btu/KwH
Diesel:	140,000	Btu/gal

Tables 3 and 4 reflect the results of the detailed energy audit.

Table 1. Row crop drip system cost.

Table 2. Solid set sprinkler/furrow system cost.

Table 3. Row crop drip system differential energy audit.

Table 4. Solid set sprinklers/furrows differential energy audit.

The first year of drip system operation (1993) indicated several identifiable changes to the grower's operation. First, there were significant improvements in the yield- an increase of 5.5 tons/acre. Second, the amount of water used decreased 0.3 AF/acre. Third, the calculated differential energy requirement was 16% higher for the drip irrigation system.

During the second year of the drip operation (1994), the significant improvements in yield highlighted by the first and third year of operation were absent. The reported water use was still less for the drip irrigation system in the second year operation.

1995, the third year of the irrigation system operation (1995) produced the greatest results.

- A yield increase of 81% over the previous furrow system. This was due in part to higher density plantings, switching to hybrid plants, and the elimination of root plugging problems in the drip irrigation system.
- A 56% increase in Water Use Efficiency was reported even though total water consumption increased 15%.
- The 1995 Energy Use Efficiency increased 39% when compared to the previous furrow system.

Table 5 is a summary of the impact of increased yields on the project.

Table 5. Water and energy use efficiency

Results for Peppers in 1993.

	Water Use (AF/acre) - Col 1-	Energy Use (MBtu/acre) - Col 2-	**Reported Yields (Tons/ac) - Col 3-**	Water Use Efficiency (Tons/AF) $\frac{\text{Col 3}}{\text{Col 1}}$	Energy Use Efficiency (Tons/MBtu) $\frac{\text{Col 3}}{\text{Col 2}}$
Sprinkler/ Furrow	2.7	21.16	**18**	6.7	0.85
Drip	2.4	24.45	**23.5**	9.8	0.96
Difference	-0.3	3.29	**5.5**	3.1	0.11
% Increase for Drip	-11%	16%	**31%**	46%	13%

Results for Peppers in 1994

	Water Use (AF/acre) - Col 1-	Energy Use (MBtu/acre) - Col 2-	Reported Yields (Tons/ac) - Col 3-	Water Use Efficiency (Tons/AF) Col 3 / Col 1	Energy Use Efficiency (Tons/MBtu) Col 3 / Col 2
Sprinkler/ Furrow	2.7	21.16	18	6.7	0.85
Drip	2.4	24.45	18	7.5	0.74
Difference	-0.3	3.29	0	0.8	-0.11
% Increase for Drip	-11%	16%	0%	12%	-13%

Results for Peppers in 1995

	Water Use (AF/acre) - Col 1-	Energy Use (MBtu/acre) - Col 2-	Reported Yields (Tons/ac) - Col 3-	Water Use Efficiency (Tons/AF) Col 3 / Col 1	Energy Use Efficiency (Tons/MBtu) Col 3 / Col 2
Sprinkler/ Furrow	2.7	21.16	18	6.7	0.85
Drip	3.1	27.55	32.5	10.5	1.18
Difference	0.4	6.39	14.5	3.78	0.33
% Increase for Drip	15%	30%	81%	56%	39%

Results for Peppers before buried drip and after buried drip

	Water Use (AF/acre) - Col 1-	Energy Use (MBtu/acre) - Col 2-	Reported Yields (Tons/ac) - Col 3-	Water Use Efficiency (Tons/AF) Col 3 / Col 1	Energy Use Efficiency (Tons/MBtu) Col 3 / Col 2
Sprinkler/ Furrow	2.70	21.16	18	6.7	0.85
Avg. '93 - '95Drip	2.63	25.48	24.7	9.26	0.96
Difference	-0.07	4.32	6.7	2.56	0.11
% Increase for Drip	-2%	20%	37%	38%	13%

From the grower's perspective, the most important aspect is the return on investment. The grower achieved a 5.5 ton increase in yield for the project in 1993. This was due to the capability to do additional harvest on the reds (5.5 tons at $165/ton). In addition, the drip provided this farmer the ability to grow peppers on the same field. The existing site conditions prohibited conventional irrigation methods from being used. The grower did not achieve an increase in yield for the project in 1994. However, the grower experienced a 14.5 ton/acre yield increase on the 1995 CEC field. The grower also noted a 40 ton/acre increase on another drip irrigated field that was not part of the CEC study. Table 6 reflects the impact of the cost of the irrigation system and the return on investment for the project. The results show that there was a significant return on the investment for the '93-'95 averaged drip system. The '93-'95 averaged data illustrate an Investment Efficiency of 585%.

Table 6. Investment Efficiency for Row Crop Drip

Results on Peppers in 1993

	Annual Irrigation System Cost ($/acre) - Column 1-	Reported Yields (Tons/ac) - Column 2-	Gross Return to Grower ($/acre) - Column 3-	Investment Efficiency (Return/ Investment) Column 3 / Column 1
Sprinkler/ Furrow	$526	18	$2,970	
Drip	$694	23.5	$3,878	
Difference	$168	5.5	$908	5
% Increase for Drip	32%	31%	31%	540%

Results on Peppers in 1994

	Annual Irrigation System Cost ($/acre) - Col 1-	Reported Yields (Tons/ac) - Col 2-	Gross Return to Grower ($/acre) - Col 3-	Investment Efficiency (Return/ Investment) Col 3 / Col 1
Sprinkler/ Furrow	$526	18	$2,970	
Drip	$694	18	$2,970	
Difference	$168	0	$0	0
% Increase for Drip	32%	0%	0%	0%

Results on Peppers in 1995

	Annual Irrigation System Cost ($/acre) - Col 1-	Reported Yields (Tons/ac) - Col 2-	Gross Return to Grower ($/acre) - Col 3-	Investment Efficiency (Return/ Investment) Col 3 / Col 1
Sprinkler/ Furrow	$526	18	$2,970	
Drip	$756	32.5	$5,363	
Difference	$230	14.5	$2,393	10
% Increase for Drip	44%	81%	81%	1,040%

Results on Peppers before buried drip and after buried drip

	Annual Irrigation System Cost ($/acre) - Col 1-	Reported Yields (Tons/ac) - Col 2-	Gross Return to Grower ($/acre) - Col 3-	Investment Efficiency (Return/ Investment) Col 3 / Col 1
Sprinkler/ Furrow	$526	18	$2,970	
Avg.'93 - '95 Drip	$715	24.7	$4,076	
Difference	$189	6.7	$1,106	6
% Increase for Drip	36%	37%	38%	585%

DISCUSSION

The performance of the drip irrigation system justified the expense for this grower. The results indicated an increase in both the yield and the energy used. The energy use efficiency was higher with drip than with conventional irrigation. The grower also achieved a 42% overall increase in water use efficiency with the buried drip irrigation system. The grower estimated water use increased 15% in 1995 due to the increased size and density of the plantings. A 15% increase in applied water resulted in an increase in both the pump electrical power bills and the applied fertilizer .

The 1995 fertilizer use increased in proportion to the applied water increase (15%). A weekly petiole sampling program for the bell peppers was implemented by Western Farm Services for the purposes of providing information to adjust fertilizer application rates. The pre-plant fertilizer being used was 17-17-17. The pre-plant fertilizer is followed up by applications of KTS, AN20, 4-10-10 and 8-0-8. The grower applies, pound for pound, the same amount of potassium as nitrogen. He feels the wetted profile of the root zone is reduced for the drip irrigation and thus produces a situation in which the K in the soil is less available. If the additional K is not added to the fertigation regime the plants will defoliate.

The following explains the cultural and yield differences between the operation of the drip and sprinkler systems. Most of these observations were made by the grower.

- Yield differential is based primarily on the assumption of the ability to irrigate during multiple pickings with drip. Using furrow irrigation, there have been tremendous losses between pickings. The problem arises when the grower must choose between completing harvest and water stressing the plants, or irrigating and losing the current set of mature reds. During the summer months, the cycle exacerbates itself as either water stress or stress of supporting over mature fruit, and causes damage to subsequent fruit sets.

- Higher planting densities in 1995 were achieved by changing to the cultural practice of 2 transplants per bed. The higher planting densities made possible with drip irrigation provide both a better yield potential with more plants/acre, and a better crop canopy which minimizes sun spotting problems.

- The grower switched to a hybrid species of pepper which grows more vigorously and is more susceptible to damage during the harvest procedure.

The grower tried irrigating one field solely with drip irrigation (ie. no pre-plant sprinklers). This strategy worked well and it may be continued in the future. Currently, sprinkler irrigation is used for the pre-plant. Elimination of the sprinkler pre-plant cultural practice would result in an annual system savings of $81/acre. Sprinkler irrigation helps establish the pepper plants and promotes a non-conducive environment for weed germination. The ground will dry down and crust with sprinkler irrigation.

The grower did not harvest greens in 1995 for several reasons

- The entire crop was contracted out for red bell peppers at $210/ton. The contract price is considerably lower than the market price of $300/ton but has the advantage of a lot less cultural practice problems for the grower.

- Because the crop was contracted as red peppers there is not much incentive to make multiple pickings. The grower feels it is more economical to pick the most tonnage possible in one or two passes.

- The harvest cost declines tremendously with a decrease in the number of harvest passes. The grower budgets $45/ton for 4 picking passes. Therefore, less picking passes represent a substantial savings in harvest costs.

- Damage to the pepper plants is greatly reduced with the elimination of the green pepper harvest and its subsequent need for multiple pickings. The grower was able to switch to a different planting density (two plants per bed) and a hybrid pepper plant. Both of these changes encourage more vegetative growth which make the plants more readily damaged by multiple harvest passes.

The outcome for this grower indicated about a 6 fold increase in gross returns based on the additional cost of the buried drip irrigation system. The data indicate an increase of $1,106/acre in gross returns is realized for each $189/acre additional investment in the drip system. These figures are based on a $165/ton net return. The net return is a resultant of the $210/ton contract price and a $45/ton harvest cost.

This grower was satisfied with the operation of the drip system. The grower maintained a pH level of 5.0 in the irrigation system by injecting N-Phuric® acid to the water downstream of the filters. Once a month the pH is lowered to 3.0 for 1/2 hour as part of a regular maintenance practice. The grower is planning on a continuing future expansion of the drip irrigation acreage. This CEC project helped provide the seed money to get the farm involved with drip irrigation

Further Developments

- The grower replaced the original project field tape in 1995 with 0.37 GPM/100 ft T-Tape. There were two reasons for the replacement. The first reason is that the tape plugged due to root intrusion. The second reason is that he planted Nappa Cabbage in 1995 and the 6" burial depth was too deep for this shallow rooted plant.

- Originally the grower was very uncomfortable with the chemical company recommendations regarding N-Phuric® acid injections. However, he encountered extensive root plugging problems. He has since opted to obtain a pH kit and maintains a constant pH level at the end of the irrigation system thru the use of N-Phuric®. This eliminated the root plugging problems.

- The grower changed to a surface tape and retrieval system in 1995 to help eliminate the root intrusion problems and add to the flexibility of crop rotation. For 1996, the grower plans on continuing the practice of tape retrieval with one difference, the tape will be buried 3" below the surface. Burying the tape 3" will allow the drip irrigation system to be used for starting the transplants and eliminate the need for sprinklers on the initial irrigations.

- An injector pump was added to the Mazzie Injector in 1995. Previously, the grower had relied on excess line pressure to provide the pressure drop required to operate the injector. The pump addition decreased the pressure requirements to the filter station.

- An additional water source was added to the CEC project field in 1995 in the form of a 3rd well. Several fields are serviced by the 3 wells. The grower has no way of separating the power records of each field from the total pump power consumption.

- Pressures vary tremendously throughout the irrigation system due to the fact that the new well pump supplies water at a lower pressure than the other two wells. The drip irrigation system's pressure changes every time a set is changed on any of the fields. This requires a manual field adjustment of all pressure regulators in the affected blocks. To combat this problem, the grower plans to switch to a valve with a better design.

- The sand media filters are being changed to simple screen filters. The grower has found that a Yardney screen filter provides his system with adequate filtering protection. He starts the drip irrigation system with the screen filter thru-flush lines open until the sand clears from the water. This clears out any sand from the wells. The filter change is cost driven - media tanks are $10,000 verses $1,200 for screens.

- The grower is changing to Cer-ti-lock mainlines from Golden State Irrigation. The farm is entirely composed of leased ground and the grower needs to have the flexibility that this type of mainline offers. The Cer-ti-Lock is available with low pressure ratings and features such as sprinkler valve risers. The mainline is trenched in just below the surface to facilitate tractor travel.

- For 1995 the grower modified his operation to a tape retrieval system. He plans to use the same tape for 3 growing seasons. A tape retrieval machine was obtained from Gonzales Irrigation Systems. The grower has experienced problems with the automatic reel winders on the retrieval system. The automated features do not perform satisfactorily and must be constantly adjusted.

- The grower had a significant problem entering the 1995 season due to the wet conditions. The wet season combined with the poorly drained field and a cool spring made the CEC project field unplantable. The CEC project field was moved to a 45 acre field directly west of the original field. The grower noted that because of the wet year, yields seem to be a function of planting time - the earliest fields produced the highest tonnage on a per acre basis. He did not irrigate some of the 1995 planted fields until after June and "buried" tractors trying to do some tillage operations.
- This grower is connected to the Internet and requested information on mail lists and how to access TRICKLE-L or any other Internet resources available for farmers. TRICKLE-L is a mail list for irrigation professionals that discusses topics within drip irrigation. The members include people from universities, government agencies, industry, and farming. This information was provided to the grower in a follow-up conversation. His e-mail address is:

  COMPUSERVE <71331.241@compuserve.com>

- The grower feels excellent irrigation management of the bell peppers results in yield increases. If the system is carefully watched and operated correctly, yields can be maintained at the higher levels. In order to do this and possibly expand their 400 acre operation, he is hiring an irrigation manager for the farm in 1996.

Field Day

A field day is to be held on a field at the High Rise Farms on October 10, 1996. The field day will be organized by the Cal Poly ITRC, with cooperation from the local Farm Advisor. A CEC representative is scheduled to provide an introduction. This will be followed by a few hours of presentations, and then visits to the fields. Andros Engineering from Santa Margarita will also participate in demonstrating some new tape retrieval equipment.

SUMMARY

The performance of the drip irrigation system more than justified the expense for this grower. The results indicated an increase in the energy used, but the yield was significantly higher. Overall, yields are higher under drip due to less problems with Phytophthora and sufficient quality of green peppers. Greens were profitably harvested with the drip system in place.

The following summarizes the results of this project:

- CEC Loan: $42,700
- Crop: Peppers
- Acres: 40 acres (45 ac. in 1995)
- Technology Evaluated: Drip Irrigation, buried row crop drip compared to sprinkler/surface irrigation

Yield Increase

- 1993: 5.5 Tons/acre - a 31% increase in yield
- 1994: 0 Tons/acre - 0% increase in yield
- 1995: 14.5 Tons/acre-81% increase in yield
- Avg. '93-'95 6.7 Tons/acre-37% overall increase in yield

Energy Savings

- 1993: Change of 3.29 MBTUs/acre. This equals an 18% increase in energy use. However, the energy use combined with the yield indicated an increase in the energy use efficiency of 13%.
- 1994: Change of 3.29 MBTUs/acre which equals an 18% increase in energy use.
- 1995: Change of 6.39 MBTUs/acre. This equals a 37% increase in energy use. However, the energy use combined with the yield indicated an increase in the energy use efficiency of 39%.
- Avg. '93-'95 Change of 4.32 MBTUs/acre. This equals a

20% increase in overall energy use. However, due to the high yield produced at a relatively low energy cost the energy use efficiency increased 13%.

Water Savings

- 1993: Change of 0.3 Ac-ft/acre - an 11% decrease in applied water.
- 1994: Change of 0.3 Ac-ft/ acre - an 11% decrease in applied water.
- 1995: Change of -0.4 Ac-ft/acre - a 15% **increase** in applied water. However, due to the dramatic increase in yield the Water Use Efficiency improved 56%.
- Avg. '93-'95 Change of 0.1 Ac-ft/acre - a 2% decrease in applied water.

Fertilizer Savings

- 1993: Negligible
- 1994: Negligible
- 1995: A 15% increase in fertilizer use.
- Avg. '93-'95 A 5% overall increase in overall fertilizer use.

This project met or exceeded the goals outlined by the CEC for the Farm Energy Assistance Program in terms of energy efficiency. The '93-'95 average energy efficiency increased 12% in conjunction with a 6 fold increase in the Investment Efficiency. Table 9 summarizes the yield increases and energy, water, and fertilizer savings.

The following reflect the projected results by the grower in the original application:

- Yield Increase: 2.7 Tons/acre (Actual increase was larger)

- Total Energy Savings: Not Estimated (Total energy increased)
- Water Savings: 0.27 Ac-ft/acre (Actual savings were recorded, but lower than the projected amount)
- Fertilizer Savings: No savings projected

Table 7. Projected and actual results of buried drip irrigation on bell peppers.

	Yield Increase	Total Energy Savings	Water Savings	Fertilizer Savings
Projected by grower	**2.7 Tons/acre**	-	0.27 Ac-ft/acre	0
Actual 1993	**5.5 Tons/acre**	-3.29 MBTUs/ac	0.3 Ac-ft/acre	0
Actual 1994	**0 Tons/acre**	-3.29 MBTUs/ac	0.3 Ac-ft/acre	0
Actual 1995	**14.5 Tons/acre**	-6.39 MBTUs/ac	-0.4 Ac-ft/acre	-15%
'93 - '95 average	**6.7 Tons/acre**	-4.32 MBTUs/ac	0.1 Ac-ft/acre	-5%

Attachment 1

Irrigation Evaluation Results

Attachment 2

PG&E Pump Test Results

Pump Energy Requirements per Acre-foot

Plant ID: 90062 (see attached PG&E Pump Test)

342.6 KWHrs/acft @ 59 psi
239.7 KWHrs/acft @ 35 psi

Plant ID: 90058 (see attached PG&E Pump Test)

504.3 KWHrs @ 65 psi
312.9 KWHrs @ 30 psi

Plant Avg.

423.45 KWHrs/acft @ 62 psi
276.3 KWHrs/act @ 32.5 psi

Standard Irrigation:

1.3 acft applied @ 60 psi - sprinkler
1.4 acft applied @ 30 psi - furrow

Estimated energy required for standard irrigation:

1.3 acft*423 KWHrs/acft*.14$/KWHr	=	$ 76.99/ ac
1.4 acft*276 KWHrs/acft*.14$/KWHr	=	$ 54.10/ ac
Total:	=	$**131.09/ ac**

Drip Irrigation:

2.4 acft applied @ 35 psi

Estimated energy required for drip irrigation:

2.4 acft * 276 KWHrs/acft * .14$/KWHr = $ **92.74/ ac**

Attachment 3

Site Photos

Figure 3-1. Sand media filter installation.

Figure 3-2. High Rise - Pepper crop.

Figure 3-3. High Rise - Pressure regulator next to a sprinkler valve and riser. This model of pressure regulator was incapable of maintaining the desired pressure.