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BEFORE THE STATE WATER RESOURCES CONTROL BOARD

OF THE STATE OF CALIFORNIA

In the Matter of **Periodic Review of the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary**	**TESTIMONY OF SAN JOAQUIN RIVER EXCHANGE CONTRACTORS WATER AUTHORITY: TESTIMONY OF CHARLES BURT ON ISSUE 2: SOUTHERN DELTA ELECTRICAL CONDUCTIVITY**

Hearing Date: March 14, 2005
Time: 9:00 a.m.

Dr. Charles Burt testifies as follows:

1. My resumé is attached to this testimony. I am a professor in the BioResource and Agricultural Engineering Department, California Polytechnic State University, San Luis Obispo, California, since 1978; where I have also served as Founder/Director/Chair of the Irrigation Training and Research Center (ITRC) since 1989, and as Chairman of the Board since 2000.

2. I am a registered professional engineer - Civil (California RCE 28995, July 1978); Agricultural (California AG 430 March 1979); Irrigation (Utah 5662, August 1981).

3. I am certified through the Irrigation Association as an Ag Irrigation Manager, and an Irrigation Designer (drip, surface, and sprinkler irrigation systems).

4. A wide variety of agricultural crops are grown in the lower San Joaquin River watershed. Salts are imported from the Delta through the federal Central Valley Project and disbursed through applied irrigation water. Return flows that eventually drain to the San Joaquin River through drainage channels, in addition to ground water accretions containing naturally occurring salts in San Joaquin soils, M&I discharges and natural tributaries, are the source of salinity in the irrigation water diverted by downstream users. Salts contained in irrigation water may, when applied to an agricultural field, accumulate in the root zone to the point that they cause a reduction in yield.

As recognized in the recent Staff Report of the SWRCB and the reports and materials utilized by the Central Valley Project Regional Water Quality Control Board in adopting salt and boron TMDL standards for the San Joaquin River, elevated salinity in the southern Delta is caused by low flows, salts imported in irrigation water by the State Water Project and Central Valley Project, and discharges of land-derived salts, primarily from agricultural and wetland drainage. This Board recognized in its Decision D-1641 that "the actions of the CVP are the principal cause of the salinity concentrations exceeding the objectives at Vernalis." (D-1641, p. 83). This Board found that the United States Bureau of Reclamation, "through its activities associated with operating the CVP in the San Joaquin River Basin, is responsible for significant deterioration of water quality in the southern Delta." (D-1641, p. 83).

The planners of the irrigation projects and the policymakers that wanted increased and more reliable agricultural production (and a stronger economy) understood that drainage was necessary for the irrigation projects. In spite of what everyone would like, it is important to realize that standards cannot reasonably be based upon wishful longing that the San Joaquin River attain the same water quality as that of a naturally flowing water body – thinking and a longing for conditions that cannot scientifically occur. It is essential for all the stakeholders that unrealistic regulatory standards not be implemented - standards that would unintentionally destroy the benefits of irrigated agriculture and an efficient food supply for our increasing population, and throw millions of societal dollars at a condition that cannot be reversed but can be efficiently managed. The San Joaquin River will be a man-created drain for salts until and unless reverse osmosis (and disposal of the extracted salt) becomes economical for non-point discharges, or a drainage system for physically removing those salts is built and operated. A sustainable drainage water quality objective (e.g., for the San Joaquin River) cannot possibly be maintained at the same or better quality than the salinity objective established for the source water (at the Delta intakes of Delta-Mendota Canal and California Aqueduct) – yet the proposed salinity standard for the river could do just that.

Even the salinity of the Delta Mendota Canal (DMC) water equals or exceeds the maximum allowable salinity target in the San Joaquin River (see the table below) during some months. Yet almost all DMC water is successfully used to grow beans, lettuce, almonds, and numerous other salt-sensitive crops. The months highlighted in **bold** in the table are when the mean monthly EC of DMC water at Check 21 (Mendota Pool) exceeded the proposed water quality objective of 0.70 dS/m in the summer and 1.0 dS/m in the winter.

Delta-Mendota Canal Mean Monthly EC (Check 21)
Mean Monthly EC values computed from daily data provided by USBR
Bold indicates exceedance of San Joaquin River salinity targets
(All values are in dS/m)

	1993	1994	1995	1996
Jan	**1.10**	0.73	0.49	0.65
Feb	0.88	0.41	0.61	0.48
Mar	0.81	0.81	**1.30**	0.36
Apr	0.65	**0.89**	0.63	0.42
May	**0.72**	**0.88**	**0.73**	0.38
Jun	0.65	**0.77**	0.20	0.39
Jul	0.48	**0.79**	0.21	0.36
Aug	0.25	**0.69**	0.36	0.37
Sep	0.43	**0.70**	0.35	0.39
Oct	0.45	0.62	0.24	0.37
Nov	0.56	0.49	0.42	0.44
Dec	0.65	0.70	0.44	0.51
Average	0.64	0.71	0.50	0.42

The Central Valley Regional Water Quality Control Board's (Regional Board) position has consistently been that an out-of-valley drain is needed to remove salts from lands irrigated on the west side of the San Joaquin River. In effect, requiring that the salts be reapplied to the lands to meet unrealistic standards will eventually destroy productive farm land and make it economically impossible to produce food and fiber needed by our growing urban populations. Moreover, in the long term, the salt that the TMDL attempts to have retained in the soil will eventually reach the San Joaquin River in any case.

Given the fact that the USBR has not provided drainage to the San Luis Unit lands as required by this Board and the courts, this Board is presented with little alternative other than to provide for the drainage of the region's farmlands through the San Joaquin River.

5. Leaching, the process of applying water over and above the evapotranspiration (ET) requirements of the plants irrigated, is a necessary on-going or annual irrigation management practice used to flush a certain fraction of water below the root zone to maintain an acceptable, constant salt concentration in the root zone. On a long-term basis, the amount of salts removed by leaching (deep percolation) must be equal to or greater than the salts imported with irrigation water or salts will build up and eventually impact crop yields.

The water needed to provide the leaching requirement is a beneficial use of irrigation water. (Irrigation Performance Measures: Efficiency and Uniformity. Burt, C.M., et al.. ASCE Journal of Irrigation and Drainage Engineering. 123(6) Nov/Dec 1997). Technically, we have formulas that allow us to compute the Leaching Requirement (LR) – which enables us to compute how much deep percolated irrigation water or rain water is required to achieve the desired salt concentration in the soil at the point in the field that receives the least amount of water.

6. In July 2004, ITRC staff and I prepared a report for the San Joaquin Valley Drainage Authority that did the following:

- Examined the proposed San Joaquin River water salinity standards by the Regional Board for the reach of the San Joaquin River from the Mendota Pool to Vernalis.
- Examined previous, related studies.
- Updated ITRC information on cropping patterns and the recent flow models for the San Joaquin River, and provided a scientific basis for determining reasonable numerical salinity targets that will provide reasonable protection of irrigated agriculture use of water from the San Joaquin River, which is the most sensitive beneficial use of water diverted from the lower San Joaquin River.

I have summarized the major points from these tasks in the sections below.

7. **<u>The Proposed Alternatives</u>**

The proposed alternatives of the Regional Board are relatively restrictive by comparison to historic conditions, especially in terms of the water quality of water supplies imported to the watershed from the Bay-Delta.

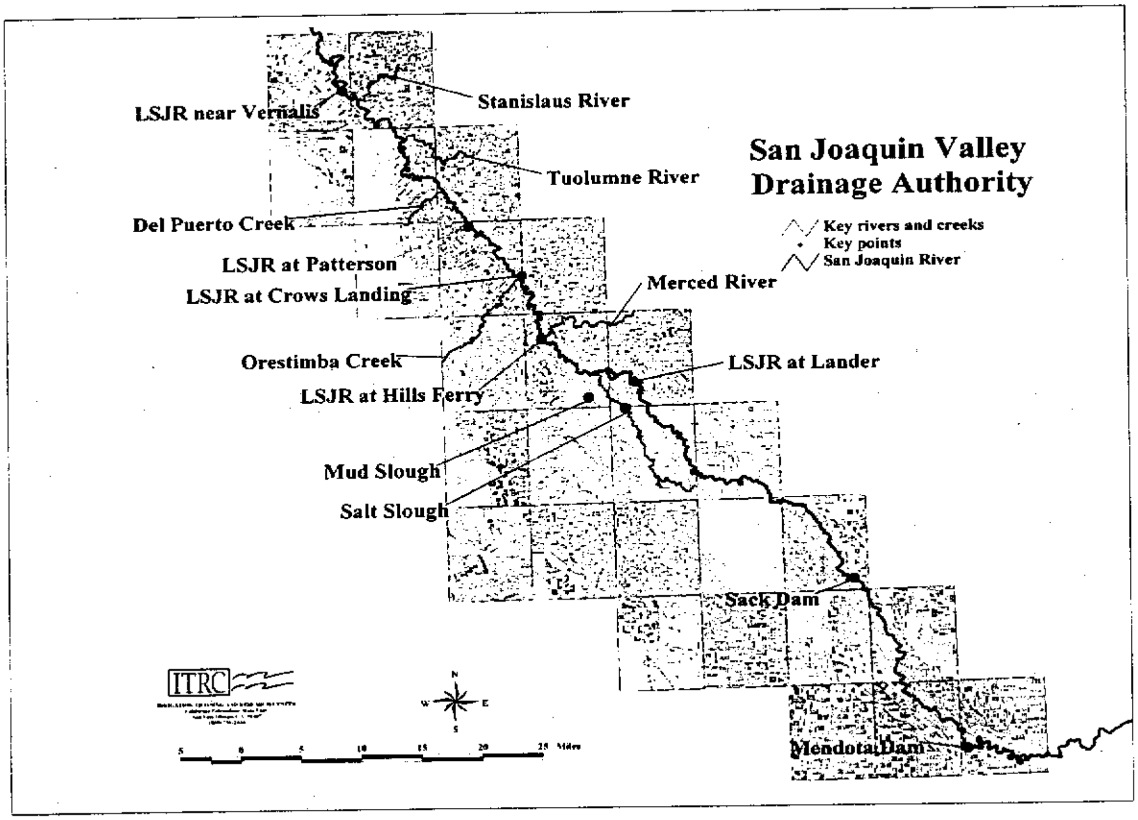
The SWRCB set a river water quality objective of 0.7 mmhos/cm (a.k.a. 0.7 dS/m) during the summer irrigation season (April 1 through August 31) based on the salt sensitivity and growing season of beans and an objective of 1.0 mmhos/cm during the winter irrigation season (September 1 through March 31) based on the growing season and salt sensitivity of alfalfa during the seedling stage. (SWRCB Staff Report Periodic Review, September 30, 2004, page 28). The source of these water quality criteria apparently originates in the 1987 Technical Committee Report entitled "Regulation of Agricultural Drainage to the San Joaquin River (SWRCB Order No. WQ 85-1). Due to the significant role in the 85-1 Technical Committee Report and subsequent policy decision making about salinity in the San Joaquin River, I note several of the key aspects of the criterion of 0.7 mmhos/cm (415-430 ppm TDS) as described in the report:

(1) Irrigated agriculture is deemed the most salinity-sensitive beneficial use.

(2) A standard based on irrigated agriculture use is lower than the criteria to protect other beneficial uses, and therefore should protect fish and wildlife.

(3) The 85-1 Technical Committee Report also includes a mention of work done by the Regional Board that had determined that a water quality objective of 1.0 mmhos/cm during the winter irrigation season for the San Joaquin River in the area immediately downstream of Hill's Ferry would provide reasonable protection to these crops on the soils in the areas (P. VIII-15). Further there is discussion of the difficulty of achieving this objective in dry and critical water year types and how this may necessitate blending with better quality water during periods of higher river salinities.

(4) Figure 1 (below) identifies the key points along the San Joaquin River that are relevant to this next point. Quite correctly, as discussed in the 1985 85-1 Technical Committee Report (TCR), there are only a few agricultural diversions between the confluence with Salt Slough and Hills Ferry, mainly for salt-tolerant pasture. The TCR authors state the following:



"An objective of 3.0 mmhos/cm EC (3.0 dS/m) supports the existing uses in Salt Slough and areas downstream to Hills Ferry consistent with the historic water quality and present agricultural practices. Therefore, an objective of 3.0 mmhos/cm EC is recommended as the water quality objective for this limited area."

This citation is offered to illustrate that alternate water quality objectives for the lower San Joaquin River have been proposed previously in a manner that recognized existing agricultural practices, specifically the use of higher water salinity threshold standards for irrigation of crops, and which also recognized the reality that Salt Slough, Mud Slough and the San Joaquin River will inevitably serve as a drainage system until a man-created system for removing salts from the watershed is developed and operated economically.

8. **Review of Some Technical Points**

Allow me to amplify/repeat some of technical details in a more orderly fashion before continuing:

a. It is a physical fact that the salt that is imported into the region must be exported, or else stored in the region.

b. The idea of meeting a "leaching requirement (LR)" from an agronomic standpoint means that irrigation is managed to continually remove salt from the soil as quickly as it is applied. It is not a concept of "storing" salt.

c. Storage of salt in the plant root zone will inevitably cause a buildup of salt levels that will eventually eliminate agriculture, which in turn can have tremendous negative consequences on air quality, recreation, and local and state economies.

d. It is possible to temporarily store salt in the soil for the next 10 years and see a *temporary* beneficial impact on river water quality in *some* reaches of the river. But the eventual consequences, which cannot be debated from a scientific standpoint, are:

i. Agricultural production would seriously decline or be eliminated in some areas as the soil salinity levels increase.

ii. Ultimately, if agricultural is to survive, some of the salt would need to be removed. The removal rate, measured in tons/year of salt, would be approximately the same as if the soil was maintained at a lower salinity level – meaning that all of the temporary efforts were to no long-term benefit.

e. The only long-term solutions that we know of for the salinity problem are:

i. Import less water, which requires a reduction in cropped acreage.

ii. Utilization of the San Joaquin River for drainage with reasonable water quality standards.

iii. Reverse osmosis (with subsequent salt disposal/storage questions and a very high cost).

f. Sometimes there is confusion about the basics of an "EC" measurement and what it means. "Soil water salinity" is different from "saturated soil paste extract (ECe)" is different from "irrigation water salinity".

Although the irrigation water salinity impacts the soil salinity (ECe), the ECe is also impacted by the leaching fraction (the percentage of deep percolation of both rainfall and irrigation water). The importance of the relationship between these different "EC" values – as related to SJ River water quality standards - should become apparent in later sections.

g. Maas (1990) defines salt tolerance as "the plant's capacity to endure the effects of excess salt in the medium of root growth." Although a plant's capacity to endure salts is not an absolute value, salt tolerance is usually expressed in terms of the yield reduction associated with specified concentrations (ECe) of saturated soil paste extract – a value that is very different from the irrigation water EC. The amount of salts in soil water tolerated by a specific crop depends on the variety, as well as being a function of the interactions between soil, fertility, climate, irrigation method, growth stage, and other environmental stresses.

h. The relative salt tolerances for agricultural crops are fairly well understood. Research on various different varieties has found differences in salt tolerances; however, the values for most crops grown in the San Joaquin Valley fall approximately into one of the categories listed in Table 1 (see next page). It is important to note the values listed on the table are soil salinity values, **not irrigation water salinity.** There is a large range in the salt tolerance of agricultural crops - up to tenfold in some cases. For example, cotton, a tolerant crop, has a salt tolerance nearly eight times as great as beans, a sensitive crop. The precise effect of salinity on yield depends on the timing of the stress effect and the growth stage.

i. The crop tolerances for soil salinity at yield potentials of 100% correspond to qualitative groups as defined by Maas (1984). The numerical divisions for relative soil salinity tolerance ratings are summarized in Table 1 included for the reader's convenience.

Table 1. Tolerance of various crops to soil salinity, after germination.

Portion of Table 3-2 from BRAE 331 text by Dr. Charles Burt, BioResource and Agricultural Engr. Dept., Cal Poly, San Luis Obispo, CA.(Adapted from Maas and Hoffman, 1977).

Crop	Threshold ECe (ECe at initial yield decline) dS/m	Crop	Threshold ECe (ECe at initial yield decline) dS/m	Crop	Threshold ECe (ECe at initial yield decline) dS/m
Alfalfa	2.0	Corn, sweet	1.7	Plum	1.5
Almond	1.5	Cotton	7.7	Potato	1.7
Apricot	1.6	Cowpea	1.3	Radish	1.2
Avocado	1.3	Cucumber	2.5	Rice, paddy	3.0
Barley (grain)	8.0	Date	4.0	Ryegrass, perennial	5.6
		Fescue, tall	3.9		
Bean	1.0	Flax	1.7	Sesbania	2.3
Beet, garden	4.0	Grape	1.5	Soybean	5.0
				Spinach	2.0
Bermudagrass	6.9	Grapefruit	1.8	Strawberry	1.0
Blackberry	1.5	Harding grass	4.6	Sudangrass	2.8
Boysenberry	1.5	Lettuce	1.3	Sugarbeet	7
Broadbean	1.6	Lovegrass	2.0	Sugarcane	1.7
Broccoli	2.8	Meadow foxtail	1.5	Sweet potato	1.5
Cabbage	1.8	Onion	1.2	Tomato	2.5
Carrot	1.0	Orange	1.7	Trefoil, Big	2.3
Clover;ladino red, strawberry	1.5	Orchardgrass	1.5	Trefoil, Birdsfoot narrow	5.0
Clover, berseem	1.5	Peach	1.7	Wheat	6.0
Corn (forage)	1.8	Peanut	3.2	Wheatgrass, crested	3.5
Corn (grain)	1.7	Pepper	1.5	Wheatgrass, fairway	7.5
				Wheatgrass, tall	7.5

j. For a given irrigation water salinity, a farmer can manage irrigation for a wide range of soil salinities (which is what the plants respond to – not to the irrigation water salinity, itself). The fairly conservative formula that I used in the studies to define this relationship is:

$$LR = \frac{ECw}{5(ECe) - ECw}$$

where LR = Leaching Required = the fraction of applied water that must deep percolate at a point in the field to maintain the desired ECe

ECe = The saturated soil paste extract salinity, dS/m (the average of the whole root zone salinity)

ECw = The average salinity of the irrigation water, dS/m

This formula is applied below to show how a ***very*** sensitive crop such as beans can be grown with an irrigation water ECw of 2 dS/m *as long as sufficient leaching water is provided.*

Example: The maximum ECe for beans with no yield decline = 1.0 dS/m

ECw = 2.0 dS/m

$$\text{The required LR} = \frac{2.0 \text{ dS/m}}{5 \times (1.0 \text{ dS/m}) - 2.0 \text{ dS/m}} = .67$$

For other sensitive crops, such as deciduous trees, the LR is only half as great as for the extreme example of beans. And if the crops are irrigated on a frequent basis, they can withstand higher salinities than the published threshold values.

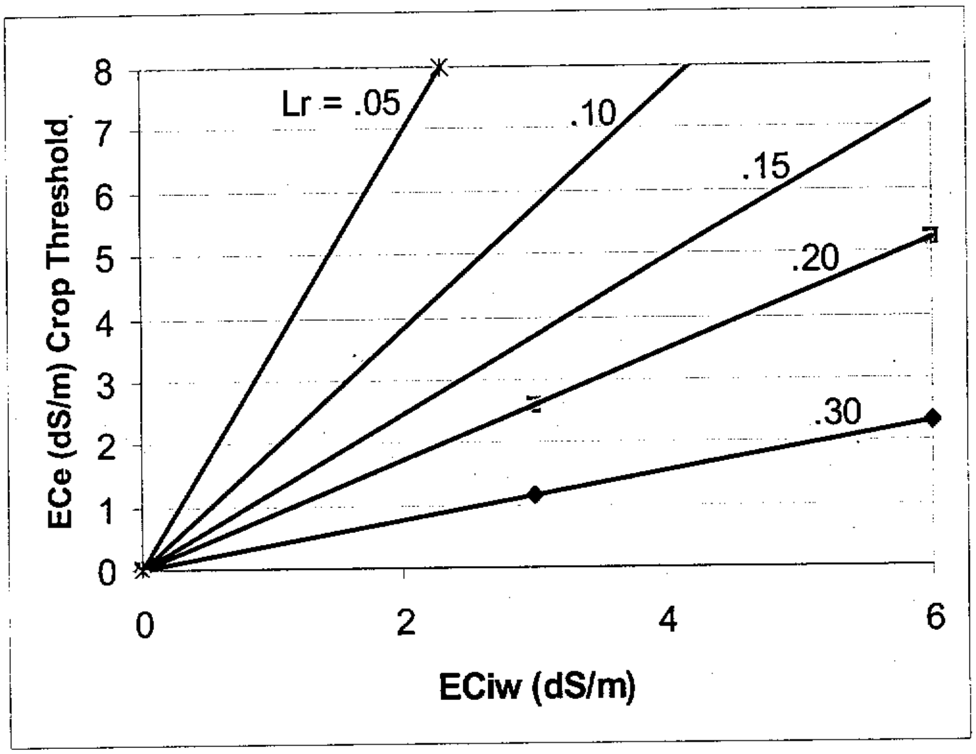
It is noteworthy that beans only represent about 5% of the crops downstream of Vernalis. It is also noteworthy that the needed fraction of deep percolation of irrigation water would be less than 0.67 because (i) rainfall contributes some of the water, and (ii) one would not expect an ECw of 2.0 dS/m for the complete year.

9. Two very important points must be made to put "LR" even more into context:

(1) The standard "LR" equation is meant to be applied to the spot in the field that receives the least amount of water. This means that if the LR is not meant, the vast majority of

the field will still have no yield decline because of extra deep percolation caused by non-uniformity of irrigation water application.

(2) There are a number of formulas available to predict the relationship between LR, water ECiw, and soil saturated past ECe. The "Agricultural Salinity Assessment and Management" book (ASCE EP No. 71, K. Tanji (ed), 1990) is probably the most common reference for salinity. The figure below illustrates its recommended relationship.



Leaching Requirement (Lr) as a Function of the Salinity of the Applied Water and Salt-Tolerance Threshold Value (after Hoffman (1983); Tanji (ed), 1990.)

The figure above shows that with an ECiw of 2.0 dS/m, the required LR would be about 0.28 to achieve an average root zone ECe of 1 dS/m. This is much less than the 0.67 value computed earlier – and upon which this testimony is based. The analysis for this testimony estimated no problem with higher ECiw, and the Hoffman relationship only strengthens that argument.

10. **Deverel and Schmidt Drainage Study**

I have reviewed related work done by Steve Deverel and Kenneth D. Schmidt. Dr. Deverel has developed a ground water flow model for Firebaugh Canal Water District and surrounding Water Districts and looked at the flux, or flow, across the common boundary between Firebaugh and upslope water districts in the San Luis Unit of the CVP. Dr. Schmidt, in 1987, conducted pump tests right at the boundary of Firebaugh Canal Water District with upslope water districts to calculate the movement of water in the subsurface across the common boundary. In Dr. Deverel's work, he came up with a number of around 235 acre-feet per year per mile of boundary. The movement of poor quality drainage water into Firebaugh is caused by the failure of the government to provide drainage service to the lands in the San Luis Unit.

a. The TDS of this water moving across the boundary is about 5142 EC.

b. I also reviewed Dr. Deverel's work where he determined a quantity of load of the poor quality water that moves outside of Firebaugh originates from areas other than the Firebaugh Canal Water District. Dr. Deverel calculated that load to be 50%. In other words, 50% of the poor quality water discharged from Firebaugh, which ultimately ends up in the San Joaquin River is attributable to activities other than Firebaugh's farming actions.

11. The Firebaugh study points to the regional nature of the problem and is a reason that this Board should be establishing standards as part of its Periodic Review to manage the San Joaquin River to allow for the drainage of salts from agricultural lands, given the fact that the government is not acting to construct a drain or otherwise provide drainage service to the region.

12. The reasonableness of achieving water quality conditions is one of the factors that the Regional Board and this Board must consider when setting salinity objectives. (Water Code §13241). The Regional Board has apparently recognized that significant reductions in salt discharges will be needed to meet the objectives that they have proposed. A major point I will now make is that the reduced surface discharges may not result in reasonable impacts.

13. **Examination of River Sections Between the Mendota Pool and Vernalis**

The 130 mile reach of the lower San Joaquin River from the Mendota Pool to the airport way bridge at Vernalis was divided into 10 sections for analysis, corresponding to the primary tributary inflow points or major hydraulic feature. The Regional Board can set, with justification, water quality objectives that vary by river section and by the time of year. And the State Board's Periodic Review of Delta Estuary standards must in its standard setting for that area recognize that salinity standards can preserve beneficial uses without attempting to idealize San Joaquin River water quality to a near natural state. The San Joaquin River has undergone extensive hydromodification. Realistically, this is a man-altered system, even though the body of water is called a "river" as contrasted with a "drainage canal."

Based on historical data sets of water quality indicating significant differences in salinity concentrations by river sections and the fact that different water agencies and private water users divert and/or drain to different river sections, it is reasonable to divide the distance between the Mendota Pool and Vernalis for the purpose of varying the salinity objectives.

The river Salinity Standards must recognize that if poor quality water is "stored" in the soil profile upstream the stored salts may come down the river at times when beneficial uses will be more severely impacted. As poor quality water stored within the soil profile and tile sumps operated by individual growers or water agencies are shut off to meet the TMDLs, it increases the lateral subsurface flows of salty water to the surrounding grounds and actually tends to increase discharge from some of the other surrounding tile sumps and from accretions which reach the San Joaquin River in an uncontrollable fashion. In other words, to a degree, TMDLs or an artificial and inflexible Vernalis Standard will cause a shutdown of tile sumps in a drainage area and this will result in an even larger problem for the landowners and users of water from the San Joaquin. The problem exists due to the failure of the government to provide drainage service to the region.

a. I directed an analysis to determine what the salinity concentrations would be in the lower San Joaquin River with no salt loading from agricultural discharges through surface drainage or surface canal spills. In other words, one way of assessing the reasonableness of the proposed salinity objectives is to first quantify the salinity concentrations that would have occurred in the river using historical data, assuming that water users on both the east and west sides of the river did not dispose of drain water or canal spill in the river or in the major tributaries and instead ground water accretion flows were the means of salts entering the river.

b. The results of my analysis indicate that under the proposed actions, the estimated EC (water salinity) in the River from Bear Creek (north of Mud and Salt Sloughs joining the River) to Del Puerto Creek (9 miles above the Tuolumne confluence with the San Joaquin River), a total reach of 43 miles, during August 2002 would have been over 100% higher than the most lenient proposed objectives in alternatives 1 through 3 proposed by the Regional Board. The value used in the numerical analysis for the ground water accretion rate had a significant influence on the predicted EC and flow rate at Vernalis under a no agricultural discharge condition indicating higher EC at Vernalis. This limited analysis of historical conditions indicates that the removal of all surface discharge, by itself, cannot be reasonably expected to bring the river into compliance with the proposed salinity objectives. In a simple logical extension, Vernalis standards that drive agricultural users to eliminate surface water drainage flows or canal spillage can require more, not less, New Melones flows.

The bottom line is that it seems unreasonable to put a regulation into place if the unintended impact will be an increase in EC at Vernalis caused by uncontrolled salt-laden ground water accretion flows into the river.

c. Using this analysis, it is seen that the unfortunate impact of a well-intentioned standard is that the mean EC in the reach of the river between Bear Creek and Del Puerto Creek was actually elevated over historical conditions when agricultural surface discharges were removed. In particular, in the section of river between Salt Slough and Mud Slough, the estimated EC in August 2002 was 80% higher than with surface discharges and the flow rates decreased by over 60%. The analysis for salinity concentrations occurring during March 2002 with no surface discharge (drain water disposal and canal spills) follows a similar pattern, with the exception that the mean EC downstream of the Merced River was about half as high due to the assimilative capacity of the natural flows of the tributary.

d. I also directed an analysis to estimate the additional instream flows that would have been required under historical conditions in order to meet the salinity objectives proposed by the Regional Board. The Regional Board's proposed alternative salinity objectives range from 700 to 1000 microseimens per centimeter (μs/cm) (0.7 – 1.0 dS/m). As discussed immediately above, there would need to be some additional instream flows provided to the river in order to provide enough assimilative capacity depending on flow conditions. I do not understand the rationale behind a regulation prohibiting surface drainage into the river, when then requires the addition of artificial surface flows to meet the water quality standards that the first steps were intended to meet.

I performed an analysis to determine reasonable salinity objectives for different sections of the lower San Joaquin River from the Mendota Pool to Vernalis using our most current knowledge of crop needs.

e. A wide variety of agricultural crops are grown in the lower San Joaquin River watershed. The analysis computed the irrigated acreage of the agricultural fields in each of the delineated river sections from Mendota Pool to Vernalis using GIS mapping with field boundary layers obtained from the Department of Water Resources. In addition, comprehensive field work done by the Regional Board was used to estimate private acreage that is presently being irrigated with San Joaquin River water.

f. Salts are imported from the Delta and disbursed through applied irrigation water.

g. The salt tolerance of various crops in various sections of the river was computed, along with the gross water requirements by month (2002) that included leaching requirements.

h. The results indicate that a soil salinity objective of 2,000 μs/cm (2 dS/m) for the San Joaquin River from the Merced River to Vernalis would provide reasonable protection of the agricultural supply beneficial uses in that region – especially because some of the river stretches have no agricultural diversions. Higher salinities are acceptable between Sack Dam and the Merced River.

i. Figure 2 (below) illustrates a worst-case August 2002 scenario for additional diversions required to avoid crop loss, as compared to available river flows. A key point to be made is that the concept of "leaching requirement" states that the required leaching does not need to be done every month, but instead can be done once/year for most crops

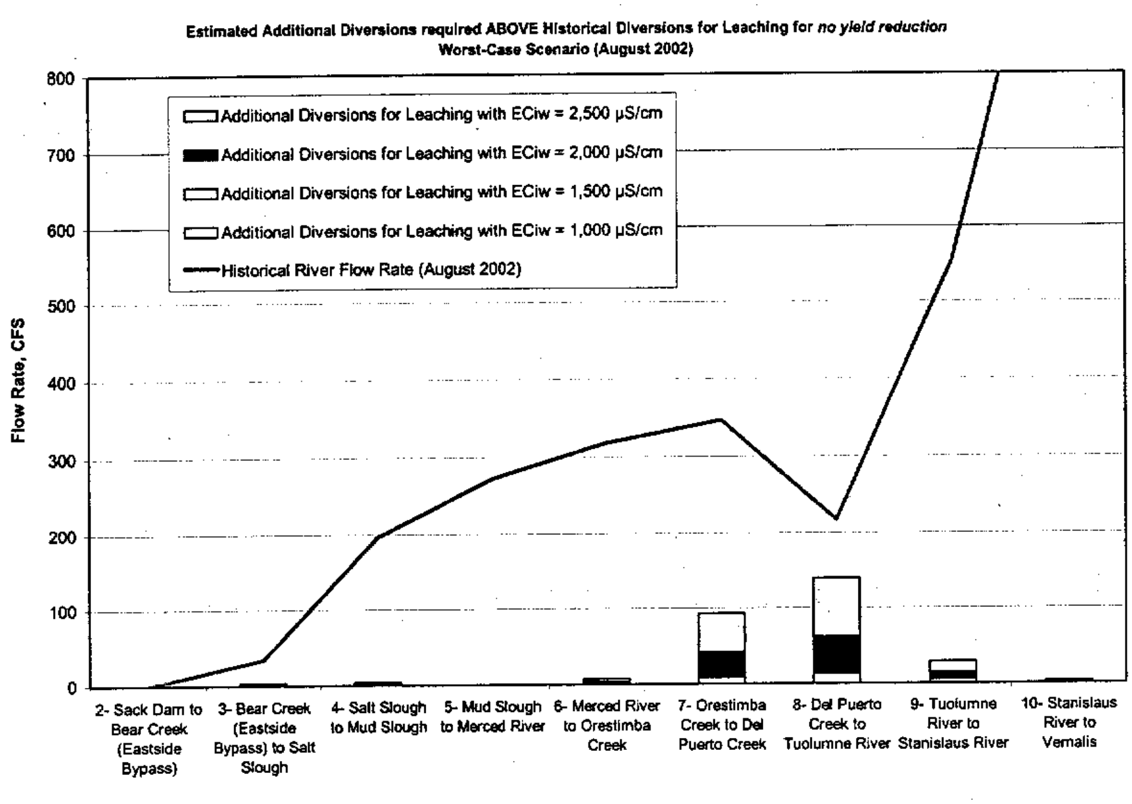


Figure 2. Additional diversions needed to avoid yield decline, in various reaches of the San Joaquin River.

j. The crop acreages for each river section according to salt tolerance ratings are summarized herein for the reader's convenience. The analysis indicates that sensitive crops represent about 1/3 of the crop acreage downstream of Sack Dam, while the majority of acreage can be classified moderately sensitive.

Table 2. Acres of crops of different qualitative salt tolerance ratings by river section in the Lower San Joaquin River

Sect.	Description	Salt Tolerance Rating[1]			
		Sensitive	Moderately Sensitive	Moderately Tolerant	Tolerant
1	Mendota Pool to Sack Dam	281	20,694	2,083	20,708
2	Sack Dam to Bear Creek	0	4,261	217	2,694
3	Bear Creek to Salt Slough	76	804	20	170
4	Salt Slough to Mud Slough	76	804	37	170
5	Mud Slough to Merced River	0	0	0	0
6	Merced River to Orestimba Creek	153	1,608	41	341
7	Orestimba Creek to Del Puerto Creek	5,908	12,166	1,250	1,074
8	Del Puerto Creek to Tuolumne River	11,223	8,625	1,194	1,160
9	Tuolumne River to Stanislaus River	1,926	1,976	648	1,098
10	Stanislaus River to Vernalis	131	208	45	70
	Total	**19,776**	**51,147**	**5,534**	**27,486**
	(%)	(19%)	(49%)	(5%)	(26%)
	Sub-total downstream of Sack Dam	**19,494**	**30,453**	**3,451**	**6,778**
	(%)	(32%)	(51%)	(6%)	(11%)

[1] Based on the agricultural crop types as listed in Table 5 of Ayers and Westcot (1989)

CONCLUSIONS

Based upon the foregoing it is my opinion that:

1. It is unreasonable from a scientific standpoint to install a drainage water quality standard that requires the drainage water to be as good as, or better than, the incoming irrigation water quality.

2. It is unreasonable from a scientific standpoint to expect to have sustainable irrigated agriculture by storing more salt in the soil every year.

3. Discontinuing the disposal of west side drain water to the San Joaquin River, by itself, will not be sufficient to meet the least restrictive of the Regional Board's salinity objectives in the reach of river from Salt Slough to the confluence with the Tuolumne River.

4. Meeting the least restrictive salinity objective proposed by the Regional Board would necessitate an additional instream flow of over 100% above historical conditions in the critical river section downstream of Mud Slough. This is equivalent to an additional flow rate of about 125 cfs during the middle of the irrigation season in August.

5. A maximum water salinity objective of 2000 µs/cm for the San Joaquin River from the Merced River to Vernalis would provide reasonable protection of the agricultural supply beneficial use, based on historical conditions.

6. Upstream of the Merced River, it can be argued that a water salinity objective as high as 2500 µs/cm is reasonable within the historical cropping patterns.

7. The Regional Board has defined a formal procedure (Resolution 88-63: Sources of Drinking Water Policy) to de-designate beneficial uses, such as municipal and domestic supply. There is justification to explicitly de-designate municipal and domestic water use as a potential beneficial use on the lower San Joaquin River because there are no urban or municipal users between Mendota Dam and Vernalis, M&I beneficial uses require better water quality than agricultural uses, and the Regional Board has made allowance to de-designate categories of beneficial use.

If called to testify in this matter, I could and would testify to each of the above matters, except as to those matters stated upon information and belief, and as to those matters I believe them to be true and correct.

Executed this 9th day of March, 2005 at San Luis Obispo, California.

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Specializations:	• On-farm irrigation system design, management, and evaluation • Control strategies and modernization for water delivery systems
Education	• Utah State University, Logan Utah. Ph.D. Engineering (1983) • Utah State University, Logan Utah. M.S. Agricultural and Irrigation Engineering (1975) • Cal Poly. State Univ., San Luis Obispo. B.S. Soil Science (1973)
Organizations/Awards Organizations, etc.:	• American Society of Agricultural Engineers • American Society of Civil Engineers; Water Resources Engineering Div. Previous chair on numerous committees. • The Irrigation Association - previous chair of numerous committees • California Irrigation Institute • United States Committee on Irrigation and Drainage (USCID) • Phi Kappa Phi • Alpha Zeta • Chairman of Friends of the Central Highlands (non-profit organization to assist Montagnards near Pleiku, Vietnam) • Member, Editorial Board of Irrigation and Drainage Systems (Kluwer Academic Publishers, The Netherlands)
Awards/Honors:	• Bronze Star Medal for Heroism; ARCOM for Heroism; ARCOM for Meritorious Service (U.S. Army) • Commended in Calif. Legislature Resolution No. 365 for international training work (1982). • Recipient of National Water and Energy Conservation Award by The Irrigation Association (1986) • Outstanding Agricultural Engineer award for the ASAE Pacific Region (1987) • 1997 Person of the Year - The Irrigation Association • 1999 Irrigation Person of the Year – Calif. Irrigation Institute • Sunkist Agriculture Faculty Award (1996) • Plant Sciences Outstanding Faculty Award (2001) • ASCE Journal of I&D Engr. "Best Discussion Award" for 2000 • Royce J. Tipton Award from the Environmental and Water Resources Institute, Amer. Society of Civil Engr. (Highest ASCE irrigation and drainage honor) • First recipient of the Distinguished Researcher Award, Cal Poly (2004) • Nominated as a Diplomate of the American Academy of Water Resources Engineers (AAWRE) (2004)

Registrations & Certifications

Registered Professional Engineer:	• Civil (California RCE 28995, July 1978) • Agricultural (California AG 430, March 1979) • Irrigation (Utah 5662, August 1981)
Certified Irrigation Designer through The Irrigation Assoc.:	• Agricultural Drip Irrigation • Agricultural Surface Irrigation • Agricultural Sprinkler Irrigation • Agricultural Irrigation Manager

Languages

English	First Language
Spanish	Reasonable reading and speaking

Experience/ Qualifications

1978-Present:

- Professor, BioResource and Agricultural Engr. Dept., California Polytechnic State University, San Luis Obispo, CA 93407.
- Irrigation Training and Research Center, California Polytechnic State University, San Luis Obispo, CA 93407 (Director/Chair 1989 - 2000; Chairman of the Board 2000+)

Early Employment Experiences:

- Farm worker during high school and college in California.
- Spec. 5. U.S. Army (1967-1970). 3 tours with 4th Infantry Division in Republic of South Vietnam Combat demolition specialist, helicopter rappelling team, S-5 team, Montagnard training, recon. patrols.
- Keller Engineering (Logan, Utah). Irrigation System Designer. Designed several large drip systems in the USSR and Iran. Field investigations in Iran (75-76).
- Wren-Oneal Co. (Fresno, CA). Irrigation System Designer. Designed, sold, and installed drip, sprinkler, and surface systems for a major agricultural irrigation company of California (76-78).
- JM Lord, Inc. (Fresno, CA) Chief engineer and partner (1 year leave from Cal Poly). Irrig. design and project planning (81-82)

International Irrigation & Drainage Work

- Work on private and international donor projects in Canada, Mexico, El Salvador, Honduras, Costa Rica, Colombia, Dominican Republic, Mali, Spain, Portugal, Morocco, Tunisia, India, Iran, Pakistan, Thailand, Vietnam, France, Saudi Arabia, Taiwan, Philippines

Recent Cal Poly ITRC Project Examples

- Automation plans, SCADA, and follow-through for various irrigation districts
- Water balance and water rights studies for irrigation districts.
- Preparation of modernization guidelines for various irrig. districts in California, Nevada, Arizona, Utah, Idaho, Oregon, Colorado, and Washington
- Manager of $7.5 million peak electric load reduction program for the Calif. Energy Com.
- Irrigation Efficiency and Drainage Reduction studies (incl. GIS)
- Row crop drip and buried drip on trees/vines, including salinity studies
- Variable speed electric drive analysis and applications
- Flow measurement strategies for Truckee-Carson ID
- Evaluation of long-term salinity buildup under drip irrigation

Recent Private Consulting Examples

- Metropolitan Water District of So. Calif. – Irrigation water conservation evaluation.
- Expert witness on various irrigation matters.

Other:

Active participant in various organizations (ASCE, IA, USCID) to organize specialty conferences and sessions at regular conferences. For example, service as chairman of 7/02 USCID conference held in SLO.

PUBLICATIONS, PAPERS, AND PROCEEDINGS

Burt, C.M. 1975. Crop Production Functions Associated with Land Grading. Unpublished M.S. Thesis. Utah State University Library. Logan, Utah.

Burt, C.M., G. Stringham, and D. James. 1975. Increasing Yields on Recently Graded Land Through Proper Phosphate Fertilization. Spring Edition 1975. Utah Science. Reprinted in Nov./Dec. 1976 issue of Irrigation Age.

Keller, J. and C.M. Burt. April 1975. Recommendations for Trickle and Sprinkle Irrigation in Pakistan. USAID/Colorado State University.

Burt, C.M. and J. Keller. 1976. Very Low Pressure Sprinkler Irrigation. ASAE Paper No. 76-2517., and Utah State University 211(d)-12 bulletin. Dept. of Agricultural and Irrigation Engineering.

Burt, C.M. and T. Ruehr. 1979. Water Penetration Problems with Drip Irrigation. ASAE Paper No. 79-2572. Presented at the winter meeting of the ASAE in New Orleans.

Burt, C.M. January 1980. Practical Efficiencies of Drip Irrigation. Presented to the annual meeting of the California Irrigation Institute at Sacramento, Calif.

Burt, C.M. February 1980. Reuse (Tailwater Recovery) Systems. Proceedings of the 1980 Technical Conference, held at Houston, Texas. The Irrigation Association.

Lord, J.M., C.M. Burt, and Thompson. October 1980. Selection of Irrigation Method. Proceedings of the Second National Irrigation Symposium, held at Lincoln, Nebraska. ASAE.

Merriam, J., M. Shearer, and C.M. Burt. 1980. Evaluating Irrigation Systems and Practices. Chapter 17 in the ASAE Monograph No. 3. M.E. Jensen, editor. pp. 721-762.

Burt, C.M. December 1980. Proceedings of the IA Short Course on Surface Irrigation. 3-day short course held at Cal Poly State University. The Irrigation Association. Chairman and speaker.

Burt, C.M. February 1981. Achieving Finger Tip Control of Surface Irrigation Flows. Proceedings of the 1981 Technical Conference, held at Salt Lake City, Utah. The Irrigation Association.

Burt, C.M. April 1981. Improving Surface Irrigation Efficiencies. Presented at the Western Regional Irrigation Association Meeting, held at Fresno, Calif.

Burt, C.M., et al. September 1981. Distribution System Improvement to Facilitate Water Delivery. A report by JM Lord, Inc. and the Ag. Division, OWC, Calif. Dept. of Water Resources.

Burt, C.M. and J.M. Lord. December 1981. Demand Theory and Application in Irrigation District Operation. Proceedings of the ASAE Specialty Conference on Irrigation Scheduling, held at Chicago, Ill.

Burt, C.M. January 1982. Flexible Scheduling and Effect on Water Supply Agencies and Farms. Presented to the annual meeting of the California Irrigation Institute, held at Fresno, Calif.

Burt, C.M. 1982. Rapid Evaluation of Furrow Irrigation Efficiencies. ASAE Paper 82-2537. Presented at the winter meeting of the ASAE in Chicago, Illinois.

Burt, C.M. 1983. Regulation of Sloping Canals by Automatic Downstream Control. Ph.D. dissertation. College of Engineering. Utah State University. Logan, Utah. University Press. Ann Arbor, Michigan.

Burt, C.M. January 1983. Designing Cost Effective Irrigation Systems. Proceedings of the annual meeting of the California Irrigation Institute, held at Sacramento, Calif.

Burt, C.M. March 1983. Tendencias Hacia Una Irrigacion Eficiente Con Poca Energia. Proceedings of the AGUA EXPO '83 Technical Conference held at Acapulco, Mexico.

Burt, C.M. 1983. Reclaiming and Irrigating Desert Soils, A Guide for Wheat Production and Center Pivot Irrigation in Saudi Arabia. 38 p. Harmon International. Davis, Calif.

Burt, C.M. September 1983. Proceedings of the IA Short Course on Advanced Surface Irrigation Design. 3-day short course held at Cal Poly. The Irrigation Association. Chairman and speaker.

Burt, C.M. December 1983. Aspects of Efficiency. Proceedings of the 1983 Technical Conference, held at Denver, Colorado. The Irrigation Association.

Burt, C.M. 1983. Regulation of Sloping Canals by Automatic Downstream Control. 1ASAE Paper No. 83-2582. Presented at the winter meeting of ASAE in Chicago, Illinois.

Burt, C.M. January 1984. On Farm Water Management - By Design. Presented to the annual meeting of the California Irrigation Institute in Fresno, California.

Burt, C.M. 1984. Evaluating the Efficiency of Irrigation Systems - What Are Our Needs? Presented to the annual meeting of the SCSA in Sacramento, California.

Burt, C.M. March 1984. Proceedings of the IA Short Course on Advanced Drip Design. 3-day short course held at Cal Poly. The Irrigation Association. Chairman and speaker.

Burt, C.M. 1984. Canal Automation for Rapid Demand Deliveries (CARDD). Proceedings of the ASCE Irrigation and Drainage Specialty Conference Water Today and Tomorrow, held at Flagstaff, AZ. pp. 502-509.

Burt, C.M., R. Walker, and S.W. Styles. 1985. Irrigation System Evaluation Manual - 1985 -. A comprehensive, documented software package for evaluation of agricultural irrigation systems. Funded by the OWC, Calif. DWR. Pub. by Dept. of Agricultural Engineering, Cal Poly, San Luis Obispo, Calif.

Burt, C.M. October 1985. Surge Flow Irrigation Is a Real Water Saver. California Farmer. October 5 issue. pg. 19.

Burt, C.M., R. Walker, and S.W. Styles. 1985. Evaluation of Micro Irrigation Systems. Proceedings of the Third Int. Drip/Trickle Irrigation Congress, held in Fresno, Calif. pp. 268-273.

Bianchi, M., C.M. Burt and T. Ruehr. 1985. Drip Fertilization Practices and Water Permeability. Proceedings of the Third Int. Drip/Trickle Irrigation Congress, held in Fresno, Calif. pp. 357-364.

Burt, C.M. and C. Hash. 1985. Sulfur Dioxide Injection for Drip Irrigation. Proceedings of the Third Int. Drip/Trickle Irrigation Congress, held in Fresno, Calif. pp. 712-717.

Burt, C.M. and G. Kah. 1985. Landscape Water Auditor Training Manual. Published by the Office of Water Conservation, Calif. Dept. of Water Resources.

Burt, C.M. 1986. Controlled Volume Design For Surface Irrigation. ASAE Paper No. 86-2085. Presented at the summer meeting of the ASAE in San Luis Obispo, Calif.

Ayers, J., Jonas, and C.M. Burt. 1986. Automation For Downstream Control On Small Irrigation Canals. ASAE Paper No. 86-2078. Presented at the summer meeting of the ASAE in San Luis Obispo, Calif.

Burt, C.M. 1986. Irrigation Evaluations. Proceedings of the 1986 Annual Technical Conference of The Irrigation Association, held at San Antonio, Texas.

Burt, C.M. 1987. Overview of Canal Control Concepts. Planning, Operation, Rehabilitation and Automation of Irrigation Water Delivery Systems. Proceedings of a Symposium in Portland sponsored by the I&D Div. of ASCE. Darell Zimbelman, Editor. pp. 81-109.

Burt, C.M. 1987. Soil-Plant-Water Relationships. Proceedings of the 1987 Annual Technical Conference of The Irrigation Association, held at Orlando, Florida.

Burt, C.M. 1987. Air Vents and Pressure Relief Devices. Presented to the Surface Irrigation Division of The Irrigation Association at the annual conference in Orlando, Florida.

Burt, C.M. 1987. Water Delivery Automation and Time-Of-Use Rates. Presented to the ACWA (Assoc. of Calif. Water Agencies) annual conference in Monterey, Calif.

Burt, C.M. 1988. Irrigation District Water Conservation. Presented to the 1988 Water Users' Conference of the U.S. Bureau of Reclamation Mid-Pacific Region in Visalia, Calif.

Burt, C.M. 1988. Water Delivery Automation. Presentation of a special session for the annual meeting of the California Irrigation Institute, held in Fresno, Calif.

Burt, C.M. 1988. Qualifications for Irrigation Evaluations. Proceedings of the 1988 Plant and Soil Conference of the California chapter of the American Society of Agronomy, held in Fresno, Calif.

Merriam, J.L. and C.M. Burt. 1988. Alleviation of Surface and Subsurface Drainage Disposal Problems by Improved Delivery Scheduling. Question 42.1.2, USCID Meeting of Sept. 14-16, held in San Diego, Calif.

Burt, C.M. and K. Katen. 1988. 1986/87 Water Conservation and Drainage Reduction Program Technical Report of the Westside Res. Cons. District. Submitted to the Office of Water Conservation, Calif. Dept. of Water Resources.

Burt, C.M. 1988. Soil/Plant/Water Relationships. Presentation to a special session for Landscape/Turf irrigation specialists of The Irrigation Association at the annual conference in Las Vegas, Nev.

Burt, C.M. 1989. Level Furrow Irrigation on Sloping Fields. Presentation to the California Irrigation Institute, held in Sacramento, Calif.

Burt, C.M. 1989. Power and Water Conservation for Irrigation Districts. Presentation to the California Irrigation Institute, held in Sacramento, Calif.

Burt, C.M. 1989. Technological Developments in the United States. Chapter in the publication Technological and Institutional Innovation in Irrigation, World Bank Technical Paper No. 94. G. Le Moigne, S. Barghouti, and H. Plusquellec, editors. The World Bank. Washington, D.C.

Burt, C.M. 1989. Pressure Control in Irrigation Pipelines. Presented at the 1989 National Water Conference, ASCE Irrig. and Drainage Div. Held at Univ. of Delaware.

Burt, C.M. and H. Plusquellec. 1990. Water Delivery Control. Chapter 11 of the ASAE monograph Management of Farm Irrigation Systems.

Burt, C.M. October 1989. Variable Speed Pumping Applications in Agriculture. Presented at the AWWA Energy Committee session of the annual AWWA conference. October 26. Long Beach, Calif.

Quinn, N., Smith, C.M. Burt, T. Slavin, S.W. Styles, and Mansoubi. 1989. Water Seepage from Unlined Ditches and Reservoirs. California Agriculture (43):6. Nov/Dec issue.

Burt, C.M. November 1989. Irrigation Efficiency and Uniformity. Presentation and Chair at a 2-day short course for Irrigation Design Preparation at the annual Irrigation Association meeting. Nov. 11-12. Anaheim, Calif.

Burt, C.M. November 1989. Pipeline Design Strategies. Presentation at a 2-day short course for Irrigation Design Preparation at the annual Irrigation Association meeting. Nov. 11-12. Anaheim, Calif.

Burt, C.M. August 1989. Research Needs in Irrigation and Drainage - 1989. Journal of Irrigation and Drainage Engineering, Vol. 115, No. 4. By the ASCE Research and Education Administrative Committee. Contributing member.

Burt, C.M. and J. Parrish. 1989. Canal Automation Providing On-Demand Water Deliveries for Efficient Irrigation. Final report for USGS Water Resources Research Program, Grant 14-08-0001-G1280. NTIS Access No. PB90119769/AS.

Burt, C.M. 1990. Applied Water and Irrigated Districts. Presented at the annual CII meeting. Jan. 25. Bakersfield, Calif.

Burt, C.M. January 1990. Getting the Most Out of District Water. Presented at the annual California Plant and Soil Conference, sponsored by American Soc. of Agronomy. January 31. Fresno, Calif.

Burt, C.M. 1990. Canal Control Training. Presented at CONSERV90, sponsored by AWWA, ASCE, and ASAE. Phoenix, Arizona.

Hawkins, T. and C.M. Burt. 1990. AGWATER - Irrigation Management and Planning Expert System. Proceedings of the Third National Irrigation Symposium. Phoenix, Arizona. ASAE Publication 04-90. pp. 64-68.

Burt, C.M. 1990. Irrigation District Canal Automation - CARDD. Proceedings of the Third National Irrigation Symposium. Phoenix, Arizona. ASAE Publication 04-90. pp. 495-500.

Burt, C.M. 1990. Research Needs. Proceedings of the Seventh World Bank Irrigation and Drainage Seminar. Baltimore, Md. December 18-20. The World Bank. Washington, D.C.

Burt, C.M. January 1991. Irrigation Scheduling. Presented at the Western Regional Water Users' Conference of the USBR, held in Reno. January 24.

Burt, C.M. and Gartrell. 1991. Canal Models and You. Proceedings of the National Conference on Irrigation and Drainage Engineering. Honolulu, Hawaii. ASCE.

Parrish, J. and C.M. Burt. 1991. Cal Poly Model Canal. Proceedings of the National Conference on Irrigation and Drainage Engineering. Honolulu, Hawaii. ASCE.

Plusquellec, H. and C.M. Burt. 1992. The Debate Over Modernization. Proceedings of the National Conference on Irrigation and Drainage Engineering, pp. 197-202. Baltimore, MD. ASCE Water Forum.

Burt, C.M. 1992. Efficient Water Usage in Agriculture. UPDATE: Strategic Directions for a Reliable Water Supply. Southern California Water Committee Update 8(4): 9.

Burt, C.M. and H. Wolter. 1992. Guidelines for Modernization of Irrigation Systems in Mexico. IPTRID/The World Bank.

Burt, C.M., R. Walker and S.W. Styles. 1992. Irrigation System Evaluation Manual - rev. 1992 -. A comprehensive, documented software package for evaluation of agricultural irrigation systems. Funded by the OWC, Calif. DWR. Pub. by ITRC, Dept. of Agricultural Engineering, Cal Poly, San Luis Obispo, Calif.

Clemmens, A.J., et al. 1993. Unsteady Flow Modeling of Irrigation Canal. ASCE Task Committee on Irrigation Canal System Unsteady Flow Modeling. Journal of Irrigation and Drainage Engineering. ASCE 119 (4):615-630. ASCE. New York.

Burt, C.M. and J. Gartrell. 1993. Irrigation Canal - Simulation Model Usage. Journal of Irrigation and Drainage Engineering. Vol. 119 (4):631-636.

Parrish, J. and C.M. Burt. 1993. Cal Poly Model Canal. Journal of Irrigation and Drainage Engineering. Vol. 119 (4):631-636.

Burt, C.M. 1993. AGWATER. Proceedings of the 1993 Nat. Conf. on Irrig. and Drainage Engr. held at Park City, Utah. Irrig. and Drainage Div., Amer. Soc. of Civil Engr. New York.

Burt, C.M. and R. Walker. 1993. GIS Utilization for Analysis of District Drainage Water Recycling. Proceedings of the 1993 Nat. Conf. on Irrig. and Drainage Engr. held at Park City, Utah. Irrig. and Drainage Div., Amer. Soc. of Civil Engr. New York.

Burt, C.M. October 1993. Irrigation Consumer Bill of Rights. Proceedings of the Micro Irrigation Workshop, held in Santa Maria, Calif. October 21.

Burt, C.M. 1993. Water Conservation: Tradeoffs Between Water & Energy. Presentation to California Water Policy III: Beyond Consensus. Los Angeles Biltmore Hotel.

Burt, C.M. 1993. Permanent Subsurface Drip in California. Proceedings of the Irrigation Association Annual Conference in San Diego, CA.

Plusquellec, H., C.M. Burt, and H. Wolter. 1994. Modern Water Control in Irrigation - Concepts, Issues, and Applications. World Bank Technical Paper Number 246. Irrigation and Drainage Series. The World Bank. Washington, D.C

Burt, C.M. 1994. Irrigation Could Be Your Cash Crop. Water Technology 17(3):105-106.

Burt, C.M. and H. Wolter. 1994. Guidelines for Irrigation System Modernization in Mexico - A Case Study. Prepared for the International Commission on Irrigation and Drainage.

Burt, C.M. 1994. The Irrigation Consumer Bill of Rights. Irrigation Journal. Vol. 44(4): 32-33.

Burt, C.M. and J. Wegener. 1994. Monolithic Concrete Irrigation Pipe. ASAE Paper 94-2061. Presented in Kansas City, Mo.

Burt, C.M. and S.W. Styles. 1994. Drip and Microirrigation for Trees, Vines, and Row Crops, *with special sections on buried drip*. Published by the Irrigation Training and Research Center, Cal Poly, San Luis Obispo, CA. ISBN 0-9643634-0-2. 261 p.

Burt, C.M. 1994. Media Filtration. Proceedings of the Irrig. Assoc. Annual Conference in Atlanta, GA.

Styles, S.W., C.M. Burt, D. Westcot and R. Steensen. 1994. Grassland Basin Irrigation and Drainage Study. ASAE Paper 94-2110. Presented in Kansas City, Mo.

Burt, C.M. 1994. Media Tanks for Filtration, Part I - Tank Sizing and Media Selection. Irrigation Journal 44 (5): 14-17.

Burt, C.M. 1994. Media Tanks for Filtration, Part II - Underdrains, Installations and Adjustments. Irrigation Journal 44(6): 17-20.

Burt, C.M. December 1994. Modern Water Control in Irrigation. World Bank Conference on Irrigation and Drainage. Leesburg, VA.

Burt, C.M. 1995. Is Buried Drip the Future with Permanent Crops? Irrigation Business and Technology 3(1): 20-22.

Burt, C.M., R. Walker, J. Parrish and S.W. Styles. 1995. Irrigation System Evaluation Manual - rev. 1995 for Windows. Funded by the OWC, Calif. DWR. Pub. by ITRC, Dept. of Agricultural Engineering, Cal Poly, San Luis Obispo, Calif.

Burt, C.M. 1995. The Surface Irrigation Manual - A Comprehensive Guide to Design and Operation of Surface Irrigation Systems. Waterman Industries. Exeter, CA. ISBN 0-9639016. 373 p.

Burt, C.M., R.S. Gooch, T.S. Strelkoff and J.L. Deltour. 1995. Response of Ideally Controlled Canals to Downstream Withdrawls. Proceedings of the ASCE Water Conference in San Antonio, Texas (Water Resources Engineering). pg. 169-173.

Clemmens, A.J., T.S. Strelkoff and C.M. Burt. 1995. Defining Efficiency and Uniformity: Problems and Perspectives. Water Resources Engineering. Proceedings of the First International Conference. Water Resources Engr. Div., ASCE. August 14-18, San Antonio, TX. pg. 1521-1525.

Burt, C.M., A.J. Clemmens and K. Solomon. 1995. Identification and Quantification of Efficiency and Uniformity Components. Water Resources Engineering. Proceedings of the First International Conference. Water Resources Engr. Div., ASCE. San Antonio, TX. August 14-18. pg. 1526-1530.

Clemmens, A.J., C.M. Burt, and D.C. Rogers. 1995. Introduction to Canal Control Algorithm Needs Proceedings of the ASCE Water Conference in San Antonio, Texas (Water Resources Engineering). pg. 1-5.

Burt, C.M. 1995. Guidelines for Establishing Irrigation Scheduling Policies. Theme V: Interaction Between Water Delivery and Irrigation Scheduling. ICID/FAO Workshop on Irrigation Scheduling: From Theory to Practice. Rome, Italy. September 12-13.

Burt, C.M., K. O'Connor and T. Ruehr. 1995. Fertigation. Published by the Irrigation Training and Research Center, Cal Poly, San Luis Obispo, CA. ISBN 0-9643634-1-0. 326 p.

Burt, C.M. 1995. Fertigation - The Next Frontier. Irrigation Business and Technology (3)4:16-19.

Burt, C.M. 1995. Advances in Chemigation. Irrigation Journal (45)6:8-9

Burt, C.M. October 1995. Irrigation Water Conservation - Benefits and Tradeoffs. Proceedings 1995 USCID Water Management Seminar - Irrigation Water Conservation - Opportunities and Limitations. Sacramento, CA. October 5-7. p 51 - 58.

Burt, C.M. November, 1995. Fertigation Techniques For Different Irrigation Methods. IA Technical Conference. Phoenix, Arizona. November 12-14. 6 p.

Burt, C.M., K. O'Connor, S.W. Styles, M. Lehmkuhl, C. Tienken and R. Walker. 1996. Status and Needs Assessment: Survey of Irrigation Districts. USBR Mid-Pacific Region. ITRC, Cal Poly. San Luis Obispo.

Burt, C.M., S.W. Styles, E. Reifsnider and K. O'Connor. June 1996. Water Delivery Flexibility of Irrigation Districts - USBR Mid-Pacific Region. Proceedings of the ASCE North American Water and Environment Congress '96. Held in Anaheim, CA.

Allen, R.G., C.M. Burt and A.J. Clemmens. June 1996. Water Conservation Definitions from a Hydrologic Viewpoint. Proceedings of the ASCE North American Water and Environment Congress '96. Held in Anaheim, CA.

Burt, C.M. 1996. Scheduling Quotients for Agricultural Irrigation. Irrigation Business and Technology (IV)6: 34-35; 54-55.

Burt, C.M. November 1996. Fertigation Engineering. Oral presentation at the American Society of Agronomy national conference. Indianapolis, Indiana. November 5.

Burt, C.M. November 1997. Modern Water Control and Management Practices in Irrigation: Methodology and Criteria for Evaluating the Impact on Performance. FAO Water Report 12; RAP Publication 1997/22. Proceedings of the Expert Consultation on Modernization of Irrigation Schemes: Past Experiences and Future Options. Bangkok, Thailand. 26-29 Nov. 1996. Food and Agricultural Organization of the United Nations.

Wolter, H. and C.M. Burt. 1997. Concepts for Irrigation System Modernization. FAO Water Report 12; RAP Publication 1997/22. Proceedings of the Expert Consultation on Modernization of Irrigation Schemes: Past Experiences and Future Options. Bangkok, Thailand. 26-29 Nov. 1996. Food and Agricultural Organization of the United Nations.

Burt, C.M. 1996. Essential Water Delivery Policies for Modern On-Farm Irrigation Management. Irrigation Scheduling: From Theory to Practice. Water Reports No. 8. Food and Agriculture Organization of the United Nations. Rome, Italy. pp. 273-278.

Burt, C.M. 1997. Gypsum Injection: Restoring Equilibrium. Irrigation Business and Technology 5(1):37.

Kasapligil, D. and C.M. Burt. 1997. Field Performance of Row Crop Drip Irrigation Systems in the Salinas Valley. Proceedings of the Irrigation and Nutrient Management Conference. Monterey County Water Resources Agency. 8 p.

Burt, C.M. 1997. Fertigation Chemicals. Proceedings of the Segundo Simposium Internacional de Ferti-Irrigacion held in Queretaro, Mexico on June 21. pp 109-118.

Solomon, K. and C.M. Burt. 1997. Irrigation Sagacity: A Performance Parameter for Reasonable and Beneficial Use. ASAE Paper 97-2181. 10 p.

Burt, C.M., S.W. Styles, M. Fidell and E, Reifsnider. 1997. Irrigation District Modernization for the Western U.S. Proceedings of Theme A - Managing Water: Coping with Scarcity and Abundance. 27th Congress of the International Association for Hydraulic Research. pp. 677-682.

Clemmens, A.J. and C.M. Burt. 1997. Accuracy of Irrigation Efficiency Estimates. Journal of Irrigation and Drainage Engineering. ASCE 123(6): 443-453.

Burt, C.M., A.J. Clemmens, T.S. Strelkoff, K. Solomon, R.D. Bliesner, L.A. Hardy, T.A. Howell and D.E. Eisenhauer. 1997. Irrigation Performance Measures - Efficiency and Uniformity. Journal of Irrigation and Drainage Engineering. ASCE 123(6):423-442.

Burt, C.M. December 1997. Irrigation Modernization. Presentation to the World Bank Water Week Conference. Annapolis, MD.

Burt, C.M., A.J. Clemmens and Baume. 1998. Influence of Canal Geometry and Dynamics on Controllability. Journal of Irrigation and Drainage Engineering. ASCE 124(1): 16-22.

Burt, C.M., R.S. Mills, R.D. Khalsa and V. Ruiz C. 1998. Improved Proportional-Integral (PI) Logic for Canal Automation. Journal of Irrigation and Drainage Engineering. ASCE 124(1): 53-57.

Burt, C.M. 1998. Experiences of Industrial-Agriculture Joint Water Use- The ITRC California Perspective. Conference of the Water Conservation Corps/Energy and Resources Laboratories/Industrial Technology Research Institute. Chutung Hsinchu. Republic of China (Taiwan). 13 p.

Burt, C.M. May 1998. On-Farm Irrigation Management - The Shift from Art to Science. Proceedings of the Irrigation Association of Australia 1998 Conference. Brisbane, Australia. May 19-21.

Burt, C.M. 1998. Selection of Irrigation Method - Drip and Microirrigation. Proceedings of the Water Resources Div., ASCE, Annual Conference. Memphis, Tenn.

Burt, C.M. October 1998. Irrigation Modernization Training Program: A New Paradigm to Prepare for the Second Revolution in Irrigated Agriculture. Information Techniques for Irrigation Systems (ITIS5). International Meeting on Modernization of Irrigation System Operations. Aurangabad, Maharahstra, India. Oct. 28-30.

Burt, C.M. and S.W. Styles. October 1998. Modern Water Control and Management Practices in Irrigation: Impact on Performance. Information Techniques for Irrigation Systems (ITIS5). International Meeting on Modernization of Irrigation System Operations. Aurangabad, Maharahstra, India. Oct. 28-30. pp. 62-79.

Burt, C.M. November 1998. Fertigation Basics. Proceedings of Pacific Northwest Vegetable Association Convention. Nov. 19. Pasco, Washington.

Burt, C.M. 1998. A Flexibility Index for Irrigation Districts. Irrigation Business and Technology 6(6): 24-28.

Burt, C.M. November 1998. Chemicals for Fertigation. Proceedings of International Irrigation Show. IA's 19th Annual Conference. Nov. 1-3. San Diego, CA. Irrigation Association Annual Conference. San Diego, CA. pp 221-228.

Burt, C.M. December 1998. The Imperial Irrigation District Water Transfer - Technical Aspects. Water Week (Dec. 14-16) Conference held in Annapolis, MD. The World Bank. Washington, D.C.

Solomon, K. and C.M. Burt. 1998. Irrigation Sagacity: A Measure of Prudent Water Use. Irrigation Science 18(3):135-140.

Burt, C.M. and S.W. Styles. March 1999. Water Balance-Related Performance Indicators for International Projects. Conference on Benchmarking Irrigation System Performance Using Water Measurement and Water Balances. San Luis Obispo, CA. March 10. USCID, Denver, Colo. pp. 337-354.

Styles, S.W. and C.M. Burt. March 1999. Subsurface Flow Water Balance Components for Irrigation Districts in the San Joaquin Valley. Conference on Benchmarking Irrigation System Performance Using Water Measurement and Water Balances. San Luis Obispo, CA. March 10. USCID, Denver, Colo. pp. 369-382.

Burt, C.M. March 1999. Irrigation Water Balance Fundamentals. Conference on Benchmarking Irrigation System Performance Using Water Measurement and Water Balances. San Luis Obispo, CA. March 10. USCID, Denver, Colo. pp. 1-14

Burt, C.M., A.J. Clemmens, K. Solomon, T.A. Howell and T.S. Strelkoff. 1999. Irrigation Performance Measures: Efficiency and Uniformity. Closure. Journal of Irrigation and Drainage Engineering. ASCE 125(2):98-100.

Burt, C.M. 1999. Fertigation Basics and Beyond. Irrigation Journal 49(2):24.

Burt, C.M. 1999. Three Reasons to Broaden Your Fertigation Knowledge. Irrigation Business and Technology 7(1):37-42.

Burt, C.M. and S.W. Styles. 1999. Modern Water Control and Management Practices in Irrigation. Impact on Performance. Water Reports #19. 224 p. Food and Agriculture Organization of the United Nations. ISSN 1020-1203. ISBN 92-5-104282-9

Burt, C.M. 1999. Guides to the Use of Air Release/Vacuum Relief and Continuous Acting Air Vents. Technical Manual 8 p. Agricultural Products, Inc. Ontario, CA.

Burt, A., M. Lehmkuhl, C.M. Burt and S.W. Styles. 1999. Water Level Sensor and Datalogger Testing and Demonstration. Irrigation Training and Research Center. 195 p.

Burt, C.M. October 1999. Current Canal Modernization from an International Perspective. Proceedings, Modernization of Irrigation Water Delivery Systems. 1999 USCID Workshop in Phoenix, AZ. October 17-21. pp. 15-28.

Burt, C.M. and D.R. Brogan. October 1999. Modernization of the Delano-Earlimart Irrigation District Proceedings, Modernization of Irrigation Water Delivery Systems. 1999 USCID Workshop in Phoenix, AZ. October 17-21. pp. 137-148

Styles, S.W., C.M. Burt, R.D. Khalsa and R. Norman. October 1999. Case Study: Modernization of the Government Highline Canal. Proceedings, Modernization of Irrigation Water Delivery Systems. 1999 USCID Workshop in Phoenix, AZ. October 17-21. pp. 187-202.

Styles, S.W., C.M. Burt, M. Lehmkuhl and J. Sweigard. October 1999. Case Study: Modernization of the Patterson Water District. Proceedings, Modernization of Irrigation Water Delivery Systems. 1999 USCID Workshop in Phoenix, AZ. October 17-21. pp. 647-662.

Burt, C.M. 1999. Evaluation of Subsurface Drip Irrigation on Peppers. Irrigation Association 20th Annual Irrigation Show Technical Proceedings. Orlando, Florida.

Burt, C.M. October 1999. Conceptos de Modernizacion. Presentation at the IX Congreso Nacional de Irrigacion. 27-29 October. Culiacan, Mexico.

Burt, C.M. October 1999. Evaluacion de Proyectos de Riego. Presentation at the IX Congreso Nacional de Irrigacion. 27-29 October. Culiacan, Mexico.

Burt, C.M., A.J. Clemmens, R.D. Bliesner, J. Merriam and L.A. Hardy. 1999. Selection of Irrigation Methods for Agriculture. On-Farm Irrigation Committee. Water Resources Division. ASCE. N.Y., N.Y. ISBN 0-7844-0462-3. 129 p.

Burt, C.M. January 2000. Overview of Technologies and Opportunities Available to Irrigation Districts. Presented to the Calif. Irrig. Institute's 38th Annual Meeting in Sacramento, CA. January 25.

Rivas A., I., V.M. Ruiz, C.M. Burt and Y.M. Bisher. March 2000. Propuesta de Modernization del Distrito de Riego del Rio Mayo. Conferencia de Modernización de Distritos de Riego. Culiacan, Mexico.

Burt, C.M. and S.W. Styles. 2000. Drip and Micro Irrigation. Irrigation Training and Research Center. Cal Poly, San Luis Obispo, CA. ISBN 0-9643634-2-9. 292 p.

Plusquellec, H., and C.M. Burt. 2000. Problems of Irrigation in Developing Countries: Discussion. Journal of Irrigation and Drainage Engineering. ASCE 126(3):197-199.

Burt, C.M. August 2000. Benchmarking Irrigation - Concepts and Strategies. Workshop on Performance Indicators and Benchmarking. FAO/IPTRID/World Bank. Rome, Italy. August 3-4. 10 p.

Burt, C.M., A. Mutziger and D. Cordova. 2000. Benchmarking of Flexibility and Needs - 2000. Survey of Irrigation Districts, Mid-Pacific Region USBR. Irrigation Training and Research Center. Cal Poly, San Luis Obispo, CA. 47 p.

Burt, C.M. and S.W. Styles. 2000. Irrigation District Service in the Western United States. Journal of Irrigation and Drainage Engineering. ASCE 126(5):279-282.

Burt, C.M. November 2000. Irrigation District Modernization in the U.S. and Worldwide – The Necessary Link for Efficient On-Farm Irrigation. Proceedings of the 4th Decennial National Irrigation Symposium. Nov. 14-16. Phoenix, AZ. ASAE. St. Joseph, MI. pp 428-434.

Burt, C.M., S.W. Styles and J.A. Forero S. 2000. Riego por Goteo y por Microaspersion para Arboles, Vides y Cultivos Anuales. Irrigation Training and Research Center. Cal Poly, San Luis Obispo, CA. ISBN 0-9643634-3-7. 334 p.

Burt, C.M., R. Angold, M. Lehmkuhl and S.W. Styles. 2001. Flap Gate Design for Automatic Upstream Canal Water Level Control. Journal of Irrigation and Drainage Engr. ASCE 127(2):84-91.

Burt, C.M. and J. Barreras. 2001. Retrievable Drip Tape Irrigation Systems: An Alternative to SDI. Irrigation Journal 51(3):17-20.

Burt, C.M. 2001. Evaluation of Drip and Microsprayer Irrigation Systems in California's Central Valley. Irrigation Business and Technology Nov/Dec. issue. pp 35-39.

Burt, C.M. and B. Freeman. 2001. Preliminary Water Balance Study. Kittitas Valley, Washington. ITRC.

Burt, C.M. 2002. Closure Discussion. Flap Gate Design for Automatic Upstream Canal Water Level Control. Journal of Irrigation and Drainage Engr. ASCE.

Burt, C.M., D. Howes and A. Mutziger. 2001. Evaporation Estimates for Irrigated Agriculture in California. Conference Proceedings of the Annual Irrigation Association meeting. San Antonio, Texas. The Irrigation Association. Falls Church, VA. pp: 103-110.

Burt, C.M. and S.W. Styles. 2001. Rapid Appraisal Process and Benchmarking. http://www.itrc.org/reports/reportsindex.html

Schantz, S.W. Styles, B. Freeman, C.M. Burt and D. Stevens. July 2002. Modernizing Irrigation Facilities at Sutter Mutual Water Company: A Case Study. Proceedings of United States Committee on Irrigation and Drainage Conference on Energy, Climate Environment and Water — Issues and Opportunities for Irrigation and Drainage. Held in San Luis Obispo, CA July 9-12. pp. 283-298.

Khalsa, R.D., S.W. Styles, C.M. Burt and R. Norman. July 2002. Case Study: Installation of Canal Control Structures on the Government Highline Canal. Proceedings of United States Committee on Irrigation and Drainage Conference on Energy, Climate Environment and Water — Issues and Opportunities for Irrigation and Drainage. Held in San Luis Obispo, CA. July 9-12. pp. 153-166.

Burt, C.M., M.B. Gilton, K. Johansen and K. Crowe. July 2002. Breaking the Technology Barriers Imposed by Cast-In-Place Concrete Pipe in Irrigation Districts — Case Study of South San Joaquin Irrigation District. Proceedings of United States Committee on Irrigation and Drainage Conference on Energy, Climate Environment and Water — Issues and Opportunities for Irrigation and Drainage. Held in San Luis Obispo, CA. July 9-12. pp. 95-108.

Burt, C.M. and X. Piao. July 2002. Advances in PLC-Based Canal Automation. Proceedings of United States Committee on Irrigation and Drainage Conference on Energy, Climate Environment and Water — Issues and Opportunities for Irrigation and Drainage. Held in San Luis Obispo, CA. July 9-12. pp. 409-422.

Burt, C.M., R. Amón and D. Cordova. July 2002. Electrical Load Shifting in Irrigation Districts — California's Program. Proceedings of United States Committee on Irrigation and Drainage Conference on Energy, Climate Environment and Water — Issues and Opportunities for Irrigation and Drainage. Held in San Luis Obispo, CA. July 9-12. pp. 435-444.

Burt, C.M. December 2002. Rapid Field Evaluation of Drip/Micro Irrigation Systems. Proceedings of the International Meeting on Advances in Drip/Micro Irrigation. Held in Puerto de la Cruz, Tenerife, Spain. Depto. de Suelos y Riegos, Instituto Canario de Investigaciones Agrarias. Jesús Rodrigo López, ed. December 2-5.

Burt, C.M., B. Isbell and L. Burt. 2002. Long-Term Salinity Buildup on Drip/Micro Irrigated Trees in California Proceedings of the Annual Technical Conference of the Irrigation Association, held in San Diego, CA.

Burt, C.M. and X. Piao. 2002. Advances in PLC-Based Irrigation Canal Automation. Irrigation and Drainage 53:29-37. Published by John Wiley & Sons, Ltd. (www.interscience.wiley.com).

Burt, C.M. 2003. Fertigation - Maximizing the Value of Your Irrigation Management. Turfgrass Management (ATM) Magazine. February issue. Australia.

Burt, C.M. and S.W. Styles. 2004. Conceptualizing Irrigation Project Modernization Through Benchmarking and the Rapid Appraisal Process. Irrigation and Drainage 53(2): 145-154. Published by John Wiley & Sons, Ltd. (http://www3.interscience.wiley.com/cgi-bin/fulltext/108563546/PDFSTART).

Burt, C.M. 2004. Basic Practices for Applying Fumigants Into the Soil Through an Irrigation System. International Water and Irrigation 24(2): 23-25. Tel Aviv, Israel.

Freeman, B. and C. M. Burt. 2004. Estimating Conservable Water in the Klamath Irrigation Project. Proceedings of the 2004 Water Management Conference on Water Rights and Related Water Supply Issues. Salt Lake City. USCID. pp. 525-535.

Burt, C.M. 2004. Completing the Connection Between Irrigation Districts and On-Farm Irrigation. 2004. International Irrigation Association Technical Conference Proceedings. Tampa, FL.

Papers Recently Accepted for Publication

Mutziger, A., C.M. Burt, D. Howes and K. Solomon. 2005. Comparison of Measured and Modified FAO 56 Modeled Bare-Soil Evaporation. ASCE I & D Journal.

van Overloop, P.J., J. Schuurmans, R. Brower and C.M. Burt. 2005. Multiple Model Optimization of Decentralized PI-Controllers on Canals. 2004 ASCE I&D Journal.

Burt, C.M., J. Mutziger, R.G. Allen and T.A. Howell. 2005. Evaporation Research – A Review and Interpretation. ASCE I&D Journal.

Burt, C.M. 2004. Rapid Field Evaluation of Drip and Microspray Distribution Uniformity. Submitted to Irrigation and Drainage Systems. Kluwer.