WC-7-0193

2953

Colorado State University Cooperative Extension

1992

Report to the

USDI-

Bureau of Reclamation

LOWER GUNNISON SURGE DEMONSTRATION PROJECT

Mahbub Alam
Extension Agent, Irrigation

Richard Antonio
Extension Agent, Irrigation

Report to the United States Department of the Interior, Bureau of Reclamation

Cooperative Agreement for Surge Irrigation Research and Demonstration Program, Lower Gunnison Basin, Colorado River Salinity Control Project Units.

Summary

In the first year of implementation, a total of 35 surge irrigation controllers and valves were distributed to the cooperating farmers to establish surge demonstration sites. The program was made possible by a grant, (Federal Identifier #1-FC-40-11630) to the Colorado State University Cooperative Extension from the United States Department of Interior, Bureau of Reclamation.

The purpose of the installation is to test and demonstrate surge technology to local farmers. It has been proven elsewhere that the surge irrigation technology enables irrigators to achieve higher irrigation efficiencies, uniform applications and deep percolation reduction. Reducing deep percolation decreases salt loading of the Colorado River. The surge irrigation units were used by the cooperators to irrigate field crops of corn, alfalfa, beans, vegetables, pasture and tree fruit crops in orchards.

Delta Units:

During the summer of 1992, the Cooperative Extension personnel studied 39 irrigation events, of which 19 events provided usable data. Results indicate that the surge irrigations helped in reducing deep percolation by approximately 145 acre inches and the irrigation application came down by more than 50%.

Reduction of 145 acre inches of deep percolation translates into a salt reduction of 666 tons. Assuming the salt load reduction associated with 19 evaluations is representative, the benefits obtained from the total of 39 surge irrigation events amount to a salt load reduction of 1367 tons.

Montrose Units:

Similarly at Montrose 39 events of irrigation were studied of which 13 events provided usable data. Results indicate that the surge irrigation helped in reducing deep percolation by approximately 104 acre inches and the irrigation application was reduced by 40%.

Reduction of 104 acre inches of deep percolation translates into a salt load reduction of approximately 387 tons. Assuming the results are representative of the surge irrigation events in Montrose, the benefits obtained from 39 events of surge irrigation have resulted in a salt load reduction of 1161 tons.

The combined salt load reduction in the Lower Gunnison Basin Salinity Control Project amounted to 2528 tons of salt for the summer of 1992. Amortizing $100,000 program cost for the first year over the 25 year life of the equipment with an 8% interest rate, results in an annual cost of $9264, or a cost effectiveness of approx. $4/ton.The additional benefits were improved water management resulting in higher yields, better quality products and reductions in fertilizer loss.

Report to the USDI, Bureau of Reclamation from Colorado State University Cooperative Extension

Background

Surge irrigation has the reputation of cutting down deep percolation, and providing uniform irrigation application in a furrow-irrigated field. Irrigation by use of furrows is by far the largest practice in a surface irrigation system.

Surge irrigation has been recognized for its ability to enhance water advance across a field. The principle involves switching irrigation water between two sets of furrows accomplished by use of a suitable valve or gate and operated by a motorized controller. The controller is battery operated and continuously re-charged by the solar panel and is relatively maintenance free. The first application of water advances down the furrow to a certain distance before it is switched over to the alternate side. The number of times of alternating the water from one side to the other is dependent upon the soil type, length of irrigation run and the amount of water available. To simplify the operation, the operator either needs to know from his past experience how much time it took to reach the end of the field under normal stream flow used or the length of the furrow. The time taken to advance the furrow stream to the end of the furrow is also known as "out time." Depending on the manufacturer, the out time or the length of furrow can be used to set the controller, which will calculate the initial alternating times called the "advance cycles" based on a computer program already provided in the controller. When the advance cycles are complete, the water should reach the end of the furrows and the "out time" is complete. The "out time" may be adjusted by making midstream change for some controllers in case the advance is complete earlier than the time entered at the start. In others the canned program number to use may have to be altered. At the end of the advance cycles, the irrigation must continue to provide "soak time" to wet the rootzone uniformly. The cycles are now shorter to avoid excess run-off or "tail water." Soak cycle has to continue until the required inches or depth of water is applied to fill the rootzone and the depth of application is normally calculated prior to the start of irrigation by taking into account the total flow, acreage, root depth and soil moisture depletion or E.T. of the crop. On-the-spot checking of the depth of wetting may be made by pushing a rod or a ball-probe into the soil. When required depth of wetting is achieved the irrigation may be stopped.

Several theories exist as to why surge irrigation works. The most accepted version is that the water may continue to penetrate the soil even after the irrigation water is removed; which results in some soil "sealing" by breaking of some capillary flow and compacting of the soil particles. The infiltration rate changes from 'intrinsic' rate to a 'basic rate' faster. The hydraulics of the furrow changes to a smoother surface. Hence, there is less penetrating during the subsequent "surge" of water and there is more water available to move faster down the furrow. Thus the depth penetrated in the wetted ground progressively becomes smaller, creating a condition of uniform depth of wetting across the field. The automatic reduction of time during soak cycle prevents excessive runoff. As a result, vastly improved irrigation efficiencies have been realized by many irrigators and the results are being continuously published.

Lower Gunnison Basin
Salinity Control Project Units 1, 2 & 3

The Lower Gunnison Salinity Control Project is situated in west central Colorado and the irrigated cropland area stretches into two counties, Delta and Montrose. The project Unit 1 and part of Unit 2 fall within Delta and are serviced out of Delta County. Units 2 and 3 within Montrose County are serviced out of Montrose County. About 169,000 acres are irrigated by gravity flow; water diverted either from the creeks coming down from Grand Mesa, or the Gunnison and Uncompahgre River system. The water is delivered to the fields by unlined canals and ditches. The entire area is underlaid by a saline marine formation known as Mancos shale. Since the irrigation water is quite plentiful and inexpensive, considerable over-irrigation occurs. This over-irrigation coupled with leakage from the unlined canals contributes about 840,000 tons of salt form the shale through the return flow to the Colorado River system. The croplands lie on both valley and high mesa. The crops are diverse, ranging from orchard fruits to hay, and these include corn for both grain and silage; hay--alfalfa, grass or mixed grass and alfalfa; small grains, several varieties of orchard fruits, onions, dry beans, sweet corn and other produce crops. Production on a per-acre basis is good and the quality of the fruits is unique.

The Surge Project

Forty one cooperators were invited to participate in the USBR sponsored surge irrigation and demonstration project. The participating cooperators were given a surge controller with either a T-valve, in-line valve for gated pipes or a ported ditch surge gate. A short workshop on the use of the surge valves was organized for the cooperators at the time of distribution of units. Thirty five cooperators installed the units in their fields and started using them. Six would-be cooperators could not obtain necessary appurtenances like gated pipe, proper water structure for ported ditch, etc. and were kept on hold.

The Delta-Montrose Cooperative Extension team was able to monitor 78 irrigation events, both surge and conventional, of which 32 produced usable data. Inflow and outflow of a furrow were measured using V-notch furrow flumes fitted with automated data gathering devices (potentiometers, datapods and computer chips). Generally a non-wheel furrow was selected to place the furrow flume for the evaluation. This presented conditions conducive to the greatest amount of deep percolation and least run-off of the applied water (a worst case scenario). Thirty-two such irrigations gave usable data; the remainder were rendered unusable due to furrow washouts, cross-overs, and occasional malfunctions of the data-gathering equipment, or simply not used because both surge and conventional data for the particular event were not available to make the comparison. Sometimes the flumes became silted, making the data questionable. It has also been observed that the float and stilling basin need some adjustment and realignment which will be done during the off-season for the existing system and changes done in new fabrication. Wild animals like raccoons love to play with the equipment and were evident from their footprints left on the equipment. Necessary caging of the equipment will be done next year.

The total area monitored included 415 acres of conventional irrigation and 304 acres of surge irrigation; the attached list shows the sites. A few fields were excluded where data collection became a problem.

The SCS monitoring team also collected data from two surge demonstration sites for total inflow and outflow water measurements for the total fields. Those data will be used to compare the results as soon as available.

Results and Discussion
Delta-Montrose

The results shown under Data Sheet, Table I, are from nineteen irrigation events that yielded usable data out of thirty-nine monitored at Delta area. Deep percolation was reduced by 145 acre inches in 194 acres of surge irrigated area and this resulted in salt load reduction of 666 tons. The slat factor used to convert the deep percolation data was 0.337 ton/acre inch. This was taken as an average value for the entire basin covering all watershed area. The results from Montrose area shown in Table II, are from thirteen irrigation events that yielded usable information out of thirty nine monitored. Nine fields out of fourteen in the Delta area provided reliable data. Similarly in Montrose eight fields out of twenty provided the most reliable data. Deep percolation reduction of 104 acre inches in Montrose area made it possible to achieve a salt load reduction of 387 tons of salt.

The principal causes of having unusable data include cross-over flow coming to the outflow flume showing excessive run-off much higher than the inflow, siltation of stilling well, displacement of the pulley from potentiometer due to strong wind or disturbances created by small animals. There were instances where surge irrigation tended to under-irrigate. The field #D6 in Table I and M2, M4, and M6 in Table II under surge irrigation show negative deep percolation indicating deficit irrigation. This could be a real concern in surge irrigation. This could also have been due to the assumption of higher soil moisture deficit. Soil moisture deficits (SMD) were established on the basis of SCS data on water-holding capacity minus a generalized fifty percent management allowable depletion. In the future SMD will be closely monitored by use of soil probe, gypsum blocks, etc. The depletion will be checked by tracking the ET data as well. There is a weather station that will help to calculate ET. This year (1992) the farmers tended to irrigate in their own way most of the time, although efforts were made to make them understand the ill effect of over-irrigation. It is difficult to make the cooperators appreciate the fact that it is all right to cut down on the volume of water which is in excess of need. Over irrigation tends to be the norm for two reasons--one is the fear of loss of right to the volume now enjoyed and the other is that water is cheap, warranting least attention.

It was observed that the surge irrigation performed better in row crops where the furrow was in good shape. Maximum crossovers were encountered in alfalfa hay fields. The furrows get blocked due to trash and the marks are broken down by heavy traffic during the haying process and remarking was very critical. First irrigations in newly planted fields requires more monitoring and adjustment of the advance cycles. Some farmers are critical about its use in the first irrigation--the complaint being that surge may not wet the ground thoroughly enough for the corn seed to germinate. Some others have the feeling that surge is a "cure-all" for ailments in irrigation. The cooperators tend to set it in their most difficult field. The fields they can handle satisfactorily by furrow irrigation are left out from the surge program, not realizing that it is a tool only to achieve better efficiency and can not overcome the constraints arising due to slope changes, gravelly soil condition, lack of appropriate furrows, unusual length of run, etc. The cooperators also think that surge should run by itself and tend to take away the managerial time for other chores. It was also observed that they did not plan their irrigation events ahead of time, and, as a result, went ahead to irrigate without informing the technicians. This resulted in missed opportunities in monitoring irrigation events. Hopefully, this will not happen in the future. More educational meetings, and frequent field visits will be necessary to overcome the situation.

The infiltration data are shown in Table III for Delta and Table IV for the Montrose area. The results are from the total irrigation events where inflow-outflow data were collected by the furrow flume. No controlled data collection was done for the purpose of infiltration evaluation. The results obtained indicate that the intake rate in conventional situations was higher. SCS intake family and furrow intake family values were more close to surge irrigation. This further validates the hypothesis that surge irrigation reduces infiltration rate for the total event--helping towards uniform application and reduction of deep percolation. The intake rate observed at Farm #M5 in Table IV does not maintain the trend as seen in Table III for deep percolation. This could be due to error or may be ascribed to gravelly subsoil 10-15" below the surface.

In conclusion, the results do indicate that there has been a considerable reduction in deep percolation. All of the cooperators expressed satisfaction on the results they saw in their fields in terms of better irrigation coverage and crop yields. The total yield of silage corn in a surge irrigated field was slightly higher than the conventionally irrigated field. Hay yield also increased and the quality was better. When asked, none agreed to return the unit. So, hopefully, next year we will have greater success.

2959

TABLE I

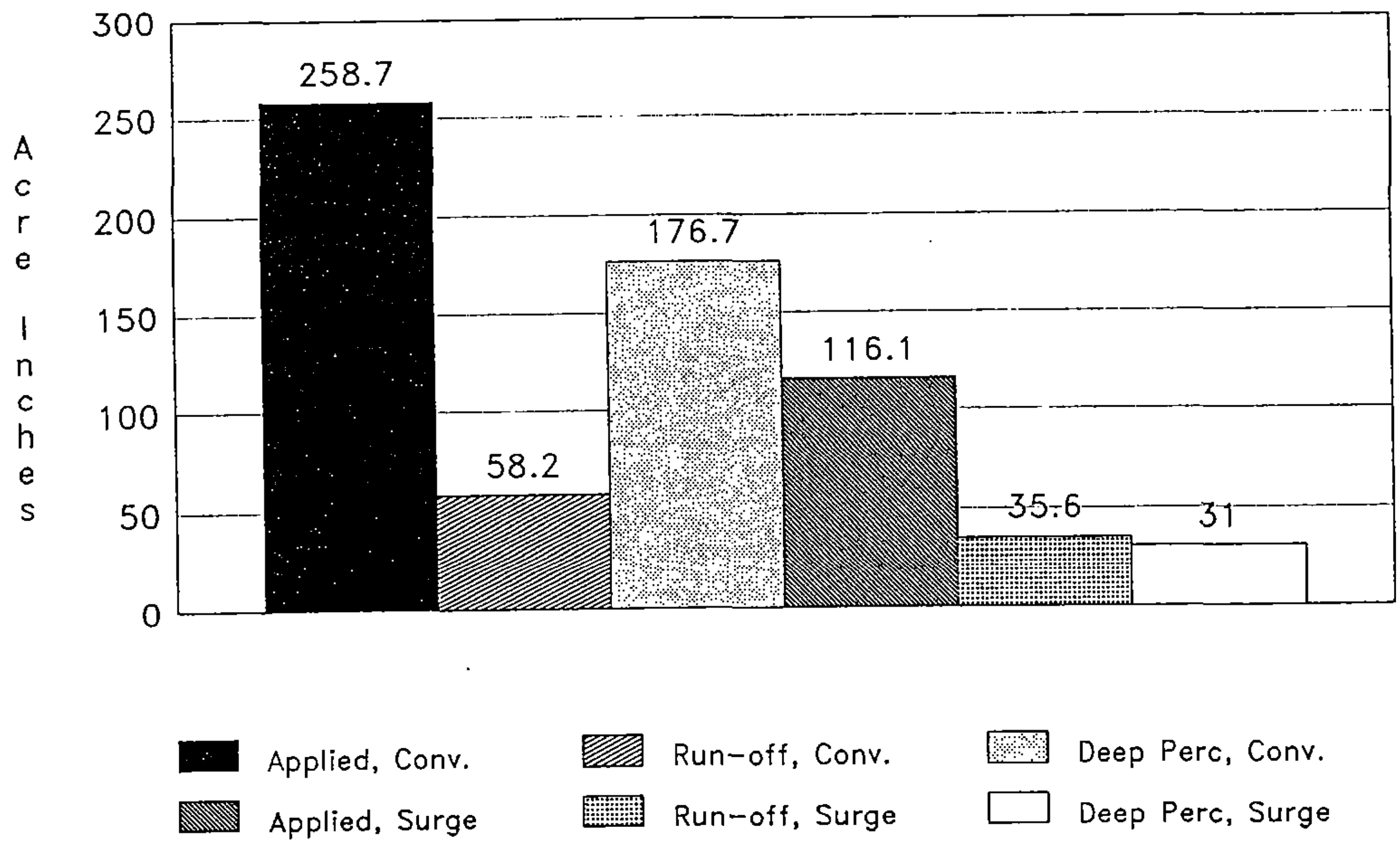
Surge Irrigation Results: Delta

Farm No	Crop	# of Irrg*	Acres		Acre inch applied		Acre inch run-off		Acre inch Deep Perc.		Acre Inch Reduction of Deep Perc by Surge	Salt Load Reduction Ac.in. reduction X 0.337 salt factor X acres in surge
			Conv	Surge	Conv	Surg	Conv	Surg	Conv	Surg		
D1	Alfalfa	1	1.5	10.5	20.2	8.94	0.06	13.4	15.2	3.94	11.23	39.7
D2	Alfalfa	1	43.5	4.5	12.7	5.25	0.25	0	7.22	-0.25	7.47	11.3
D3	Corn	1	5.0	16.0	4.86	4.43	0.99	3.31	1.36	0.93	0.43	2.3
D4	Alfalfa	1	3.5	7.0	20.9	8.53	0	0	16.4	4.03	12.33	29.1
D5	Corn	6	7.0	7.0	45.3	29.7	7.5	3.6	20.3	4.41	15.87	37.4
D6	Alfalfa	1	1.8	112.5	6.83	3.25	3.42	1.67	2.83	-0.8	3.58	15.1
D7	Alfalfa	2	4.5	13.5	12.9	10.0	2.67	5.68	2.89	2.04	0.853	3.9
D8	Alfalfa	2	0.8	5.2	31.2	25.1	26.3	3.55	20.2	14.1	6.06	10.62
D9	Corn	4	2.5	17.5	103.8	20.9	17.0	4.43	90.3	2.61	87.68	517.1
		19	70.10	193.7	258.69	116.10	58.19	35.64	176.70	31.01	145.50	666.52

* Monitored - 39

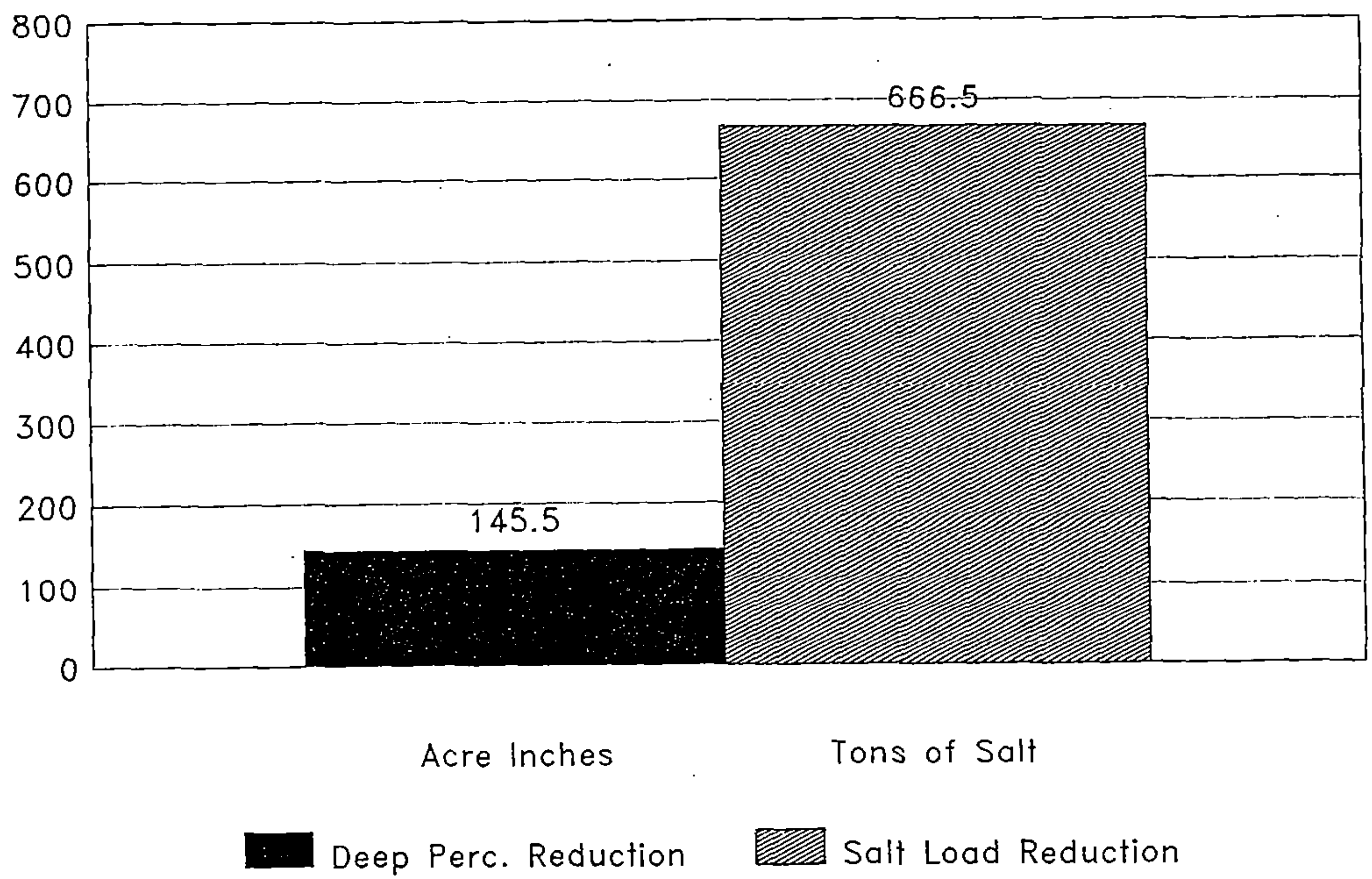
Surge vs. Conventional Irrigation

Results from 19 Irrigation Events, Delta



Surge vs. Conventional Irrigation

Results from 19 Irrigation Events, Delta



2962

Surge Irrigation Research
and Demonstration, 1992

TABLE II

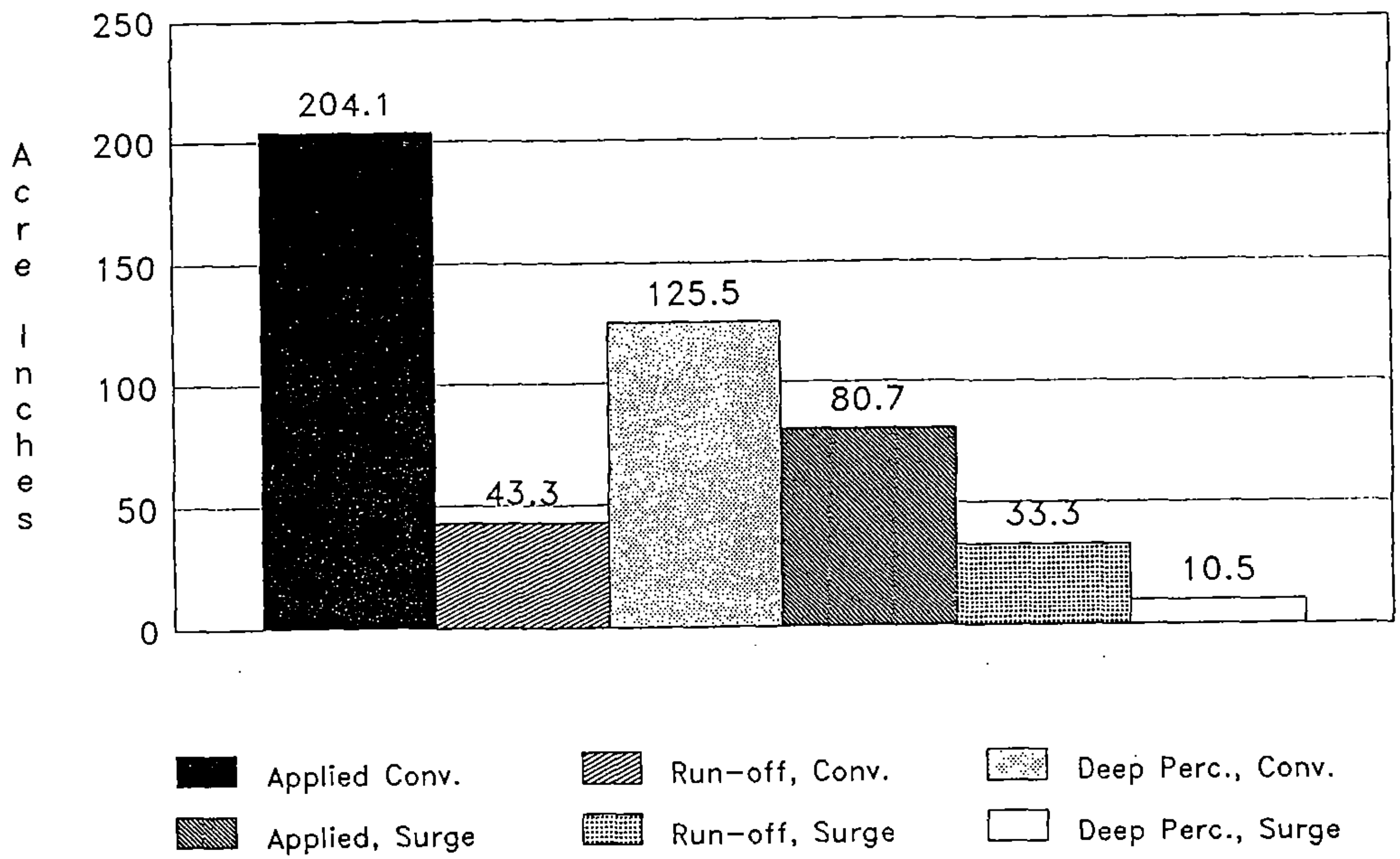
Surge Irrigation Results:
Montrose

Farm No	Crop	# of Irrg*	Acres		Acre inch applied		Acre inch run-off		Acre inch Deep Perc.		Acre Inch Reduction of Deep Perc by Surge	Salt Load Reduction Acre inch reduction X 0.337 salt factor X acres in surge
			Conv	Surge	Conv	Surg	Conv	Surg	Conv	Surg		
M1	Pinto Beans	1	63	7	26.8	3.39	8.21	0	15.6	.39	15.21	35.91
M2	Corn	2	138	14	14.0	5.86	3.08	1.88	5.91	-1.03	4.88	23.02
M3	Beans	4	29	21	26.4	30.62	19.47	13.3	-3.92	4.93	-8.85	-62.63
M4	Wheat	1	5.37	10	5.05	0.56	2.16	2.5	.39	-4.44	-4.05	-13.65
M5	Corn	1	5.0	6.0	12.36	9.78	3.36	1.57	6.47	5.72	0.75	1.52
M6	Oats	1	45.0	8.0	11.74	3.48	.075	8.79	9.17	-7.82	16.99	45.8
M7	Wheat	2	55.5	14.5	83.9	12.07	2.61	1.63	76.59	5.75	70.84	346.2
M8	Apples	1	4.0	30.0	23.89	14.94	4.35	3.66	15.25	6.98	8.27	11.15
		13	344.9	110.5	204.14	80.70	43.35	33.33	125.46	10.48	104.04	387.32

*Monitored 39

Surge vs. Conventional Irrigation

Results of 13 Irrigation Events Montrose



Surge Vs. Conventional Irrigation

Results of 13 Irrigation Events Montrose

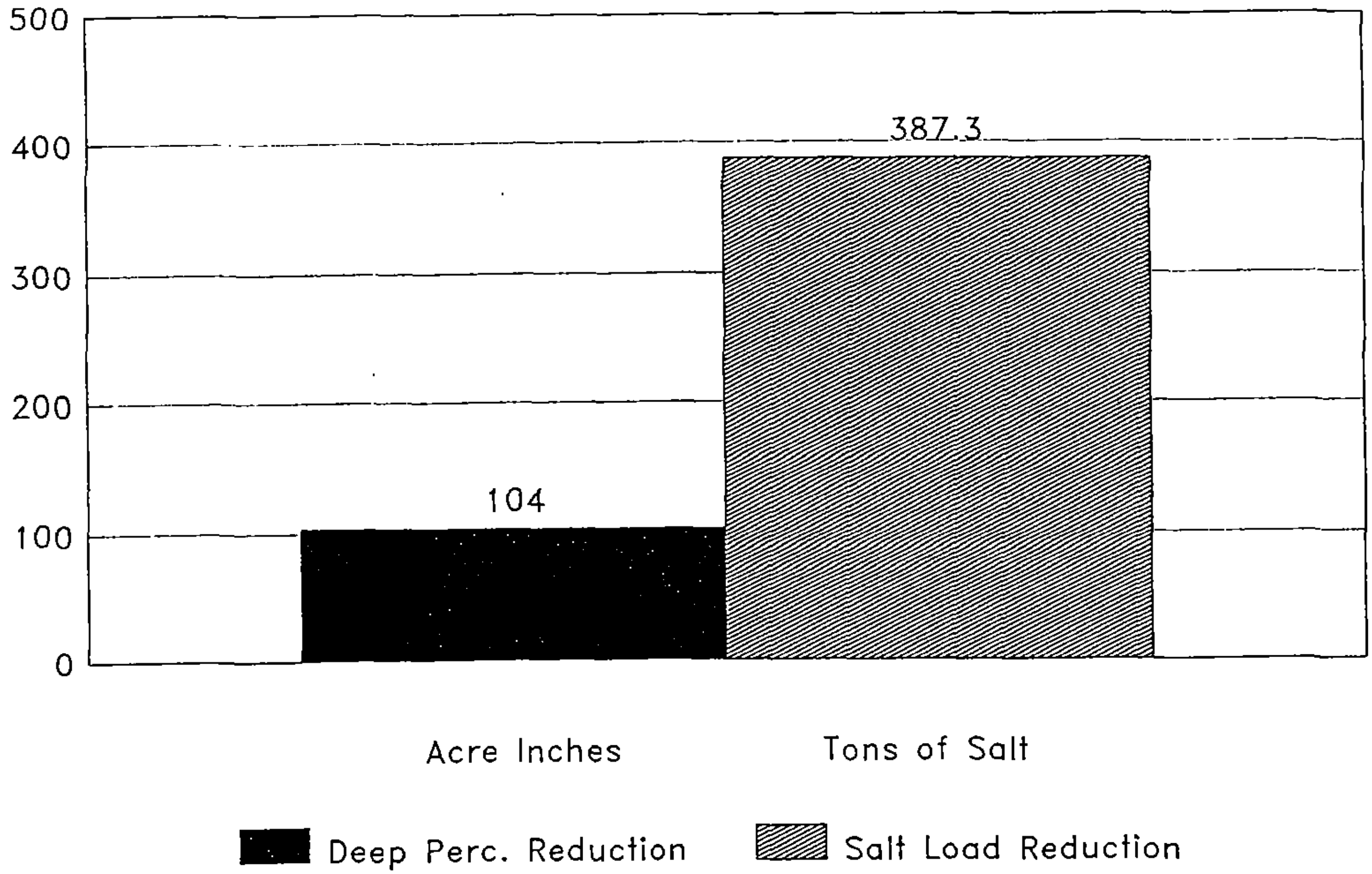


TABLE III

Infiltration Data
Delta

Farm No.	Soil Type	Intake Family*		Comments	
		Conven. Irrigation	Surge Irrigation	Observed Intake Averages	SCS Intake Family
D3	Billings Silty Clay	1.47	0.22	Billings Silty Clay Loam	
D4	" "	1.07	0.16	Conventional - 1.25	SCS Intake Family - 0.3
D5	" "	1.3	0.26	Surge - 0.30	Furrow Intake Family - 0.5
D9	" "	1.3	0.45		
D8	" "	1.13	0.40		
D7	Mesa Clay Loam	1.27	0.40	Mesa Clay Loam	
D10	" "	—	0.40	Conventional – 2.04	Intake Family - 1.0
D2	" "	2.07	0.20	Surge - 0.45	Furrow Intake Family – 0.5
D11	" "	—	0.59		
D1	" "	2.30	0.23		
D12	" "	2.55	—		
D6	Apishapa Silty Clay Loam	2.5	0.12	Apishapa Silty Clay Loam Conventional – 2.5 Surge – 0.12	Intake Family – 0.3 Furrow Intake Family – 0.06 to 0.2

*Data from furrow flumes used for monitoring inflow and outflow of an entire irrigation event at the demonstration site.

TABLE IV

Infiltration Data
Montrose

Farm No.	Soil Type	Intake Family*		Comments	
		Conven. Irrigation	Surge Irrigation	Observed Intake Averages	SCS Intake Family
M1	Billings Silty Clay	1.22	0	Billings Silty Clay Loam & Vernal Clay Loam Conventional – 1.55	SCS Intake Family - 0.1
M3	Vernal Clay Loam	1.88	1.09	Surge - 0.55	Furrow Intake - 0.5 Family
M2	Rance Complex	1.31	.45	Rance Complex & Mesa Clay Loam	
M8	Mesa Clay Loam	49.11	.27	Conventional – 16.85	SCS Intake Family - 1.0
M10	" "	.14	0	Surge - .24	Furrow Intake – 1.0 Family (Rance) Furrow Intake – 0.5 Family (Mesa Soils)
M4	Billings Silty Clay Loam	1.08	-.25	Billings Silty Clay Loam Conventional – 0.54	SCS Intake Family – 0.3
M12	" "	0	.75	Surge – 0.25	Furrow Intake Family – 0.5
M7	Fruitland Fine Sandy Loam	3.75	1.19	Fruitland Sandy Clay Loam, Fruitland Fine Sandy Loam Conventional – 1.87	SCS Intake Family – 1.5
M9	" "	0	.75	Surge – .97	Furrow Intake Family – 1.0
M5	Mack Gravelly Clay Loam	1.53	2.68	Mack Gravelly Clay Loam Conventional – 1.53 Surge – 2.68	SCS Intake Family – 1.5 Furrow Intake Family – 0.5

*Data from furrow flumes used for monitoring inflow and outflow of an entire irrigation event at the demonstration site.

Appendix A

Brief description of particiapting farms in Delta

Farm D1 - The demonstration plot was in 12 acres of alfalfa field. Surge was practiced in 10.5 acres. The field chosen by the owner is irregular one and had to be irrigated at 60/40 ratio. The owner has to irrigate quite a large area in a short time with the amount of water allotted to him. This was one of his incentives to try surge. Benefits of surge in alfalfa field becomes less apparent for lack of good furrow or marking.

Farm D2 - The demonstration plot in this farm is 48 acres of alfalfa hay field. The ground is on a high mesa rolling in three different directions. The soil is deep Mesa clay loam overlying gravelly well drained substratum. The furrows are considerable long and the field is irrigated in three different directions with lots of crossover taking place. Out of 48 acres only 4.5 acres could be covered under surge. The present irrigation configuration does not allow to bring more area under surge. Here surge was not used to its maximum potential.

Furrow conditions were very poor and with cross slope it was difficult to monitor outflow for the purpose of evaluation.

Farm D3 - The demonstration of surge in Farm D3 was set up in an irrigated field of corn. The surge was tried in 16 acres and the remaining 5 acres were used to collect data on conventional irrigation. Missed the first irrigation for data collection. The owner suspected that the surge may not put enough water for germination and did not call during first irrigation. The greatest benefit would have been achieved in the first irrigation in terms of avoiding deep percolation, because the loose soil would be sealed in the process of surge.

Farm D4 - The demonstration was set up in 10.5 acres of alfalfa field, where 7 acres were under surge. The furrow length was 1/4 mile and the ground lays over a gravelly substratum. Under conventional irrigation water never reached the end of the field. With surge irrigation water reached to the bottom of the field and irrigation time was reduced. Farming is secondary to the owner, since he has another job. Programming of the controller was done by extension personnel and later explained to the owner.

Farm D5 - The surge demonstration was set up in a fourteen acre field growing silage corn. This was an excellent site and the farmer was one of the best. Only difficulty encountered was when the farmer fertilized (injected ammonia gas), the water ran very slowly in the gassed furrow as compared to wheel furrow. The irrigator working for the owner had the tendency to change sets in 24 hours as before without realizing he was in fact covering the area of two sets in surge. This resulted in occassional under irrigation.

The field is irrigated from underground pipe which delivers water from a series of alfalfa riser valves. To cover the entire farm in surge the farmer would require more valves, one for each riser and only move the controller from set to set. Irrigating by one surge unit, moving it from riser to riser is inconvenient because the gated pipe would require to be hooked and unhooked twice in each irrigation. This will involve using more labor compared to the capital investment for valves. Apart from this, the site is an excellent one.

Farm D6 - The demonstration plot in this farm had the largest area under surge. The field consisted of 115 acres of alfalfa hay. The underground pipeline and gated pipe system has been built under salinity cost share. The field had a tile drain put across the middle of the field recently, making irrigation run difficult. The field did not have good furrow markings. The soil type is apishapa silty clay loam with a very low intake rate. Reliable data collection was difficult.

Farm D7 - The surge demonstration was set up in ported ditch system using a surge gate mounted with a controller. The demonstration field was 18 acres of newly seeded alfalfa. The owner was exposed to surge in the previous year and was deeply sold to the idea of surge. He installed the ported ditch system under salinity control cost share to be able to practice surge. Only drawback was that the field system was already developed for surge making it difficult to run a conventional set for the sake of comparative data collection. Taking away a set for conventional irrigation would mess up subsequent sets in surge. This is an excellent demonstration site.

Farm D8 - The demonstration plot in this farm is a six acre field of alfalfa hay. The soil is billings silty clay with variable slope. Part of the field has a hard pan, making water penetration a slow process. Over watering occurs in the rest of the field by the time water soaks in the problem area. The owner has two different pipe sizes - 8" at the beginning and changes to 6" on the other side of the valve where it rises uphill. This causes differential water flow between sets. At present the ditch water is put into the gated pipe at a point where the head differential is very low.

The problem has been explained and the owner plans to buy enough 8" gated pipe and some length of conveyance pipe to move uphill at a higher elevation point in the ditch to secure enough water head pressure.

Farm D9 - The demonstration set up established in this farm was a twenty acre plot of corn. An in-line valve system was used. The in-line valve used is a proto-type. If found successful the owner will be provided with an appropriate in-line valve to be retained free according to contract. The plot has a hump in the middle making it difficult for the water to run over the rise. The furrows in the low spot tend to break and create crossover. In the first irrigation the canned program could not handle the advance. The advance to the end of the furrow was delayed and soak cycle would start before water reached the end. The situation was overcome by increasing the time for advance cycle. Program #6 or 7 was used where time of advance to one sixth length was little exaggerated.

The owner sometimes had difficulty in appreciating that the field had already received enough water at the end of irrigation. So he would stop the program and run some more water conventionally making data unusable. In few occasions the over irrigation was high and there was tremendous deep percolation, both in conventional and surge. Of course the highest deep percolation always occurred in conventional situation (see Table I). We faced difficulty in running program #6 or #7 - the "waterman" controller would center itself at the end of advance. This is being resolved.

Farm D10 - The demonstration was set up on a seven acre alfalfa hay field. The soil is Mesa clay loam with a gravelly subsoil. The field has a cross slope and remarking of furrows were essential to avoid cross over. The field is quite narrow with long furrows.

The field has been divided into two sections and the owner irrigated them by gated pipes. The upper section of the field is close to his dwelling house and water would seep into the basement during irrigation. The owner's decision to try surge was prompted by the desire of avoiding flooding of his basement.

The surge valve was fitted by the owner in a manner that it would switch water between upper and lower half of the field to accomplish surge. The water tended to run out of the lower half of the field quicker than the upper half due to variation in soil. So the controller was set to operate at 60/40 ratio. The cooperator did not have an area to run conventional for comparison, but there was no more flooding of his basement. The irrigation set time needs to be adjusted to the water holding capacity of the field. The farmer was helped to develop his irrigation set time and ball probes were provided so that he could probe the depth of water penetration to avoid over irrigation.

Farm D11 - The demonstration site was a 20 acre alfalfa hay field. Most of the furrows were quarter mile long. The cooperator's experience with the conventional irrigation in this field was that the water would never reach the end of the field and would sit halfway for a prolonged period of time. The soil is Mesa clay loam with well drained subsoil. With surge it was possible to reach the end of the furrows in a timely manner and there was saving of water. But, this prompted the owner to divert the water to his more important crop - tree fruit, before the soak was achieved. This resulted in under irrigation. As the season progressed it was difficult to get the water to reach the end because of deteriorated furrow condition. Cross over started to occur as the furrows were all gone during the haying process. The owner had too many things to attend and had little time to attend to the irrigation of his hayfield. However, he expressed great satisfaction since he could now cover the entire length of the field much faster.

Farm D12 - The demonstration plot was on approximately six acres of corn in this farm. The owner was extremely busy in his other job. Did not have the time to setup the system as suggested. Data collection was not possible.

Farm D13 - This is a small 5 acre farm with grass hay and tree fruit crop. Monitoring was difficult for lack of well maintained furrows. Irrigation set time was dictated by the availability of water. Surge could not be compared to conventional for lack of sufficient acreage and lack of irrigation water. Although surge may not have made an appreciable impact the irrigation operation became much smoother.

Farm D14 - The surge system for this farm was a surge gate to be used in an old ported ditch. The ditch did not have any built in grooves to place any closing device or gate. The owner requested a ditch lining contractor for help, but the firm didn't have time for the small job. Data collection was not possible.

Appendix B

Brief description of participating farms in Montrose

Montrose 1992 Farmer Participants

Farm #M1 is a 310 acres of irrigated cropland under family operation. Hay, Corn, and Beans are the major crops. The surge demonstration site consisted of approximately 7 acres. The farm ground overlies a gravelly substratum and drainage and salinity problems are not likely to develop and is not highly susceptible to erosion. The demonstration plot was established on pinto beans that have an effective root zone between 6" - 30". Restricting irrigation to the root zone may be difficult contributing to deep percolation.

Farm #M2 is 280.5 acres irrigated farm in family operation. Corn, Barley, Wheat and Alfalfa are the major crops. The surge demonstration site consisted of approximately 14 acres. The grounds are highly susceptible to erosion and therefore, is a difficult area to be tilled. The demonstration plot was established on wheat that has an effective root depth of 12" - 30", which often is the cause for deep percolation.

Farm #M3 is 206 acres of irrigated farm under family operation. Alfalfa, Beans, Corn and Wheat are the major crops. The surge demonstration site consisted of approximately 21 acres. The soils in this farm require frequent irrigation, because of it's course gravel content which limits its water holding capacity. The demonstration plot was established on Corn.

Farm #M4 is 210 acres of irrigated land under family operation. Beans, Corn, Alfalfa, and Wheat are the major crops. The surge demonstration site consisted of approximately 10 acres. The demonstration plot was established on Wheat that has a critical rooting depth of 12" - 30". The soils are likely to be more saline.

Farm #M5 is 90 acres of irrigated cropland under family operation. Corn, Barley and Alfalfa are the major crops. The surge demonstration site consisted of approximately 6 acres. Soils in this farm consists of gravelly material and cobblestones. These soils are well drained and of fine texture with a moderate susceptibility to erosion. The demonstration plot was established on Corn.

Farm #M6 is 60 acres of irrigated farm under family operation. Oats and Alfalfa are the major crops. The surge demonstration site consisted of approximately 8 acres. These soils consisted of gravel and cobblestones, but successfully tilled for crops. Subsoil drainage is restricted and likely to cause problems of drainage and salinity, but not highly susceptible to erosion. The demonstration plot was established on Oats.

Farm #M7 is 220 acres of irrigated land under family operation. Alfalfa, Wheat, Beans and Corn are the major crops. The surge demonstration site consisted of approximately 14.5 acres. This ground is used successfully for tilled crops and are moderately susceptible to erosion. The demonstration plot was established on Wheat.

Farm #M8 is 35 acres irrigated orchard in family operation. Apples, Pears, Cherries, and Peaches are the major crops. The surge demonstration site consisted of approximately 30 acres. Water holding capacity is fair, soils are not highly susceptible to erosion. The demonstration plot was established on a mature Apple orchard.

Farm #M9 is 70 acres of irrigated farm under family operation. Corn, Alfalfa, Oat cover, and Pasture grasses are the major crops. The surge demonstration site consisted of approximately 9 acres. The demonstration plot was established on Corn.

Farm #M10 is 76 acres of irrigated farm in family operation. Sweet Corn, Beans, Corn seed, Lettuce, and Broccoli are the major crops. The surge demonstration site consisted of approximately 10 acres. Water holding capacity of the soil in this farm is fair. These soils are not highly susceptible to erosion. The demonstration plot was established on Sweet Corn.

Farm #M11 is 150 acres of irrigated farm in family operation. Hay, Sudan grass and Pasture grass are the major crops. The surge demonstration site consisted of approximately 16 acres. The soils here require careful management, because the subsoil is fine textured. These soils are not highly susceptible to erosion. The demonstration plot was established on Sudan grass.

Farm #M12 is 337 acres of irrigated farm in family operation. Corn, Alfalfa, Winter wheat and Beans are the major crops. The surge demonstration site consisted of approximately 34 acres. The shale beds restrict subsoil drainage in this farm and if not carefully managed, moderate salinity is likely to develop. The demonstration plot was established on Corn.